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A Review on Calculating Carbon Footprint of an Educational Institute

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Abstract: ***Carbon footprint is the carbon emitted from various greenhouse gases during any activity within or outside its operational boundary. Presently various building operations are contributing significantly towards the carbon footprint. Various commercial and public buildings are thus under observations for such calculations. Educational institutes around the world have gained special popularity in the direction of calculating the carbon footprint, as these have huge potential towards fulfilling the goal of sustainable planet. In this study, the prime focus is on reviewing various methodology adopted to find out these carbon emissions.***

Keywords: Carbon footprint, Greenhouse Gases, Direct Emissions, Indirect Emissions, Sustainable Buildings

I. INTRODUCTION

Greenhouse gases have a tendency to trap solar radiation within the atmosphere of the Earth and thereby causing a temperature rise on Earth's surface. This rise was however slow initially but as the concentration of CO_2 and other greenhouse gases is increasing, the temperature is also rising manifolds. Today anthropogenic activities are the biggest contributor in this direction; One among such activities is numerous building operations. Efforts have been made around the world to limit such activities or replace these activities with sustainable activities so that the sustainability of the planet is ensured. There is an intense need to limit the global temperature well below 2^oC than the pre industrial level. For this to happen, first and the foremost step is to identify these sources of emissions in the building operations and then to quantify their emission potential. The extent and the amount of various mitigation strategies will then depend upon the emissions caused.

II. LITERATURE REVIEW

Kulkarni S et al. (2019) The paper provided a detailed insight on the bottom-up approach, which is a method of Life Cycle Analysis, for calculating the amount of greenhouse gas emission i.e., carbon footprint of the higher educational institute in India. It involved a comprehensive idea about each individual source of greenhouse gas within the institute and thereby calculating the resulting carbon emission. The author developed various equations, calculated various conversion factors for all 3 scope emission categories defined as per GHG Protocol. Lastly the author recommended some measures to reduce the carbon footprint such as switching to renewable source of energy, using energy efficient appliance, reducing waste produced within the organization and reducing transportation emissions.

Sangwan et al. (2018) The paper described the Life cycle analysis for the institutional campus of BITS Pilani using ISO 14064 for checking out the Inventory list. This list was made to calculate the carbon emission from all the potential sources that are present in the institute.

Operational boundaries were set and related carbon footprint was calculated. In the study it was found out that the main source of emission was electricity accounting nearly 70% of total emission, followed by transportation (16%) and food waste (10%). This study also suggested the measure to reduce carbon footprint by adopting various sustainable solution like use of renewable energy, reduction in the use of fossil fuel and reducing food waste.

Robinson et al. (2018) The paper examined the need to adopt a standard tool for calculating carbon footprint of various universities. The author reviewed six of the existing carbon footprints calculating methodology and worked out numerous areas that lacked consistency. The author suggested numerous measures such as defining the boundary setting for such calculation, consistent format for data collection and formatting, distinct and transparent methodology for calculating carbon footprint and vigorous verification process. Thus, the author reasoned that a universal carbon footprint standard would aid universities to reduce their carbon emissions and equate their performance with other universities thereby refining the precision and comparability of such emissions from numerous universities.

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Kiehle et al. (2023) The paper provided a hybrid model that combined the Life Cycle Analysis and Extended environmental input output method to calculate carbon footprint for the campus of university of Oulu in 2019. Emissions from Electricity were found to be the highest followed by heating requirements and transportation requirement which further reduced by 20% since 2007. The study exemplified how institutions of higher education can play a critical role in combating climate change by reducing their carbon footprint. Through comprehensive valuations, sustainable infrastructure investments, and nurturing a culture of environmental responsibility, the university sets an inspiring example for others to follow. As climate action becomes increasingly urgent, universities must continue to innovate and collaborate to create a more sustainable future for generations to come.

Sen et al. (2022) This paper explored the use synthesis of existing research and sharing successful case studies in accomplishing sustainability and carbon neutrality in higher education institutions. The review aimed to identify the best practices, challenges and potential strategies that can help in transition towards a greener and more sustainable future. The first step towards this transition, is to examine various methodologies adopted to assess the carbon footprint of higher education institutions, including Scope 1, Scope 2 and Scope 3 emissions. Furthermore, it explored the importance of transparent and exact reporting to track progress towards sustainability goals. As the urgency of climate action increases, these institutions must continue to innovate, collaborate, and lead the way towards a greener and more sustainable future.

Battistini et al. (2023) The study focused on assessment of the carbon footprint of a multi campus university. The study included all the possible sources of emission both direct and indirect under Scope 1, 2 and 3. The methodology involved include clear steps from defining the scopes of assessment, collecting the data for greenhouse gas emission, calculating the carbon footprint and interpreting the results to the communication of those results to various stakeholders. The researchers also provided valuable insights into the university's ecological impact and concerns and identified probable zones for development. This information enabled the university to develop targeted strategies and action plans to achieve carbon neutrality.

Sudarshan J. et al (2019) The research aimed to quantify all form of greenhouse gas emission associated with educational buildings that are mentioned in various scope categories as per GHG Protocol. The methodology is based on the life cycle assessment (LCA) methodology with the intention identifying accurate boundaries, identify emission sources, integrating those sources, quantifying the carbon footprint and interpreting those results to neutralize the carbon emissions from such institutions. Overall, the research contributed to the drive towards sustainable development by investigating the carbon footprint of education buildings and the potential for implementing sustainable practices use of efficient building design, energy efficient appliances and adopting ecofriendly materials. The conclusions can be used as a proposal for numerous other educational establishments to evaluate and alleviate their environmental impression, promoting a more sustainable future for the education sector and beyond.

Cano et al. (2023)

The study employed two commonly documented standards for greenhouse gas emission (GHG) accounting: the UNE-ISO 14064-1 and the WRI/WBCSD GHG Protocol Corporate Standard. By utilizing these robust methodologies, the researchers aimed to precisely quantify the greenhouse gas emissions, facilitating the identification of emission hotspots and updating the progress of targeted emission reduction approaches. The study incorporated a complete investigation of direct emissions (Scope 1) from on-campus sources, such as fuel combustion and industrial processes, as well as indirect emissions (Scope 2) from acquired electricity. Furthermore, the researchers accounted for Scope 3 emissions, which included indirect emissions linked to the university's activities such as business tours, waste generation and procurement. By following the internationally recognized GHG accounting standards, this study ensured the reliability and comparability of its results towards achieving sustainability and carbon neutrality, aligning with global efforts to combat climate change.

Adeyeye et al. (2023) The study used a comprehensive approach by combining GHG Protocol Corporate Standard and life cycle assessment to calculate the carbon footprint of the university. It provided insights on the chief contributors to the university's carbon footprint, shedding light on the informed decision-making and targeted emission reduction strategies. By benchmarking their GHG emissions against global standards, the university gained a better understanding of its environmental impressions and can identify areas for improvement and sustainable practices like improving energy efficiency, adopting renewable energy sources, endorsing sustainable transportation choices, executing waste management practices and assimilating sustainability principles into the prospectus and university activities. The research also highlighted the significance of multi-stakeholder collaboration to fight against the global climate change scenarios.

Gulcimen et al. (2023) The paper presented a methodology for measuring the sustainability of a university campus using a life cycle assessment (LCA), which is a systematic method for assessing the environmental impacts of products, services, and systems throughout their life cycle of planning, design, construction, operation, maintenance, and eventual decommissioning or recycling.

The LCA integrated the Environmental Life Cycle Assessment(E-LCA), measuring parameters like greenhouse gas emissions, energy consumption, water usage and waste generation, Life Cycle Costing (LCC), calculating the monetary feasibility and cost-effectiveness of sustainable practices, and Social Life Cycle Assessment, evaluating the communal interactions, student well-being. Thus, the life cycle assessment helps in the identification of most substantial areas when it comes to environmental degradation, such as energy-intensive operations or waste generation during construction. This information enabled the university to develop targeted strategies to mitigate these impacts and enhance its overall environmental performance.

Pandey et al. (2011) These researched reviewed various methodologies for emission of carbon footprint by considering both direct and indirect emissions with in the campus and explored the strength and weakness of each method. The study also managed to find the applicability of these methods in different contexts. Various estimation methodology that was examined included the use of life cycle assessment (LCA), input-output analysis (IOA), and emissions factors from various sources. The study emphasized on collecting accurate and reliable data, need for standardized protocol in order to facilitate the comparison. The paper also discussed the role of carbon footprint estimation in guiding sustainable decision-making organizations and policymakers to provide for improved and effective carbon reduction strategies.

Cooper et al. (2023) The study employed a robust method for calculating carbon footprint from direct emissions (Scope 1) and indirect emissions (Scope 2 and Scope 3) using Life Cycle Assessment (LCA). The largest source of carbon emission was from electricity consumption followed by transportation emissions and food wastes. The study highlighted the importance of assimilating sustainability principles into academic and research activities. Besides, the research emphasized the worth of stakeholder engagement and their collaboration to drive numerous sustainability solutions. Involving students, faculty, staff and other university community nurtures a culture of environmental responsibility and innovative approaches towards carbon reduction. As the globe today faces growing environmental challenges, universities play a vigorous role in leading the way towards a more sustainable future.

Guo et al. (2023) The paper presented a life cycle assessment (LCA) for quantifying the carbon emission in buildings in china by considering direct and indirect emissions. The authors found that the carbon emissions from buildings in China accounted for 30% of the country's total emissions. Construction phase accounted for 45% of the total emissions which is largest followed by operation phase and the demolition and disposal phase accounted for 35% and 20% of the total emissions respectively. The paper also provided an insight on the significance of green building in reducing the carbon footprint of a building for example a LEED Platinum certified building emits carbon less than 70% than that of conventional building. Additionally, the authors identified a number of opportunities for reducing carbon emissions by using energy-efficient materials and technologies during construction improving the energy efficiency of buildings during the operation phase by promoting the use of renewable energy sources in buildings and designing buildings to be more easily demolished and recycled at the end of their life. The paper was concluded by calling for more research on carbon emissions from buildings.

Ropo et al. (2023) The study presented a life cycle cost (LCC) optimization model for making buildings carbon neutral. The study goes beyond conventional life cycle cost analysis by including embodied CO2 emissions and carbon compensation cost considerations. Embodied CO2 emissions denotes the carbon emissions linked with the manufacturing, conveyance and installation of building materials and energy systems. This study not only took the economic viability into account but also emphasized on the environmental sustainability in terms of embodied carbon. The study also mentioned the idea of carbon compensation cost, which refers to the financial cost of offsetting or compensating for the carbon emissions linked with a building energy scheme. By assimilating this cost into the life cycle cost assessment, the study recognized the importance of justifying the carbon footprint of buildings to achieve carbon neutrality goals.

Wiche et al. (2022) The research focused on understanding the difficulties and limitations faced when assessing the environmental impact of buildings throughout their life cycle. These challenges comprised of lack of complete data on building materials and construction practices, lack of availability of standardized and uniform methodologies and tools to conduct carbon footprint assessment, accurate accounting for the embodied carbon emissions and variations in energy sources and network emissions in diverse areas of the nation. The study delivered a gainful insight on the barriers that need to be overcome to make more conversant verdicts while prioritizing environmental sustainability strategies in building design, construction and operation.

Klein-Banai & Theis et al. (2013) This study employed a data- driven method of analyzing numerous factor that affect the emission of greenhouse gases in a university. These emissions may be derived from energy consumption, transportation, waste generation, procurements and research activities. This quantitative assessment helped in providing an insight on the main drivers of the emissions and thereby prioritizing the efforts in implementing numerous mitigation strategies.

In this study it was concluded that the consumption of energy was the major carbon emission contributor and provided gainful insights into optimizing various energy consumption scenarios from using energy efficiency appliance to choosing renewable energy sources as alternatives. The study also highlighted the significance of using sustainable transportation alternatives and research activities. The study contributed to the increasing knowledge base on sustainability in higher education and supported international efforts to provide for sustainable future through accountable institutional practices.

Savolainen et al. (2023) The study utilized a robust carbon footprint assessment methodology that contemplated both direct emissions (Scope 1) from on-site sources, such as energy consumption and indirect emissions (Scope 2 and Scope 3) from purchased electricity, and waste generation etc. The report highlighted the importance of data-driven valuations and transparent reporting. Precise data collection and measurement are essential for calculating reliable carbon footprints, which enabled to set accurate carbon reduction targets and check progress towards sustainability goals. Additionally, the learning recognized the importance of stakeholder engagement and collaboration. By linking staff, management, and other stakeholders, the institution can foster a culture of environmental responsibility and encourage the implementation of sustainable practices throughout the institution. By calculating its carbon footprint and detecting emission hotspots, the library can take eloquent steps towards becoming a more environmentally accountable institution.

Fouladvand et al. (2023) The study provided a detailed insight on the life cycle analysis for calculating the carbon emissions which was found to be 4000 ton of CO2. The largest contributor was electricity consumption followed by transportation and food waste. By quantifying its carbon footprint and writing on emission reduction initiatives, the organization can inspire its audience and industry peers to take similar steps towards sustainability. The study also considered the challenges and opportunities in reducing the carbon footprint of a news broadcasting organization. It communicated the difficulties of manufacturing processes, travel requirements and energy consumption, as well as the probable scopes for implementing renewable energy sources and sustainable practices.

Norouzi et al. (2023) This paper provided a detailed in sights on the potential of low energy building to reduce the greenhouse gas emission. It provided a holistic view on the carbon footprint of a building using Life Cycle assessment (LCA). Three different heating and ventilation alternatives (a heat pump, a gas boiler, and an electric radiator), two electricity generation scenarios (a carbon- intensive grid and a decarbonized grid), and two different waste treatment alternative for timber products (landfill and incineration) were assessed and it was found out that depending on the technological and decarbonization pathways considered, the carbon footprint of the dwelling units varies significantly and by making use of the available knowledge through this study, above aspects can be altered to best fit the need of the hour.

B. Liu et al. (2023) The paper aimed at providing an inclusive understanding of various factors that contribute towards the emission growth and various drivers in five southeast Asian countries namely Cambodia, Laos, Myanmar, Thailand, and Vietnam. Rapid economic development and population growth have caused amplified energy consumption and industrial activities, which in turn have resulted in significant rise in GHG emissions in the region. However, the energy consumption, primarily from fossil fuels, is the primary driver of this emission growth. Additionally, change in land- use and agricultural practices, methane emissions from livestock, peatland degradation, hasty industrial expansion and the increased transportation demand also contribute substantially towards this emission.

Gaarder et al. (2023) The paper provided a gainful insight on the optimum insulation thickness of building envelope in cold climates, in view of both the embodied carbon emission during the production of insulation material and the energy saving attained through the reduced heating requirements i.e. operational greenhouse gas (GHG). The author made use of life cycle assessment (LCA) approach to compare the environmental impacts of various insulation thicknesses provided depending upon the insulation material, the climate and the energy mix. In colder climates, thicker insulation usually leads to amplified energy savings and reduced operational emissions. However, a trade-off between the two needs to be worked. Thicker insulation leads to lower operational GHG emissions, simultaneously increases the embodied GHG emissions. Thus, the optimum thickness was worked out to be 5-20cm to achieve net zero building.

Wilberforce et al. (2023) This paper explored the potential benefits and drawbacks associated with the net zero energy buildings which are achieved balancing the energy consumption and generation through the renewable sources delicately. The main advantage of such buildings is their capability of combating climate change by adopting sustainable construction practices like use of renewable energy sources and thereby reducing greenhouse gas emissions and depends upon the conventional sources of energy to satisfy its demands. These also have a potential towards lowering energy cost for occupants which make them financially appealing over long term. High initial construction cost, high cost incurred in implementing energy efficient technologies and high cost in integrating renewable energy sources make these constructions difficult.

Additionally, geographical location and climate also affect the feasibility and effectiveness of such construction. Thus, the study presented an analysis of zero energy buildings, explaining their positive as well as negative impacts.

Da Silva et al. (2023) The study aimed at analyzing existing research that investigate decarbonization strategies and their role in achieving sustainable environment. The sustainable strategies, that are adopted worldwide, like use of renewable energy sources, enhancing energy efficiency, promoting sustainable transportation options, and implementing carbon offset programs provided a supportive framework towards combating climate change issue. Additionally, the study addressed the role of institutional policies, governance, and leadership in facilitating successful decarbonization efforts. Enhanced community engagement, research opportunities in sustainability and renewable energy and the potential to influence environmental consciousness among students and staff can be a way forward in this direction.

Gao et al. (2023) This paper provided an insight on the current state of progress made in understanding the carbon emissions of public buildings using CiteSpace and VOSviewe. It highlighted five key hotspots of studies in carbon emissions of public buildings viz. (1) theoretical research and simulation modelling (2) energy systems (3) materials (4) public building retrofitting (5) factors that contribute to the reduction in CEPB. Architectural features, structural and digital technology can play key role in making these buildings sustainable by reducing carbon emissions.

Ruggieri et al. (2023) This paper discussed the crucial role of building sector in meeting the zero emission scenarios especially in European Union. It was found out that the residential and educational buildings in Italy are responsible for a considerable amount energy consumption and greenhouse gas emission As the current rate of energy renovation is insufficient, a three-phase policy roadmap for energy renovation was proposed. In its first phase the focus was on removing market barriers and providing financial incentives for energy renovation, developing a national database of energy- efficient buildings was the second phase while the third phase would focus on promoting energy renovation through public procurement etc. The policy so created will then not only help in combating various climate issue but will also create jobs to boost economy.

III. CONCLUSION

The authors of various research papers have categorised the total emission from the institute in majorly 3 scope categories by following GHG Protocol Corporate Standards guidelines. While Scope 1 is a direct source of emission, Scope 2 and Scope 3 are the indirect sources of emissions from various activities. Various researches have followed diverse methodology for quantifying the emissions. While some have followed Life Cycle Analysis (LCA), Environment Life Cycle Analysis (E-LCA) and Life Cycle Costing (LCC) other have used a hybrid model of LCA by combining it with Extended environmental input output method (EIOA) of analysis. Some even have made use of software like CiteSpace and VOSviewer. Some prepared the inventory list based on ISO 14064-1 while other made some practical consideration while selecting the list of activities to be included in the analysis. Also, the equivalent conversion factors adopted are different by different authors. Thus, for the same institute if different methods of analysis are adopted, different amount of carbon emission will be obtained. Above discussion suggests that there is a lack of consistency calculating these emissions. Even though effort has been made towards standardising these emissions by GHG Protocol Corporate Standards, yet it lacks in providing suitable carbon emission factors for all the activities under conversation. Additionally, there is no consistency in adopting the methodology to be followed, which will give varying results for the same institute. Emissions under Scope 3 are kept optional and therefore no specific inventory list is suggested. In order to obtain a truly standardised result, there is a need to make a comprehensive list of inventories to be prepared, provide with suitable conversion factors in order to quantify the emission from various activities and a universally accepted methodology with suitable correction factors depending upon the regional requirements.

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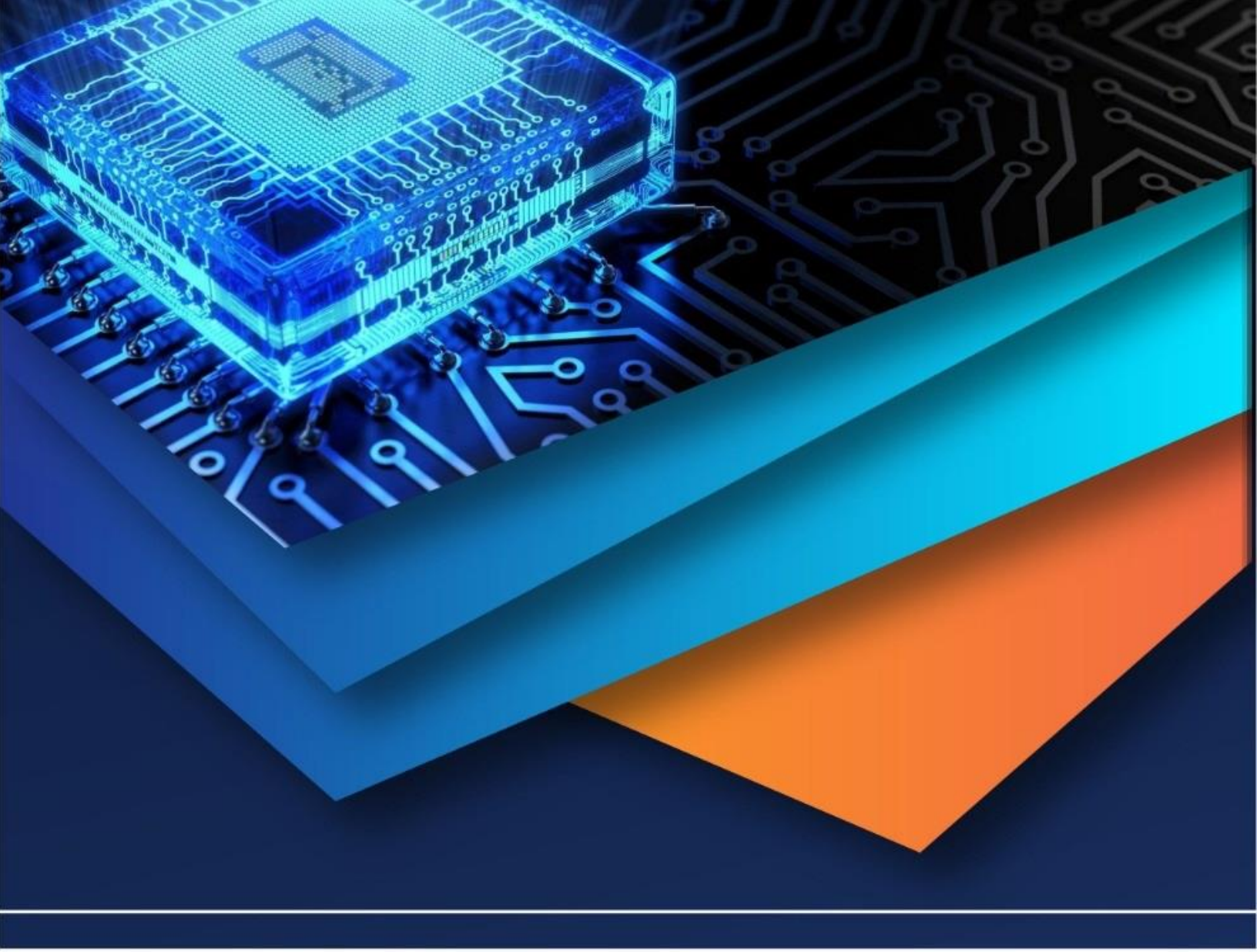
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