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Case Study of Calculating Carbon Footprint and Cultivating Carbon Sinks in Educational Institute

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***Abstract:** The escalating concentration of greenhouse gases (GHGs) in Earth's atmosphere, driven by anthropogenic activities, poses a critical threat, leading to global warming and climate change. This paper synthesizes current knowledge on the greenhouse effect and the quantification of emissions through carbon footprint assessment, with a particular emphasis on the building sector. Globally, buildings and construction contribute significantly, accounting for over 34% of energy demands and 37% of energy and process-related CO2 emissions in 2022, with a consistent growth trend. The paper outlines the GHG Protocol's classification of emissions into Scope 1 (direct), Scope 2 (indirect from purchased energy), and Scope 3 (other indirect), highlighting the complexities in measuring Scope 3 emissions. It discusses the pressing challenges of climate change and proposes a multifaceted approach for emission reduction, including transitioning to renewable energy, enhancing energy efficiency, electrifying transport, promoting afforestation, utilizing Carbon Capture and Storage (CCS) technologies, implementing sustainable agricultural practices, and enacting robust policies. This paper examines various methodologies for carbon footprint assessment in educational institutions, identifies key emission sources, and explores the potential of carbon sinks and offsets. Finally, it highlights critical research gaps, particularly regarding comprehensive Scope 3 emissions measurement and the integrated application of carbon sinks and offsets for sustainable built environments.*
***Keywords:** GHGs, Carbon footprint, climate change, Carbon sink, Carbon offset etc*

I. INTRODUCTION

The greenhouse effect, a natural phenomenon essential for maintaining Earth's habitable temperature, involves the trapping of heat near the planet's surface by substances known as greenhouse gases (GHGs). These gases primarily include carbon dioxide (CO2), methane (CH4), ozone (O3), nitrous oxide (N2O), chlorofluorocarbons (CFCs), and water vapor (H2O). While naturally occurring GHGs are vital for sustaining life on Earth, human activities have led to an unprecedented increase in their atmospheric concentrations, resulting in an abrupt rise in global temperatures, a phenomenon commonly referred to as Global Warming. This escalation in global temperature presents a pressing concern for the planet's sustainability.

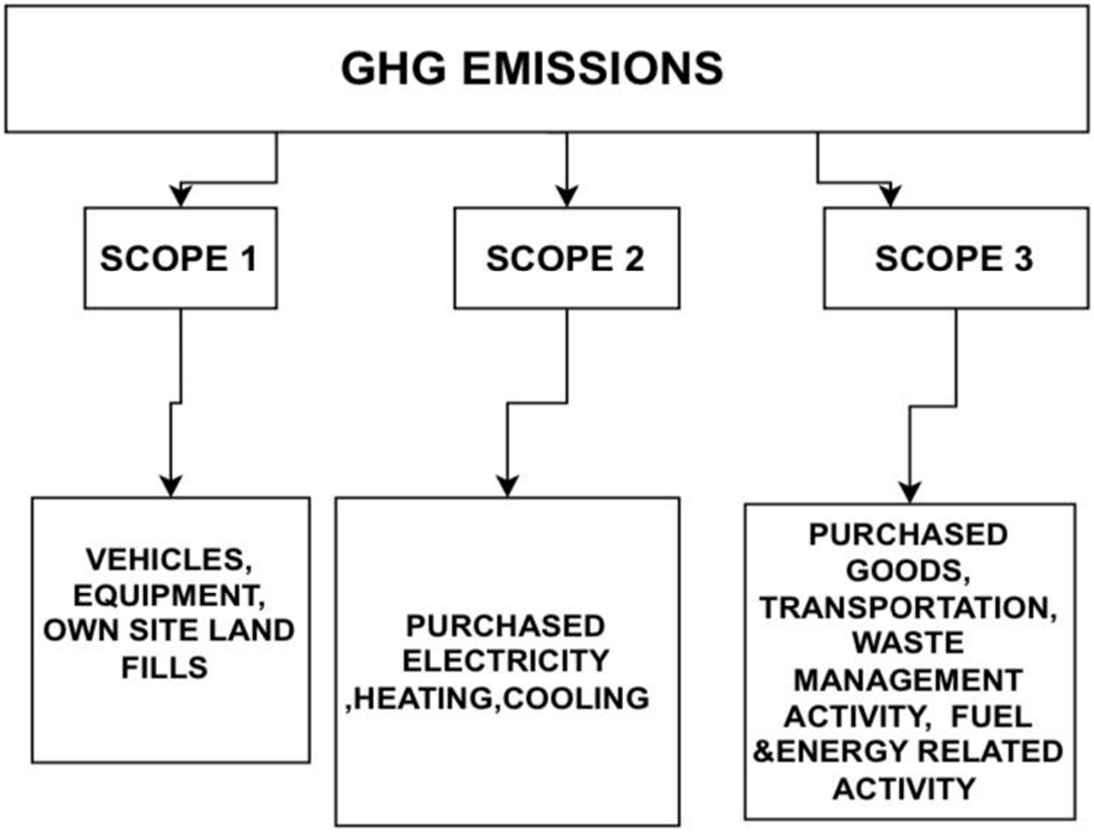
To quantify and standardize these diverse GHG emissions, they are typically converted into a common unit, most often expressed in terms of carbon equivalent. The total amount thus calculated is termed the carbon footprint. While carbon emissions stem from various sectors, this review primarily focuses on the building sector's contribution to this global challenge.

According to the "Global Status Report for Buildings and Construction" (UNEP, COP27, Egypt), the building and construction sectors were responsible for over 34% of global energy demands and approximately 37% of energy and process-related CO2 emissions in 2022. This sector's emissions have consistently grown at an average rate of 1% per year since 2015. India, in particular, attributes 40% of its CO2 emissions to the building sector, with projections indicating a doubling of these emissions by 2050 in the absence of sustainable alternate methods and technologies. The 2022 Emissions Gap Report (UNEP) underscores the urgency, calling for a nearly 45% global emission reduction to avert the most severe impacts of climate change.

In line with these global efforts, the UNCCC (Climate Change Conference) (COP21) in Paris, France, on December 12, 2015, emphasized the critical need to restrict the global temperature increase to within 1.5∘C above pre-industrial levels. This target aims to reduce global carbon emissions by decreasing ambient temperatures, thereby lowering energy demand.

Carbon emissions from buildings are typically categorized under three scopes, as defined by the GHG Protocol, the world's most widely adopted standard for greenhouse gas accounting. A comprehensive understanding of these scope categories is crucial for achieving "NET ZERO" emissions:

Figure 1 (refer to original source material), "Various Scope Categories as Defined by GHG Protocol Standard Corporate," visually illustrates these distinctions.



II. CHALLENGES OF THE PRESENT ERA

Greenhouse gas emissions pose significant challenges, primarily manifesting as climate change and its far-reaching effects on Earth and human society. While the natural greenhouse effect is necessary for life, the sharp rise in anthropogenic GHG emissions has created a global state of anxiety. To prevent the severe adverse effects of climate change and preserve a habitable planet, the Intergovernmental Panel on Climate Change (IPCC 2018) stresses that the global temperature must not increase by more than 1.5∘C over pre-industrial levels. Despite international pledges to combat climate change, global emission rates continue to climb, with the current warming already reaching 1.1∘C. Projections indicate that swift action to cut GHG emissions could still limit warming to 1.5∘C by 2050; otherwise, the global temperature could surge to 3∘C by 2100 (IPCC). The consequences are already evident, with recent events like widespread floods and Australian forest fires serving as stark reminders of climate change's impacts.

Reducing global GHG emissions is paramount for the planet's long-term sustainability, ensuring the safety of current and future generations, and preserving Earth's bionetwork and biodiversity. Encouragingly, increased awareness regarding sustainable development has led to positive responses in emission reduction scenarios.

In conclusion, the building sector, encompassing both construction and operational phases, holds a decisive role in reducing carbon emissions associated with the built environment, contributing significantly to a sustainable future.

III. LITERATURE REVIEW

A literature review is a critical tool that aids in comprehending the academic knowledge on a specific subject within the framework of a study. It facilitates the identification of research gaps in existing studies, thereby providing a summary of current knowledge and assisting in the identification of various methods, theories, and approaches to inform future research in the area concerned.

The following is a summary of relevant papers on carbon footprint assessment and reduction, particularly in educational institutions and the building sector:

[1] Nidhi Chauhan et al. (2024) focused on reviewing methodologies for assessing carbon emissions in educational institutions, emphasizing their potential for contributing to a sustainable planet. The study highlighted the importance of calculating carbon footprints within these institutes and discussed different approaches to identify and quantify emissions for implementing reduction strategies.
[2] Kulkarni S et al. (2019) calculated the carbon footprint of an Indian higher education institute using a bottom-up Life Cycle Analysis (LCA), identifying emission sources across GHG Protocol scopes. Recommendations included transitioning to renewable energy, using energy-efficient appliances, reducing waste, and minimizing transportation emissions.
[3] Sangwan et al. (2018) examined the carbon footprint of BITS Pilani using ISO 14064. The study identified electricity (70%) as the primary emission source, followed by transportation (16%) and food waste (10%), recommending focus on renewable energy, reduced fossil fuel use, and minimizing food waste.
[4] Robinson et al. (2018) evaluated six carbon footprint methodologies, identifying inconsistencies. They suggested standardized boundary definitions, data collection formats, and verification processes to improve comparability among universities.
[5] Kiehle et al. (2023) used a hybrid LCA and input-output method for the University of Oulu, showing electricity as the largest emission source and a 20% reduction since 2007. The study underscored the role of universities in reducing carbon footprints through sustainable infrastructure and practices.
[6] Sen et al. (2022) synthesized existing research and shared successful case studies in achieving sustainability and carbon neutrality in higher education institutions. This paper explored methodologies for assessing carbon footprint, including Scope 1, 2, and 3 emissions, emphasizing the importance of transparent and exact reporting for tracking progress towards sustainability goals.
[7] Battistini et al. (2023) focused on assessing the carbon footprint of a large university, guided by the GHG Protocol, ISO 14064, and ISO/TR 14069 to understand the environmental impact of GHG emissions.
[8] Sudarshan J. et al. (2019) aimed to measure all GHG emissions related to educational institutes, covering various scope categories under the GHG Protocol. The study utilized a Life Cycle Assessment (LCA) methodology to neutralize carbon emissions from such institutions, focusing on precise limits, emission source identification, integration, carbon footprint measurement, and results interpretation.
[9] Cano et al. (2023) examined UNE-ISO 14064-1 and the WRI/WBCSD GHG Protocol Corporate Standard for GHG emission accounting. Adherence to these globally accepted standards established the reliability and applicability of the study's findings towards achieving sustainability and carbon neutrality.
[10] Adeyeye et al. (2023) used a comprehensive approach combining the GHG Protocol Corporate Standard and LCA to calculate a university's carbon footprint, providing insights into major contributors for informed decision-making and targeted emission reduction strategies. Suggested strategies included renewable energy, sustainable transport, and waste management.
[11] Gulcimen et al. (2023) employed the LCA method for measuring university campus sustainability, an organized approach to evaluating environmental impacts across a system's entire life cycle (planning, designing, building, operating, maintaining, decommissioning, or recycling).
[12] Pandey et al. (2011) examined carbon footprint methodologies, including LCA and input-output analysis, identifying their advantages and applications in efficient carbon reduction strategies.
[13] Cooper et al. (2023) used LCA to identify electricity, transportation, and food waste as major emission sources. They advocated for stakeholder collaboration and sustainability integration in academics, noting universities' active role in paving the path for a more sustainable future.
[14] Guo et al. (2023) presented an LCA calculating carbon emissions in Chinese buildings, considering both direct and indirect emissions. They found buildings responsible for 30% of national emissions, with construction (45%) and operation (35%) phases being the largest contributors. They identified ways to improve energy efficiency and reduce emissions using energy-efficient materials and technologies.
[15] Wiche et al. (2022) highlighted primary challenges in measuring building carbon footprints across their life cycle in Chile (applicable elsewhere), including incomplete material/method information, lack of standardized methods, accounting for embodied carbon, and variations in energy sources and network emissions.
[16] Klein-Banai & Theis et al. (2013) employed a data-driven method analyzing factors affecting GHG emissions in universities. They found correlations with institutional size (building area, student enrollment), laboratory/residential space, presence of a medical school, and faculty/staff/student commuting. Climate had a secondary impact, with physical size being the biggest factor for Scope 1 and 2 emissions.

[17] Savolainen et al. (2023) assessed carbon footprints, including direct (Scope 1) and indirect (Scope 2 and 3) emissions from waste, electricity, and other sources. They emphasized transparent reporting and data-driven values, stressing precise data collection for accurate calculations, targets, and progress monitoring, and promoting environmental responsibility through coordination.
[18] Norouzi et al. (2023) provided insights into the potential of low-energy buildings to reduce GHG emissions, estimating a building's carbon footprint using LCA. Their assessment of heating/ventilation options, electricity generation scenarios, and waste treatment alternatives revealed significant variations in carbon footprint based on technological and decarbonization pathways.
[19] Gaarder et al. (2023) provided information on the optimum insulation thickness for building envelopes in cold climates, considering embodied carbon emissions during material production and energy savings from reduced heating. They used LCA to compare environmental effects across different insulation thicknesses, materials, climates, and energy mixes.
[20] Sharma et al. (2021) aimed to understand how various tree species contribute to CO2 sequestration. They calculated Above Ground Biomass using allometric formulas and emphasized selecting species with higher carbon sequestering potential for landscape planning in urban green spaces to reduce carbon footprints.
[21] da Silva et al. (2023) evaluated studies on decarbonization methods, highlighting globally adopted sustainable practices like renewable energy, energy efficiency, eco-friendly transport, and carbon offset programs. The study also discussed the role of leadership, governance, and institutional policies in supporting effective decarbonization initiatives.
[22] Mehta et al. (2022) focused on minimizing the carbon footprint of an Indian research and educational institution. Their study involved assessing Scope 1, 2, and 3 carbon emissions, considering inclusions and exclusions, and examining carbon sinks and offsets on campus.
[23] Wang et al. (2022) investigated how turfgrass spaces (sports fields, lawns) act as significant carbon sinks, absorbing CO2. They explored how management techniques (fertilizer, irrigation, mowing height) impacted turfgrass carbon sequestration rates due to extensive root systems and high biomass production.
[24] Sirin et al. (2023) provided insights into Building Integrated Photovoltaic/Thermal (BIPV/T) systems, which simultaneously generate electricity and provide thermal comfort. Their research evaluated BIPV/T performance in terms of electricity production and thermal comfort for overall energy efficiency.
[25] Moghayedi et al. (2023) introduced retrofitting building windows by filling the air gap between glass panes with polyurethane foam (PU foam). This rapid, non-destructive, economical, and ecologically conscious technique lowered window transmittance by 25%, resulting in significant energy savings.
[26] Gao et al. (2023) provided an overview of CiteSpace and VOSviewer use in understanding carbon emissions of public buildings, emphasizing five major study areas: simulation modeling/theoretical research, energy systems, materials, retrofitting, and the use of digital technologies, structural elements, and architectural characteristics for sustainability.
[27] Ruggieri et al. (2023) highlighted the building industry's significance in achieving zero-emission targets, particularly in the EU, noting that residential and educational structures in Italy contribute substantially to energy demand and GHG emissions. They established a three-phase policy roadmap for energy renovation: market barrier reduction/financial incentives, national database creation, and promotion through public procurement.
[28] Abdelaal & Guo et al. (2021) provided an understanding of stakeholder participation in green building construction in New Zealand, including knowledge, attitudes, and practices among investors, engineers, architects, developers, government representatives, contractors, building owners, and tenants. They identified a gap between knowledge and practice due to lack of awareness regarding sustainable building materials, integrated design, and energy-efficient systems.

IV. METHODOLOGY AND OBSERVATIONS

The methodology used in this case involves first determining the carbon emissions of **Govt. Polytechnic College Sawai Madhopur (Rajasthan)** using the LIFE CYCLE ASSESSMENT approach in accordance with ISO 14064-1, using a variety of conversion factors from the GHG Protocol Corporate Standard, a collaborative effort between the World Business Council for Sustainable Development (WBCSD) and the World Resource Institutes (WRI) . Finding the institutes' various carbon sinks and estimating their capacity to sequester carbon are the next steps. It may also be recommended to employ a variety of carbon offsets to offset the carbon emissions by further utilizing the technology available today. The following steps are used for research.

1) Defining boundary i.e., the operational area and setting the timeline
2) Identifying carbon emission sources
3) Collecting the data for emission calculation
4) Calculating the carbon footprint using above data
5) Finding various carbon sink of institute and estimating their capacity and recommend various carbon offset

A. Defining Boundary and setting timeline

In this study, the operational boundary is confined to the campus of Government Polytechnic College, Sawai Madhopur, located in Rajasthan, India. The institute is positioned at 26.036279°N latitude and 76.34663°E longitude, with an elevation of around 265.8 meters above sea level. Nestled on the banks of the Banas River, the area experiences a semi-arid climate with average annual rainfall of nearly 800 mm. The environmental conditions, including hot summers and cold winters influenced by nearby higher elevations, play a key role in determining energy requirements. In terms of the timeline, the study adopts a semester-wise approach that spans two academic years, divided into the following four periods:

- January – June 2023
- July – December 2023
- January – June 2024
- July – December 2024
- January – June 2025

This structured division allows for the capture of seasonal variations in energy usage and emissions. For instance, during summer months, electricity consumption for cooling increases, while winter months may witness a rise in fuel usage for heating and cooking purposes, particularly in hostels and canteen areas. Additionally, changes in student presence, academic activity, and infrastructure use can also impact emission levels across semesters.

By analyzing emissions across these defined periods, the institute can gain insight into how climate and operational changes affect its carbon footprint, and can use this information to develop effective mitigation and sustainability strategies.

B. Identifying Carbon Emission Sources

To effectively address and mitigate the environmental impact of greenhouse gas (GHG) emissions, it is critically important to identify and categorize all potential emission sources associated with the institution" A proven framework for this goal is provided by the Greenhouse Gas Protocol Corporate Standard, which was jointly created by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). Depending on how much control and accountability an organization has over each source, it divides emissions into three different scopes. A systematic identification of emission sources enables the institute to better understand its environmental footprint, recognize areas for improvement, and prioritize mitigation strategies accordingly. Each emission scope is explained in detail below as applied to Government Polytechnic College, Sawai Madhopur.

1) Scope 1: Direct Emissions

Scope 1 includes direct GHG emissions that originate from sources owned or controlled by the institution. These emissions occur within the defined boundary of the institute and are the result of on-site fuel combustion or institutional activities. In the case of this study, two primary types of direct emissions are identified:

a) Mobile Emissions: These emissions are a result of fuel consumption in **institute-owned vehicles**, such as staff cars, buses, or any transport used for official activities including administrative duties, academic field visits, and logistics. The burning of petrol or diesel in these vehicles releases carbon dioxide (CO_2), nitrogen oxides (NO_x), and other pollutants directly into the atmosphere. The frequency of vehicle usage, fuel type, and distance travelled are all critical factors that determine the magnitude of emissions.

b) Static Emissions: These arise from the combustion of fossil fuels like LPG (Liquefied Petroleum Gas) in stationary equipment and appliances. In the context of the institute, LPG is primarily used in the cafeteria, hostel kitchens, and canteens for cooking purposes. These emissions are directly measurable by monitoring the amount of LPG consumed over each semester. Since these are within the institute's operational control, they form a significant and accountable part of the direct emissions.

2) Scope 2: Indirect Emissions from Energy Consumption

Scope 2 refers to indirect GHG emissions resulting from the purchase of electricity, steam, heating, or cooling that is generated off-site but used within the institute's premises. Although the institute does not directly emit the GHGs from generating electricity, it is indirectly responsible for the emissions caused by the regional power generation facilities, especially if they rely on fossil fuels like coal, oil, or natural gas. In this study, Scope 2 emissions mainly come from the electricity consumed for lighting, laboratory equipment, computers, fans, air conditioning, and water pumps. The total electricity usage in kilowatt-hours (kWh) is monitored and multiplied by a regional Carbon Conversion Factor (CCF) to estimate the carbon emissions associated with electricity use.

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This helps in identifying energy-intensive operations and highlights opportunities for energy efficiency and use of renewable energy alternatives such as rooftop solar panels.

3) Scope 3: Other Indirect Emissions

All additional indirect emissions resulting from institutional operations that come from sources not directly owned or managed by the institute are included in scope 3 emissions. These emissions make up a sizable portion of the overall carbon footprint and are necessary for a thorough evaluation, despite being the most challenging to measure because of their variety and frequently dispersed nature.

The following categories are included under Scope 3 emissions for this study:

a) Employee and Student Commuting: A considerable portion of carbon emissions results from the daily commute of students, faculty, and staff using personal vehicles such as motorbikes, cars, and public transportation. These emissions depend on the number of commuters, distance travelled, mode of transport, and frequency of travel. Though these vehicles are not owned by the institute, the commuting activity is directly related to its operations and must be accounted for in the overall carbon footprint.

b) Waste Generation and Disposal: The institute produces solid and liquid waste through various activities such as classroom instruction, administrative work, laboratory experiments, canteen operations, and student hostel occupancy. Improper disposal of organic waste, paper, plastic, and electronic waste can lead to methane (CH_4) and other GHG emissions, especially if waste is landfilled or incinerated. Quantifying the amount and type of waste produced allows the institution to estimate emissions and identify areas where waste reduction or recycling strategies can be implemented.

c) Water Consumption: Although water itself is not a greenhouse gas, the processes associated with water extraction, purification, pumping, and distribution consume energy, which leads to GHG emissions. Every liter of water used on campus—whether for drinking, sanitation, irrigation, or laboratory use—carries an embedded carbon cost. Measuring water usage helps in estimating emissions indirectly associated with water-related infrastructure.

d) Procurement of Goods and Materials**:** The purchase and consumption of stationery, office supplies, laboratory consumables, and printing materials also contribute to carbon emissions**.** Items such as paper, drawing sheets, ink cartridges, and packaging materials have an embodied carbon footprint due to emissions generated during their production, transportation, and disposal. Even though these emissions occur outside the institute's premises, they are a result of operational needs and hence, form part of Scope 3.

By identifying and categorizing emissions across these three scopes, the institute can construct a **complete emissions inventory**, which forms the backbone of any environmental sustainability or carbon neutrality initiative. This categorization not only aids in accurate reporting but also helps in **strategic decision-making**, such as focusing on on-site fuel reductions, switching to renewable electricity, promoting public transport or carpooling, reducing waste generation, and adopting green procurement policies.

C. Collecting the data

The process of data collection forms the foundation of any accurate and comprehensive carbon footprint assessment. Once the emission sources have been identified and categorized under Scopes 1, 2, and 3, the next critical step is to systematically gather all relevant data that will allow for the quantification of greenhouse gas (GHG) emissions. Effective data collection not only improves the reliability of the carbon inventory but also ensures transparency and consistency throughout the carbon auditing process.

To begin with, a detailed emission inventory checklist is developed, incorporating all identified activities contributing to direct and indirect emissions. These activities span various functional areas of the institute such as transportation, energy usage, procurement, waste management, and water consumption. Given the diverse nature of emission sources, data must be gathered from a wide array of departments including administration, facilities management, transport office, canteen services, water supply and sanitation, academic departments, and procurement cells.

Below is a breakdown of how data is collected for various emission scopes:

1) Scope 1 – Direct Emissions

a) Mobile Sources (Institute Vehicles): Logbooks maintained by the transport department are reviewed to record fuel consumption for institute-owned vehicles. This includes the type of fuel (petrol/diesel), quantity used (in litres), purpose of travel, and frequency of trips. This data is then used to calculate emissions based on standard conversion factors.

b) Static Sources (Cooking Fuel): Records of LPG cylinder usage in the canteen and cafeteria are collected. The number of cylinders consumed each month, the weight of LPG per cylinder, and refill frequency provide the basis for estimating CO_2 emissions from combustion.

2) Scope 2 – Indirect Emissions (Electricity Use)

The monthly electricity bills issued by the local electricity distribution authority are the primary source for energy consumption data. These bills provide the total kilowatt-hour (kWh) usage across various zones of the institute such as classrooms, labs, administrative blocks, hostels, and outdoor lighting. For additional accuracy, smart meters or sub-meters, if installed, can be used to segregate consumption by building or activity type. This energy usage is then multiplied by a region-specific emission factor (kg CO_2/kWh) to determine the total emissions from purchased electricity.

3) Scope 3 – Other Indirect Emissions

a) Employee and Student Commuting: A travel survey questionnaire is conducted among faculty, staff, and students to collect data on their daily commuting habits. This includes mode of transport (car, bike, bus, etc.), average distance travelled, frequency (number of days per week), fuel type used, and vehicle occupancy. This data is aggregated and converted into emission values based on standard fuel efficiency assumptions and conversion factors.

b) Waste Generation: Waste data is collected from the housekeeping and waste management contractor records, which detail the quantity and type of waste generated—biodegradable, recyclable, electronic, and hazardous. The waste disposal methods (landfill, incineration, composting, or recycling) are also documented, as each method has different GHG implications. On-site waste audits can further refine these estimates by providing sample-based insights.

c) Water Consumption: The institute's monthly water usage is obtained from water supply authorities or internal plumbing department records. Water meters (where available) provide real-time data on the volume of water consumed (in litres or kilolitres). Indirect emissions are estimated based on energy consumption for water extraction, treatment, and pumping.

d) Procurement of Goods (e.g., Paper): Purchase records from the accounts and procurement departments are examined to determine the quantity of consumables such as paper, drawing sheets, ink, and office supplies. These items are assigned emission values using life-cycle emission factors that take into account manufacturing, packaging, and transport-related emissions.

To streamline data collection, the following tools and techniques are recommended:

- Structured Data Collection Forms: Standardized templates for each emission source category to ensure uniform data gathering.
- Interviews and Staff Inputs: Engaging relevant personnel (e.g., drivers, canteen managers, administrative staff) to validate data points and fill in gaps.
- Automated Data Logging: Where infrastructure permits, smart meters and digital tracking tools can automate data gathering for energy, water, and fuel usage.
- Data Validation Checks: Cross-verification of data through billing statements, receipts, and visual inspection to ensure authenticity and consistency.

A centralized data repository is maintained where all raw data, calculations, assumptions, and references are stored semester-wise. This repository forms the backbone of the **carbon audit trail**, ensuring that future assessments can build upon previous work and that results can be easily reviewed and verified by external auditors or academic committees.

D. Calculating the carbon footprint

One of the most useful and widely recognized metrics for assessing the environmental effects of human activity, especially with regard to its role in climate change, is the idea of carbon footprint. In terms of carbon dioxide equivalents (CO_2e), a carbon footprint is the total amount of greenhouse gases (GHGs) that an individual, group, or institution emits, either directly or indirectly. This unit facilitates the assessment and comparison of emissions by standardizing several greenhouse gases with disparate global warming potentials (GWPs) into a single quantifiable measure.

In the context of an academic institution like Government Polytechnic College, Sawai Madhopur, calculating the carbon footprint is a critical step toward developing sustainable operational practices and reducing environmental impact. Institutions engage in a wide array of activities ranging from electricity consumption and transportation to waste generation and material usage all of which contribute to greenhouse gas emissions. Quantifying these emissions allows decision-makers to identify the primary sources of emissions, monitor changes over time, and implement appropriate mitigation strategies.

Need for Quantification in Standard Units

Greenhouse gases include a range of compounds such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), each with different heat-trapping capabilities. For instance, methane has a global warming potential 28–36 times higher than CO_2 over a 100-year period, while nitrous oxide is approximately 265 times more potent. Due to this variability, emissions must be normalized into a common metric CO_2 equivalents (CO_2e) to effectively measure and analyze the overall climate impact.

The calculation process involves determining the activity data (e.g., fuel consumption, electricity usage, waste generated) and multiplying it by the corresponding carbon conversion factors (CCFs), which are standardized values provided by international organizations like the IPCC (Intergovernmental Panel on Climate Change)**,** GHG Protocol, and national agencies.

$CO_{2\ equivalent}$ = Activity x CCF* (1)

*CCF means Carbon Conversion Factor

Activity: Following set of activities are defined

Static Emission $CO_{2\ eq}$ = LPG consumption (Kg)

Mobile Emission $CO_{2\ eq}$ = Fuel Consumption (Litre)

Electricity consumption, $CO_{2\ eq}$ = Unit electricity consumption (kWh)

Employee Commuting using their personal vehicles ,$CO_{2\ eq}$ = Fuel Consumption (Litre)

Waste disposal, $CO_{2\ eq}$ = Waste Generated (Kg)

Water use, $CO_{2\ eq}$ = Water Used (Liter)

Paper Consumption, $CO_{2\ eq}$ = Paper Consumed (per sheet)

E. Carbon Sinks and offsets

For making the institute carbon neutral several existing sinks are identified. Most common existing sink is presence of tree cover within the operational boundary of the institute. Their carbon sequestration potential is calculated by using allometric equation. Allometric equation is a set of empirical equation which provides us with non-destructive tool of calculating biomass stored in the trees. Above Ground Biomass and Below Ground Biomass both are calculated by following the equation given below:

AGB (kg)=0.0224×(D2×H)^0.9767 (2)

Above Ground Biomass (AGB)

Where D is the diameter/Girth (cm) of the Tree at 1.37m height

H is height of tree

Above equation is valid for semi arid region of Rajasthan and above equation holds good for the area under study.

Below ground mass is approximately 26% of the above ground mass. (IPCC 2006 Guidelines)

BGB = AGB × (26/100) Kg (3)

Total biomass was calculated by adding both ABG and BGB.

TB= AGB+BGB (Kg) (4)

Out of total biomass present in the tree, only 50% is stored as carbon content in the trees and its carbon equivalent was calculated by using following formula:

CO_2 (eq.) = 0.5xTotal Biomass x (44/12) (5)

Other sinks are also identified which have the potential to reduce the carbon either directly or indirectly. The institute has a potential to install rooftop solar panels. In addition to this, various other sustainable practices can also be adopted in many activities like making use of daylight hours, using natural ventilation system, solar chimney concepts, use of double plumbing system etc

V. RESULT AND DISCUSSION

Based on the inventory list prepared by following ISO 14064-1 guidelines, data is collected for each category as specified by GHG Protocol Corporate Standards. The data depicted in table 9 includes the carbon emission because of human respiration as well. By multiplying this data with suitable conversion factor in the analysis total carbon emission is easily calculated. The current study is done by following a bottom-up approach in Life Cycle Analysis under ISO guidelines. Total carbon emission is found to be 16335 Kg when only 3 scope categories, as defined by GHG Protocol Corporate Standards, are taken into account. When human respiration is included, total carbon emission is found to be 75283.00 Kg. Table 1 clearly indicates the total carbon emission under each scope category including human respiration.

Table1 Total Carbon Emission for the Year 2024 within the Institute

Sr. No.	Scope Category	Carbon Emission (Kg)	Data Source
1	Scope-I		
	Static Emission	699	Girls Hostel, Boys Hostel and Institution Canteen
	Mobile Emission	3117	Institution owned vehicle
2	Scope-II		
	Electricity Consumption	4473	Lighting and Heating System in Institution, Girls Hostel and Boys Hostel
3	Scope-III		
	Employee Commuting	4213	Personal Vehicle
	Waste Disposal	300	Institution canteen, Girls' hostel and Boys' hostel mess
	Water Consumption	302.40	Institution campus, Girls' hostel and Boys' hostel
	Paper/Stationery Consumption	3230.60	Office work and Academic activities
4	Human Respiration	58948	
Total Carbon Equivalent= 75283.00 Kg			

From figure 2, it is clear that for the year 2024, nearly 78% of the carbon emission is through human respiration. This emission is because of the strength present within the institute. For each session, total staff members are also taken into consideration. Considering the health condition of the students and staff members, total carbon emission is calculated by multiplying the data with suitable conversion factor.

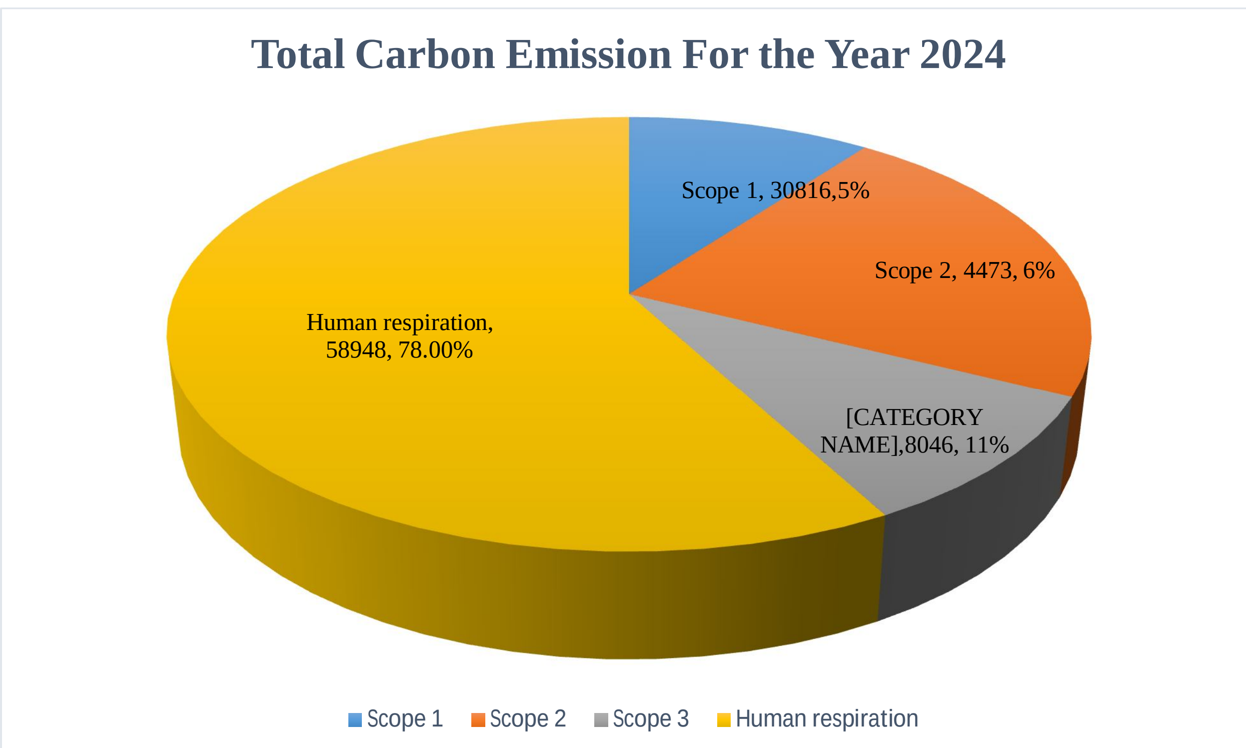

Figure 2 Percentage distribution of total carbon emission

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However, if the carbon emission is calculated considering only the Scope 1, Scope 2 and Scope 3 categories as defined in the GHG Protocol Corporate Standards, major source of carbon emission is because of Scope 3, followed by the electricity consumption under Scope 2 category and Scope 3 categories as depicted in figure 3 below:

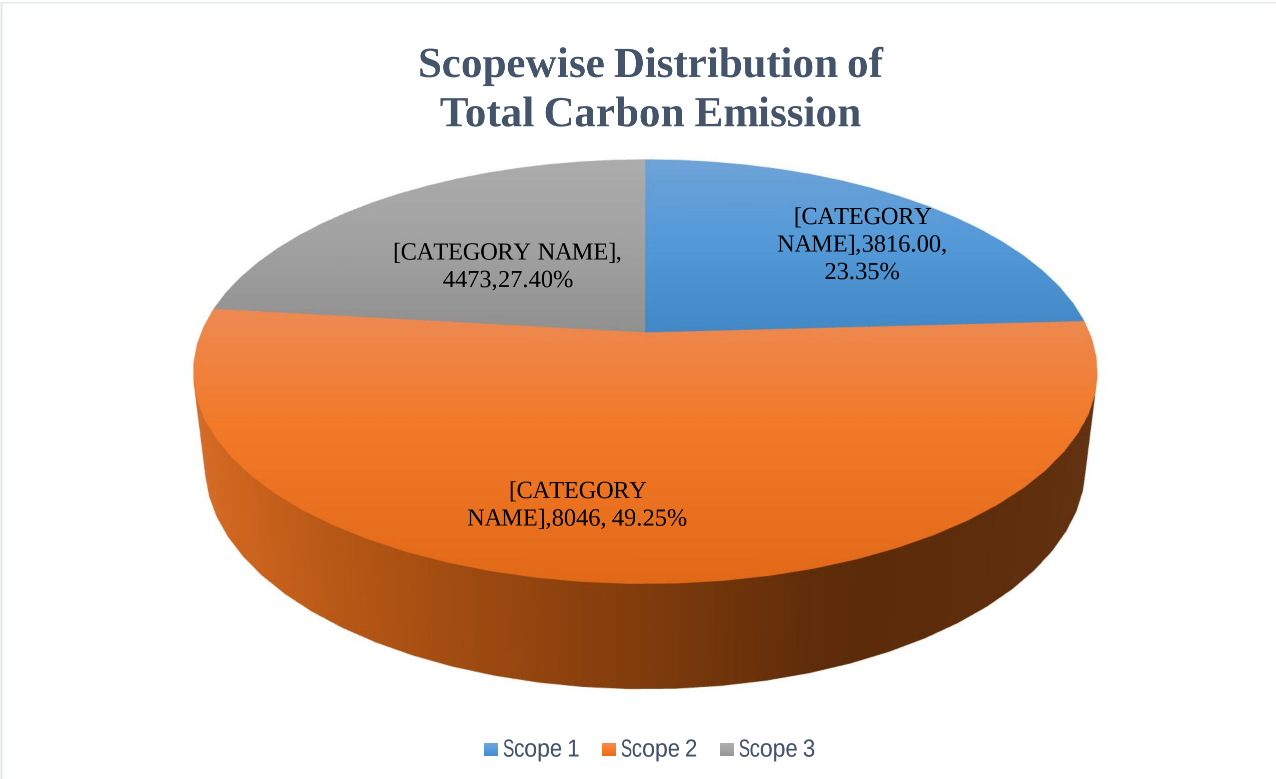

Figure 3 Scope wise Distribution of the Total Carbon Emission

Sawai Madhopur, located in the eastern part of Rajasthan, experiences a semi-arid climate characterized by extreme temperatures and low to moderate rainfall. Summers are typically hot and dry, with temperatures often exceeding 40°C, while winters are relatively cool and dry, with minimum temperatures occasionally falling below 10°C. The monsoon season, occurring from July to September, brings the majority of the annual rainfall, averaging around 800 mm. Furthermore, electricity is consumed for the lighting of the institute. Various other activities also require use of electricity and thus is a major source of carbon emission. Maximium carbon emission is observed in category 3 because of various factors emission considered in this category. This is followed by scope 2 category. Minimum carbon emission is observed under scope 1. Since there is no standard inventory list suggested by GHG Protocol Corporate Standards, most of the categories are not taken into the consideration due to the lack of available data. In order to suggest measures to make the campus as carbon neutral, the first step is taken to identify the carbon sequestration potential of the existing tree cover within the operational boundary of the campus. For this tree census is conducted and by making use of allometric equation i.e., eq. 2 to eq. 5 mentioned in methodology, total carbon sink is calculated. Table 2 clearly indicates the sequestration potential of each tree.

Table 2 Tree census and their sequestration Potential

Sr. No.	Tree Type	Nos.	AGB (Kg)	BGB (Kg)	TB (Kg)	Eq. Carbon Content (Kg)
1	Azadirachta indica	15	3992.92	7038	5031	9224
2	Ficus Religiosa(Peepal)	9	2351.42	611	2963	5432
3	Manoon Longifolium	3	2.0	0.54	2.54	4.84

	(Ashoka)					
4	Neltuma Laevigata	4	239.39	62.24	301.63	553
5	Dalbergia sissoo(Sheesum	7	1288.40	335	1624	2976
6	Mangifera Indica	2	1062.22	276	1338.88	2453
7	Lemon Tree	1	218	56.87	275	505
8	Ficus benghalensis (Banyan)	2	704	183.27	8302.42	1628.37
9	Ailanthus excelsa(Ardu)	8	646.67	168.13	814	1493.87
10	blackbaord tree(Saptparni)	1	54.32	14.12	68	125.51
11	Cassia fistula(Amaltas)	1	90.91	23.63	114	210
12	Aegle marmelos(belpatra)	1	121	31.51	152.51	280
Total Carbon Sequestration = 24888.75kg						

Total sequestration potential of the existing tree cover is 24888 Kg. Among all the varieties present, sequestration potential of Azadirachta indica comes out to be maximum, which may be due to the huge numbers they are present in. Same reason can be used to justify the minimum sequestration potential of Blackboard tree. Out of 54 trees present under 12 different varieties, 15 no. of trees are of Azadirachta indica and only 1 tree of Blackboard tree, cassia fistula, Aegle marmelos and lemon are present. Additionally, the diameter at 1.37 m height for Azadirachta indica and ficus religiosa are more when compared to most of other trees.

Figure 4 clearly indicates that the carbon sink provided by existing tree cover is more than the carbon emission generated by activities mentioned under GHG Protocol Corporate Standards, which exclude human respiration from the total emission. Thus, by considering this data only, the institute is already operating as a carbon neutral campus.

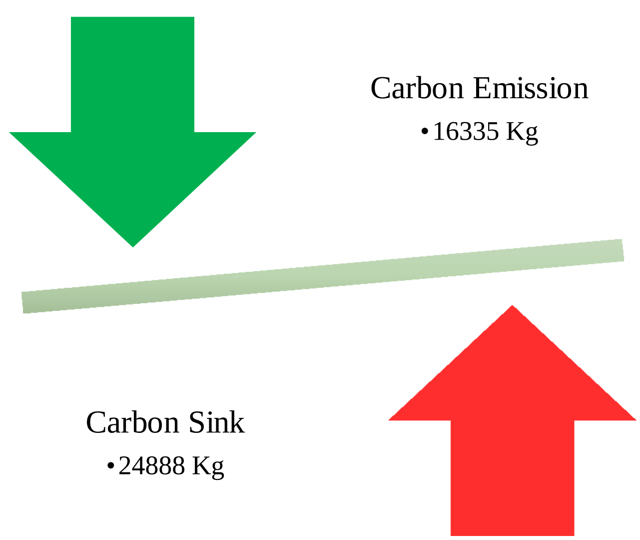

Figure 1 Balancing the Equation for Carbon Sink and Carbon Emission (Excluding Human Respiration)

The institute has a potential for installing a rooftop solar panel, which will help in the production of cleaner energy. This clean energy can be used to fulfill the electricity requirements for heating, lighting and even cooking etc. which will indirectly help in the providing a carbon sink within the institute. Excess of solar energy produced can also be sold to the electricity department and this will be converted into a carbon offset for the institute. Table 3 indicates the data for available rooftop area which will help in achieving more sustainability in building operation once installed. However, total carbon sink is dependent upon the incoming solar radiation (GHI), available sunshine hours and total number of panels to be installed and their rated capacity.

Table 3Available Rooftop Area for installing solar PV panels

Sr. No.	Institution Block Name/	Roof Top Area
1	Total built up area	3711 sqm
2	Cafeteria	160 sqm
3	Boys Hostel	475 sqm
4	Girls Hostel Building	430 sqm

Furthermore, the institute also has a rain water harvesting system which is not fully in operation yet. By adopting double plumbing system within the institute, the rain water can be utilised without any treatment in flushing system and various other sanitary operations. This will reduce the carbon emission caused due to use of water under Scope 3. Further providing various water tight fixtures, star rated appliances and using greener products in operation of buildings will prove to be more sustainable solutions in the longer run. By making use of natural ventilation systems like solar chimney, making efficient use of daylight hours will reduce the electricity consumption which in turn will reduce the carbon emission caused. Additionally, the practice of carbon offsetting is also adopted by the institute. In this regard, the students of the institute in association with the state forest department have planted nearly 200 trees in the college campus. We are developing one part of our college as a green zone. Further the institute has pledged to take care of these trees over the course of their life time. The institute has formed an Eco-club, members of which will be responsible for the upkeep process. These trees, in the coming years, will provide a huge carbon sink and thus make the operation of the institute more sustainable.

VI. CONCLUSION

A detailed survey of the campus and its operational activities led to the identification of the numerous emission sources and thus helped in preparing the inventory list under the guidelines of ISO 14064-1 in bottom-up approach used in Life Cycle Analysis. The total emission under various direct and indirect sources is found to be 16335 kg out of which electricity consumption under scope 2 contributed nearly 27% and scope 3 contribute nearly 49%. However, if human respiration is also to be included, the emission will go upto 75283 Kg which is more than the emission identified under the categories specified by GHG Protocol Corporate Standards and is the biggest source of carbon emission identified in the institution.

Existing carbon sink in the form of tree cover is first identified through tree census and their sequestration potential is then calculated using allometric equations. Total carbon sink provided by the tress is found to be 24888 Kg.

Thus, considering only scope 1, 2 and 3 categories, the institute is operating as a carbon neutral campus. But since human respiration is also considered, further sinks need to be identified or suggested in the form of solar rooftop panels, operational rainwater harvesting system and by adopting various green products and activities like making use of star rated appliances, efficient water and energy fittings, making use of daylight hours etc. Additionally, in order to make institute more sustainable, Carbon offset is also identified.

The study will thus help in providing a comprehensive solution in adopting numerous sustainable strategies and policies to make any educational institute a carbon neutral campus. This study, in nutshell, can provide for combating global climate change in longer run and thus will help in realizing the ambitious goal of SDG 13.

Although this study is very comprehensive in itself yet, an effort can also be made in the direction of calculating additional carbon sources under scope 3 like carbon emission by using chemicals in lab, carbon emission due to ongoing construction, carbon emission due to embodied carbon etc. An effort can also be made in the direction of calculating carbon sink due to grass cover, carbon offsets like donating solar power street lights in local areas etc.

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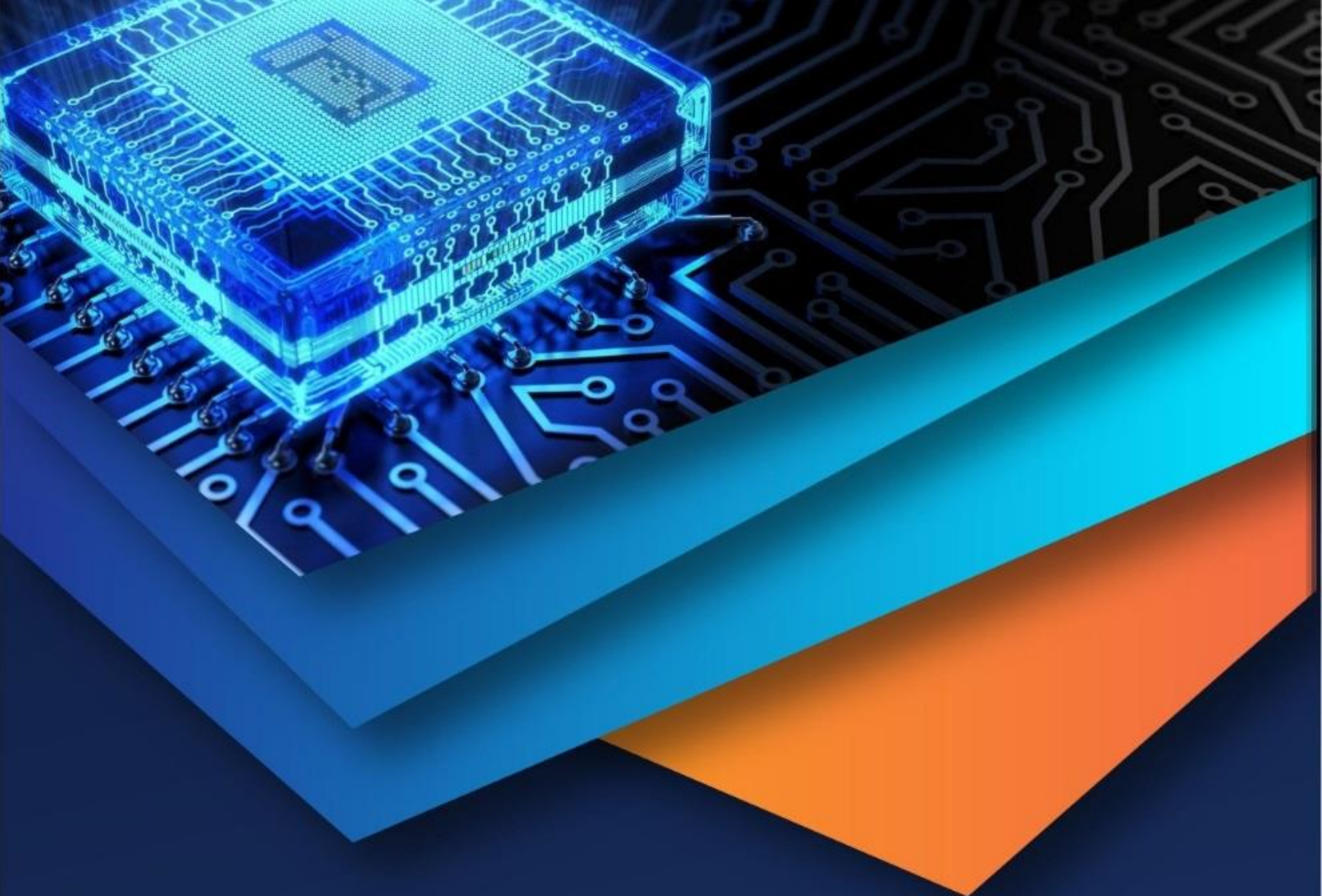

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