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CARBON FOOTPRINT MONITORING AND MITIGATION IN HIGHER EDUCATION: A META-ANALYSIS REVIEW

A. Maher. Abdelbasier[1]; Moataz M. Kamel[2]; Noha S. Donia[1] and H. A. Nawar[3].

1) Environmental Engineering Department, Faculty of Graduate Studies and Environmental Research, Ain Shams University, Egypt 2) Postgraduate student at Environmental Engineering Department, Faculty of Graduate Studies and Environmental Research, Ain Shams University, Egypt 3) Environmental Basic Sciences Department, Faculty of Graduate Studies and Environmental Research, Ain Shams University, Egypt

Corresponding author: E-mail: ahmed.maher@iesr.asu.edu.eg

ABSTRACT

This review article looks at past research on monitoring and reducing the carbon footprint (CFP). A meta-analysis approach was used to review different methods. The scope of the work was concentrated on the available published data for different campus locations: the BITS Pilani campus (in India), the AUS campus in Sharjah (in the UAE), King's College London (in the UK), and St. Edward's University (in the USA). Clemson University, USA Electricity consumption contributes a significant percentage of the CFP, with the AUS campus consuming 58,773 MWh of electricity annually, equivalent to 61% of the total emissions. At Clemson University, emissions from electricity generation were 38,718 $MTCO_2eq$, and on the BITS Pilani campus, 16,500 $MTCO_2eq$. This indicates that electricity consumption has improved greatly when it comes to decreasing CFP. The findings indicate that while some progress has been made, there is still much room for improvement. The paper highlights the limitations and challenges of existing methods and provides valuable insights and recommendations for future research. The review serves as a resource for educators, researchers, and

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policymakers. The calculation methodology states that for educational buildings, the second section has the maximum CFP value, while electrical and water consumption are the main contributors.

Keywords: Carbon Footprint, Educational Facilities, Climate Impact.

INTRODUCTION

With the world’s population growth and the expansion of economic and industrial activities, air pollution is on the rise. This contributes to global warming by decreasing the Earth's ability to absorb carbon emissions. The concept of 'carbon footprint' has been introduced to address this challenge. The emission of Green House Gases (GHGs) has a damaging impact on the environment as they are the leading source of climate change caused by humans. It exacerbates urban air pollution, produces toxic acid rain, contributes to the acidification of coasts and oceans, and worsens the melting of glaciers and polar ice.

The origin of the term carbon footprint has been discussed many times, as mentioned by Durojaye and his colleagues in their descriptive review of the carbon footprint at the University of Johannesburg, (Durojaye *et al.*, 2020), as they state that the term was used extensively among meteorologists and by the public in general in public discussions where responsibility and mitigation measures in combating the threats of global warming and climate change, are discussed. For several years now, the use of the expression has been on the rise due to its importance and urgency. These days, the expression is used across various media and in the fields of business and government.

However, despite its constant use, the term 'carbon footprint' has no generally accepted academic definition. In addition, there are some confusions and misunderstandings regarding what the term means, as well as the exact unit to be used. Although the expression is rooted in the language of ecological footprints, the generally accepted opinion is that the carbon footprint represents a specific amount of gas emissions that have been considered important for climate change and are also related to human production and consumption activities. However, this is the only area of convergence because there is no agreement on measuring or quantifying the carbon footprint.

So, one of the definitions goes from direct carbon dioxide emissions to the whole life cycle of greenhouse gas emissions, but the actual units of measurement are not clear. But in an attempt by Durojaye, *et al*, (2020), to define the expression carbon footprint, they mentioned many definitions in their study, e.g., It may be defined as the quantity of CO_2 emitted due to human daily activities. Such activities range from driving vehicles to using heavy construction machinery, from doing laundry with washing machines to microwaving food items at fast food joints, and many more. Others have called it a method for figuring out how much greenhouse gas a product releases over its entire life cycle, from the time it starts out as unprocessed raw materials to the time it is made. Other reports classified the carbon footprint as the full range of carbon dioxide emissions resulting from various commercial activities, including direct and indirect business activities. So, the carbon footprint is expressed as grams of carbon dioxide equivalent per kilowatt-hour of generation (carbon dioxide eq / kWh). From this point of view, the carbon footprint represents the various greenhouse effects caused by other greenhouse gases. Therefore, the "carbon footprint" can be expressed as a common alternative to carbon dioxide emissions or any other greenhouse gases expressed as carbon dioxide equivalents.

Also, the term "carbon footprint" is defined by the Intergovernmental Panel on Climate Change (IPCC) Guidelines as "a representation of the effect on climate in terms of the total amount of Greenhouse Gases (GHG) that are produced, measured in units of CO_2eq, as a result of the activities of an organization." CFP is an extremely useful tool for exercising a greater degree of control over activities that impact the environment (Robinson *et al.* 2018).

Universities like our Faculty of Graduate Studies and Environmental Research (GSER), which focuses on environmental studies, play a key role in promoting sustainable development and dealing with climate change. Given how serious the problem is, it is important to understand and reduce universities' carbon footprints, especially those that focus on environmental studies. Considering this, our review study will concentrate on the carbon

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footprint that using electricity creates and offer practical ways to reduce it. Universities should set a good example by keeping track of their carbon footprints, finding ways to reduce them, and implementing policies that are good for the environment. The studies of Samara et al., (2022), and Letete et al., (2011), which focus on environmental studies, play a key role in promoting sustainable development and dealing with climate change. Given how serious the problem is, it is important to understand and reduce universities' carbon footprints, especially those that focus on environmental studies. Considering this, our review study will focus on the carbon footprint caused by using electricity and offer real-world ways to reduce it. Universities must lead by example and track their carbon footprints, putting reduction strategies and sustainable policies in place. The studies of Samara *et al*.,(2022), Letete (2011); and Valls-Val, and Bovea (2021) will be reviewed in this study.

Previous studies on this topic often focus on an activity-based greenhouse gas emissions inventory (Valls-Val, and Bovea 2021) or categorizing emissions into direct (e.g., university fleet emissions) and indirect emissions (e.g., electricity, water consumption) and other indirect emissions (e.g., commuting and business travel, material transportation, waste management) as defined by ISO 14064 standards (Samara *et al.*,2022); Sangwanst *et al.*, 2018). Our study focuses on the CFP impact of electricity consumption as a meta-analysis of related educational institutes showed that

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it is often the major source of emissions, accounting for over 50% of total emissions on campuses like BITS Pilani, India; (Sangwan et al.,2018), AUS campus Sharjah Samara et al.,2022, St. Edward's and Clemson University (USA) (Bailey, 2016). Some facilities may have a different major source, such as a supply chain (King’s College, 2019). This can be further studied in a separate review. The importance of reducing carbon emissions in higher education cannot be overstated. According to the Intergovernmental Panel on Climate Change (IPCC), the world must reduce carbon emissions by at least 45% by 2030 to limit global warming to 1.5°C and avoid the most severe consequences of climate change. Higher education institutions are in a unique position to make significant contributions to this effort through their research, teaching, and operational activities. By reducing their carbon footprint, they can demonstrate leadership and inspire others to act, while also contributing to the development of knowledge and technologies that can be applied more widely.

Furthermore, the study aims to explore the potential of real-time monitoring of carbon footprints in our Faculty of Graduate Studies and Environmental Research. The study will also review previous methods used for monitoring carbon footprints and how they can be applied to display the emissions value in real-time, related to actual electricity consumption. Climate change is one of the most pressing issues of our time, and higher education institutions have a unique opportunity to make a significant impact on reducing carbon emissions. As a result, many universities and colleges are implementing various measures to monitor and mitigate their carbon footprint. However, the effectiveness of these efforts can vary greatly, and there is a need for a comprehensive review of the existing literature to identify best practices and areas for improvement.

Higher education institutions have a unique chance to lead the way in reducing carbon emissions and promoting sustainable practices because they are hubs of knowledge and new ideas. Because of this, many universities and colleges are taking different steps to track and reduce their carbon footprints. But the success of these efforts can vary a lot, and there is a need for a thorough review of the existing literature to find the best ways to do things and the places where things could be better.

This article uses a meta-analysis to look at how universities track and reduce their carbon footprint. Also, the research aims to put together information from different studies to find the most important things that help carbon reduction strategies work. By looking at a large set of studies done in different parts of the world, we can get a full picture of the state of the field and figure out what we still don't know. The meta-analysis method also lets us find patterns and trends that may not be clear from individual studies. This gives us a more nuanced understanding of the factors that contribute to the success or failure of carbon reduction efforts in higher education institutions.

METHODS

This review article on the carbon footprint of educational buildings involves a systematic and rigorous process of searching, selecting, analyzing, synthesizing, evaluating, and writing. The final product should be a well-structured, informative, and practical article that contributes to the existing knowledge in the field. The first step is to define the scope of the review article, which includes identifying the research question to be addressed. The research question is, "What are the factors that contribute to carbon emissions in educational buildings, and how can they be reduced?". The study was conducted using databases such as Google Scholar, Scopus, and Web of Science. After conducting the literature review, the next step is to select the relevant studies to be included in the review article. The inclusion and exclusion criteria are defined to ensure that only high-quality and relevant studies are selected. The selected studies should be critically evaluated to determine their relevance and quality. The study includes literature from different locations. The excluded published data are articles in the same area or the same climate region.

To answer the research question, the data from the chosen studies were analyzed and put together. The analysis included identifying common themes, trends, and patterns across the studies. The results of the analysis were presented using a meta-analysis methodology. The data from the selected studies were coded and extracted into a spreadsheet or database. The

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data included study characteristics, such as study design, sample size, and intervention type, as well as the effect of the camp area and measures of variance. The results of the meta-analysis were interpreted in light of the research question and the limitations of the study. The interpretation includes a discussion of the effect of population capacity, the confidence interval, and the implications for policy and practice.

- **Carbon Footprint (CFP) classification and monitoring.**

Tracking and reporting the carbon footprint is fundamental to understanding how different activities impact global sustainability as well as visually displaying the impact to promote awareness in the entire organization and make it easier to understand, monitor and mitigate. CFPs are categorized into 3 scopes based on the sources of emissions where this method is called GHG Protocol

- Scope 1 is the direct emissions from facilities within its organizational boundaries. emissions from university fleets, and emissions from burning fossil fuel in an electric generator.
- Scope 2 is the indirect emissions that resulted from generating energy (electricity, heat, or steam) outside the organization to be used within its premises and can be calculated from the consumption, electricity, and water consumption.
- Scope 3 includes other indirect GHG emissions (Other than Scope 2 emissions) that result from the activities of the organization controlled by

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other organizations. e.g. Emissions from mobility and business travel, transportation of materials, people, or waste; waste generated by an organization but managed by another organization as in Definition of various scopes under the standard ISO-14064 (Samara *et al.*,2022) and (Sangwan *et al.*, 2018). However not all the source emissions are always considered in the same scope.

(Valls-Val, and Bovea 2021) Refrigerant leakage is usually considered to be in Scope 1, although (Sangwan *et al.*,2018) included them in Scope 3. On the other hand, other emission sources which are usually considered in Scope 3 are included in Scope 1 in some studies. For example, the purchase of fertilizers is included in Scope 1 (Bailey, 2016) and (Clabeaux et al, 2020) water supply (Budihardjo, *et. al.*, 2020), (Syafrudin, *et. al.*, 2020) and wastewater treatment by (Clabeaux et al., 2020). Finally, fuel used in power generators, which is usually considered in Scope 1, is included in Scope 2 (Güereca, *et al.*, 2013). This was summarised and displayed in Fig. 1

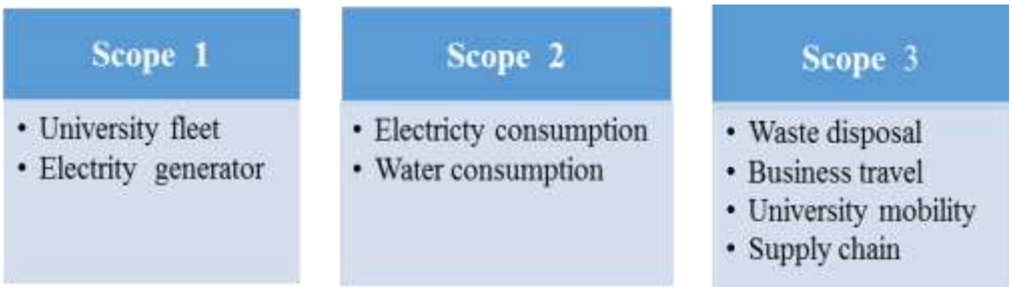

Fig. 1: The scopes and sources of emissions.

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CAMPUS UNDER INVESTIGATION

It is clear that most of the studies show that the least percentage of the emissions was from scope 1 (the direct emissions) and the most percentage was from scope 2 mainly from electricity and water consumption, which of course depends on the size of the organization in terms of surface area, expenditure, and population Also, sometimes the case changes and scope 3 become the most source of emissions depending on what was included in this scope by the study itself and the size of the supply chain the organization uses that was included in scope 3 like what happened in King's college sustainability report for the academic year 2019 (King's College , 2019)

This was demonstrated in Table. 1,2 and 3 by taking data on emissions related to scope categories in some universities in a specific year. Those studies and values were conducted during the period between 2013-2019 in the mentioned locations. And it was displayed in comparing charts in Fig. 3 and Fig. 4

Table. 1 Data on emissions related to scope 1 of universities under investigation.

Campus	Year	Scope 1		Source
		MTCO$_2$eq	CFP %	
BITS Pilani campus - India	2018	182	1.10%	(Sangwan et al.,2018)
AUS campus Sharjah – (UAE)*	2019	352.2	0.37%	(Samara et al.,2022)
King's College London – (UK)**	2019	10,838	8.00%	(King's College, 2019)
St. Edward's Uni – United (USA)***	2013	2,833	15.28%	(Bailey, 2016)
Clemson University- USA	2014	18,041	18.91%	(Clabeaux, et al., 2020)

*United Arab of Emirates (UAE).
** United Kingdom (UK).
*** United States of America (USA).

Table. 2 Data on emissions related to scope 2 of universities under investigation.

Campus	Year	Scope 2		Source
		MTCO$_2$eq	CFP %	
BITS Pilani campus - India	2018	8,250	50.00%	(Sangwan et al.,2018)
AUS campus Sharjah – UAE*	2019	57792.1	61.12%	(Samara et al.,2022)
King's College London – UK**	2019	20,044	16.00%	(King's College , 2019)
St. Edward's Uni – USA***	2013	9,306	50.19%	(Bailey, 2016)
Clemson University- USA	2014	38,718	40.57%	(Clabeaux, et al., 2020)

*United Arab of Emirates (UAE).
** United Kingdom (UK).
*** United States of America (USA).

Table. 3: Data on emissions related to scope 3 of universities under investigation.

Campus	Year	Scope 3		Source
		MTCO2eq	CFP %	
BITS Pilani campus - India	2018	8,069	48.90%	(Sangwan et al.,2018)
AUS campus Sharjah – UAE*	2019	36,409	38.51%	(Samara et al.,2022)
King's College London – UK**	2019	20,044	76.00%	(King's College , 2019)
St. Edward's Uni – USA***	2013	6,403	34.53%	(Bailey, 2016)
Clemson University- USA	2014	38,659	40.52%	(Clabeaux, et al., 2020)

*United Arab of Emirates (UAE).
** United Kingdom (UK).
*** United States of America (USA).

Viewing those data indicates that the least emissions are from direct sources as described in scope 1 while the most emissions are either from scope 2 or 3 depending on what was included in the category of the scope itself as well as the size of operation in the institute itself as will be discussed in the next paragraphs. Where the time of the study the below paragraph will describe the campuses where the data were collected.

- BITS Pilani campus - India:

It has an area of 200,000 m^2 (49 acres) and is in the semi-arid region of northwestern India in 2018 the population of the campus was 5699 consisting of 3452 students, 316 teaching faculty members, 588 non-teaching staff, and 1343 combination of Family members, visitors, and Ph.D. students, its developed area is 49 acres (20 ha) of which 15 acres are reserved for academic buildings. The campus has classrooms and laboratories. 14 student hostels and 1 large hostel for female students (Sangwan et al.,2018).

- AUS campus Sharjah - UAE:

  It has an area of 1,280,000 (316 acres) and in the 2018-2019 academic year the population of the campus was 6041 of which the number of students was 5122, the number of teaching faculty members was 355 and the staff was 564 employees. It also contains many buildings like The College of Arts and Sciences (five buildings), the College of Architecture, Arts, and design (two buildings), the College of Engineering (three buildings), the College of Business, Administration (two buildings), and a library. It also has faculty housing, student residences, a sports complex, a healthcare center, a mosque, a range of restaurants/cafes, grocery stores, a barber shop, a travel agency office, a pharmacy, and a bank branch (Sharjah Islamic Bank).

- King's College London - UK:

It has an area of 250,000 m^2 (62 acres) and in the 2018-2019 academic year, the population of the campus was 35764 consisting of students and staff.

- St. Edward's Uni - USA: (Bailey, 2016)

It has an area of 125,000 m^2 (31 acres) and in 2013 the population of the campus was 4991 of which the number of students ware 4308, the number of teaching faculty members were 201 and the staff was 482 employees.

- Clemson University- USA: (Clabeaux et al., 2020)

It has an area of 613,816 m^2 (150.7 acres) and in 2014 the population of the campus was 26757 of which the number of undergraduate students were 17260, the number of graduate students were 4597, the number of teaching faculty members were 1388 and the staff was 3512 employees.

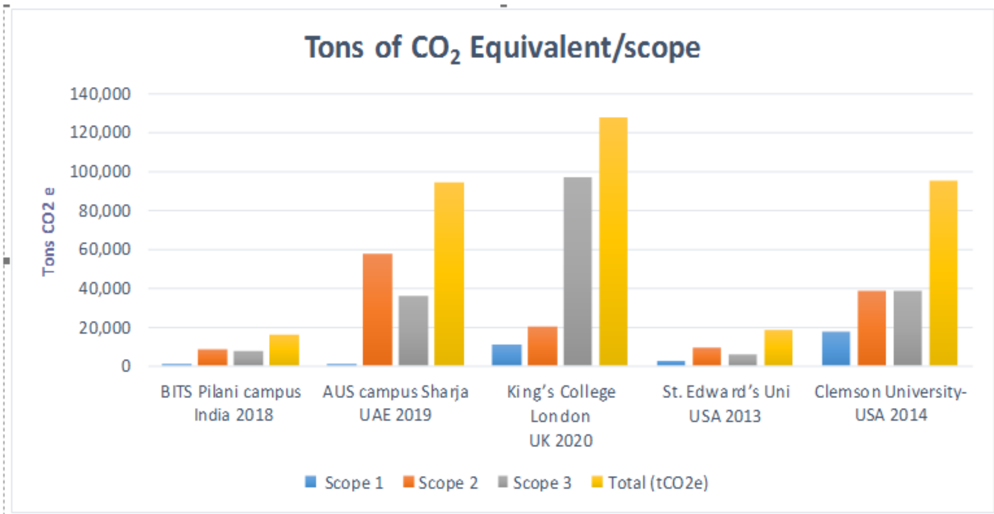

Fig. 2: Calculation scopes of CFP with different campuses.

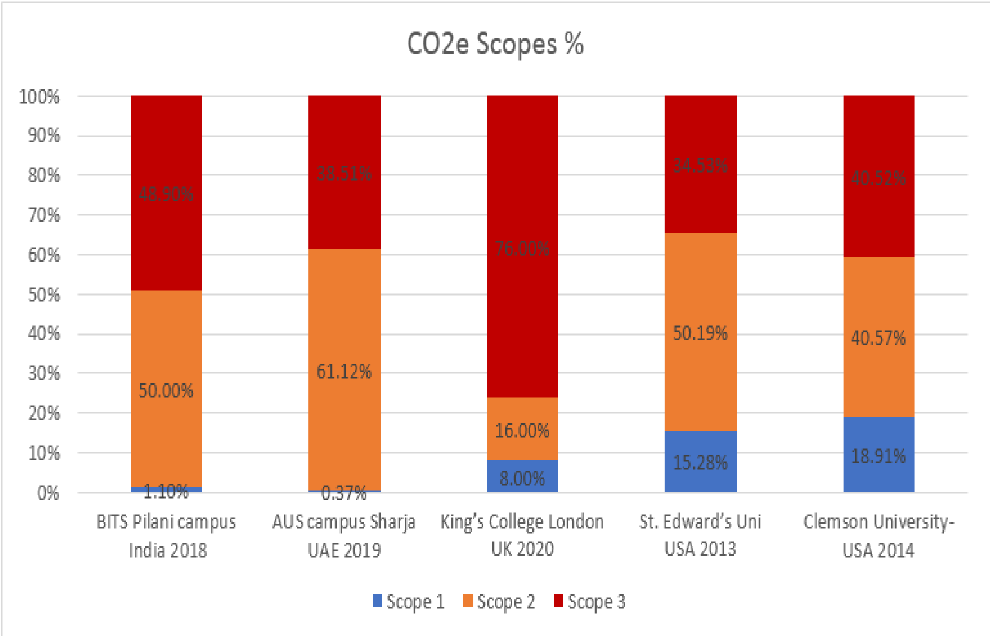

Fig. 3: Collective data figure for different universities in different climate conditions.

However, Fig. 4 shows the relation between the area/population of the campuses and the CO_2 emissions it shows that the physical area covered by the educational institute including its building spaces have a minor impact on the CFP while the number of flocking goers may impact, it will only depend on the size of the operation itself. As in King's college-London the occupied area was relatively small compared to another campus i.e. AUS-Sharjah and scope 3 was the highest CFP % as it included the supply chain which calculates the equivalent emissions for any Products and Services purchased

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from a 3rd party which reflects the needs of the high number of its premises population across the academic year while in AUS-Sharjah the most percentage of emissions was form scope 2 which is the electric consumption where it has a large facility with relatively low population

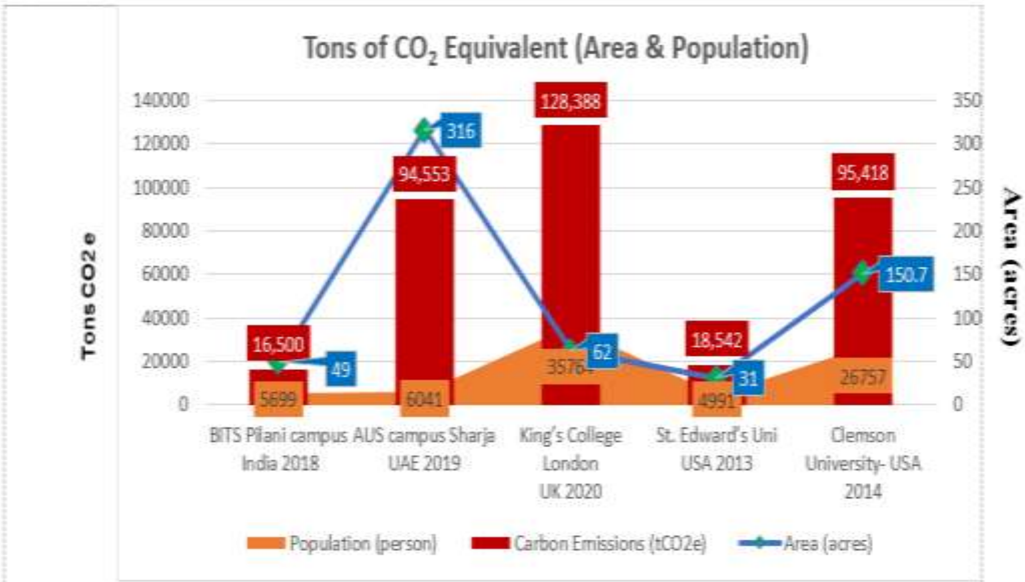

Fig. 4: Relation between the area/population of the campuses and the CO_2 emissions

Although, when having a closer look at the details of the data, it is noticeable that in scope 2, electricity consumption contributes a significant percentage of the CFP, as has been studied by Samara et al.,2022; Clabeaux, et al., 2020; and Sangwan et al.,2018. the AUS Campus consumed annually 58,77 MWh of electricity, which is equivalent to 57,596 $MTCO_2eq$ (CO_2 emissions) which is 61% of the total emissions of the AUS campus, where they used an emission factor of 0.98 $MTCO_2eq$/MWh that was obtained from the UNDP project document of the United Arab Emirates (UAE), and in Clemson University emissions from electricity generation that was included in scope 2 were 38,718 $MTCO_2eq$ that was 40.5% of the total emissions, in addition to 5207 $MTCO_2eq$ from the electricity life cycle and 2393 $MTCO_2eq$ from transmission and distribution losses that were included in scope 3, which was an additional 8. Also, on the BITS Pilani campus, emissions from electricity generation that were included in scope 2 were 16,500 $MTCO_2eq$, which was 50 percent of the total GHG emissions. This indicates that electricity consumption has a great deal of improvement when it comes to decreasing CFP.

CFP MEASURING AND MONITORING

Carbon footprint is important to quantify the emissions, identify the sources of emissions, and prioritize areas for improvement for reducing emissions and increasing efficiencies. So any organization needs to start collecting GHG emissions data and calculate a CFP to be monitored to allow the opportunity for environmental efficiencies and cost reductions. Also, monitoring, tracking, and reporting emissions helps increase transparency to investors, clients, and the public, increase efficiency, lower unnecessary energy costs, and increase knowledge of energy consumption trends. As mentioned in the book by Franchetti, and Apul (2012), Carbon Footprint

Analysis " is the measurement of GHG emissions, origins, composition, and quantities. The term "carbon footprint" is used loosely to refer to the extent of GHG emissions generated by the activities of a person or enterprise in general. The phrase "carbon footprint analysis" has the same meaning as "greenhouse gas inventory," and the word carbon is used because carbon dioxide is the dominant greenhouse gas emitted by human actions. However, emissions of other greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O) have significant contributions to global warming. So, to obtain a single reporting unit of the results, emissions from these other gases are normalized with the mass of carbon dioxide, and the results of the carbon footprint are reported as the mass equivalent of carbon dioxide ($MTCO_2eq$) to make it possible to estimate the carbon footprint of countries, events, products, or services.

The usual method of monitoring emissions is to calculate the consumption of each source or activity multiplied by the related emission factor over a period, which is considered a patch processing method. Some have extended this to near real-time data, which is a snapshot of historical data, so teams are left viewing a situation as it existed in the recent past rather than as it is now. There are many ways to calculate and measure carbon emissions. The most widely used method is the GHG Protocol, which is an initiative that was launched in 1998 and aims to develop internationally accepted GHG accounting and reporting standards for various institutions, as mentioned in many references such as Samara et al., 2022 and Syafrudin *et al.*, 2020. It does this by categorizing sources of emissions into three main scopes:

Scope 1: Direct emissions from sources owned or controlled by the institute (e.g., combustion of fuel in fleet vehicles "owned by the company" or used in boilers)

Scope 2: Indirect emissions are emissions released into the atmosphere from the use of purchased energy (e.g., electricity), while the actual emissions are generated at another facility, such as a power plant.

Scope 3: All other indirect emissions related to activities neither owned nor controlled by the institute (e.g., business travel and waste disposal)

Some extended to cover an approach called life cycle assessment (LCA), which takes into consideration the amount of GHG released, recovered, or embodied in the product or process life cycle that should be considered when calculating the carbon footprint. All involved stages are included in the lifecycle, from the initial step of bringing raw materials to the packing process, passing through the supply chain processes of distribution and usage, until the final stage of disposal, as mentioned in the Life Cycle Analysis "LCA" is sometimes called "cradle-to-grave analysis." The life cycle assessment (LCA) allows a wholesome view of the inputs and outputs regarding the generation of GHG emissions. In the last few years, there has been an increased interest in LCA methods to evaluate buildings and products and to design efficiently and with environmentally preferable materials. The ISO 14000 environmental management standard series was implemented in the 1990s, with the 14040 series concentrating on LCA methodologies. The standard's major characteristic is its four-stage structure (Fenner*, et al.*, 2018).

CFP OF EDUCATIONAL BUILDINGS

Higher education institutions, also known as universities, are institutions dedicated to post-secondary education and research that award academic degrees in various disciplines. Therefore, as organizations engaged in education, research, and community services, they play an important role in sustainable development and the fight against climate change (Valls-Val, and Bovea 2021) University campuses can be leaders of change by tracking carbon footprints and establishing strategies for reductions (Samara et al.,2022). Technical education is an important sector for greenhouse gas studies for two reasons. Each of these institutes contributes significantly to greenhouse gas emissions. Secondly, millions of students are enrolled in these institutions, and it is expected that increasing awareness about greenhouse gas emissions among these students at the initial stages of their education will make them future climate champions. Higher education institutions can take a leading role by estimating their emissions, developing climate change plans, and identifying reduction potential. (Sangwan *et al.*,2018)

Real-time emissions data is rapidly becoming the superior way to evaluate GHG emissions. Real-time emissions data, generated by interval meters and/or smart meters, can provide higher education institutions with accurate and up-to-date information on their carbon footprint, allowing them to make informed decisions and take action toward reducing their emissions. Additionally, this data can be used to track progress and measure the effectiveness of climate change plans. Real-time data allows you to look at what is going on in your building right now. Thus, it is much more efficient at managing a building than monthly utility bill data. Not only that, but real-time data also improves the accuracy of your GHG reporting and allows for a more effective demand response. Emission monitoring and tracking is a way to measure the efficiency and sustainability of operations by tracking the greenhouse gas emissions generated by the electricity used for maintaining the operation's process. This will allow the organization—by tracking and reporting emissions—to increase transparency with all stakeholders, including the government, investors, clients, and the public, increase the efficiency of the operation, decrease unnecessary energy costs, and improve awareness of energy consumption behaviors.

Average Emissions for a Period (Batch Processing): where emissions data is collected or estimated over some time and processed before concluding an output. When this method is used for tracking GHG emissions, it estimates the number of GHGs emitted through the process during the period of the required timeframe, but it has the disadvantage of being not very accurate to be used in comparing emissions values at different points in time as the emissions intensity can vary significantly from time to time. So the average emissions factors only consider a change in the total amount of consumed energy without differentiating when that energy is deferred, stored, or consumed, and this will reflect negatively on the reduction process or mitigation recommendation

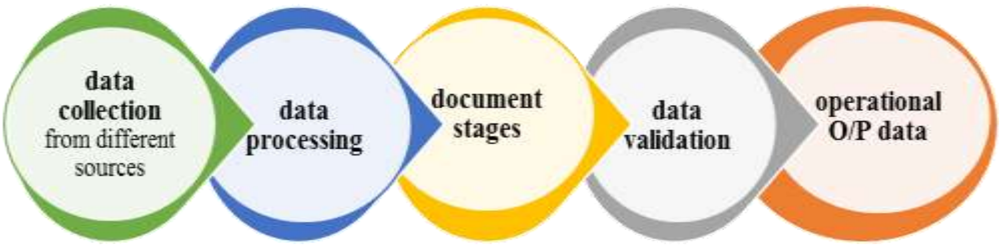

Fig. 5: The steps of reduction methodology for a carbon footprint assessment process.

Near real-time Emissions data (interval monitoring): This is when speed is important, but processing is conducted through the interval of time, and consumption data comes from multiple sources like sensors or measuring meters instead of monthly bill data that is typically used on the Batch processing method. Those sources can provide data over a short period increasing the number of data points to be used in processing that will allow efficiency in diagnosing consumption trends as well as improving the mitigation and reduction recommendations.

MITIGATIONS OF CARBON FOOTPRINT

Identifying that most emissions sources will allow prioritizing mitigation measures for the most significant impact, and as reviewed in the previous studies (Samara *et al*.,2022) it's clear that usually, the highest percentage is either electric consumption from scope 2 or supply chain/commuting from scope 3 and this highlight for any organization depends on its operation scheme where to start when it comes to reducing the CFP. As shown in fig.6 and fig.7

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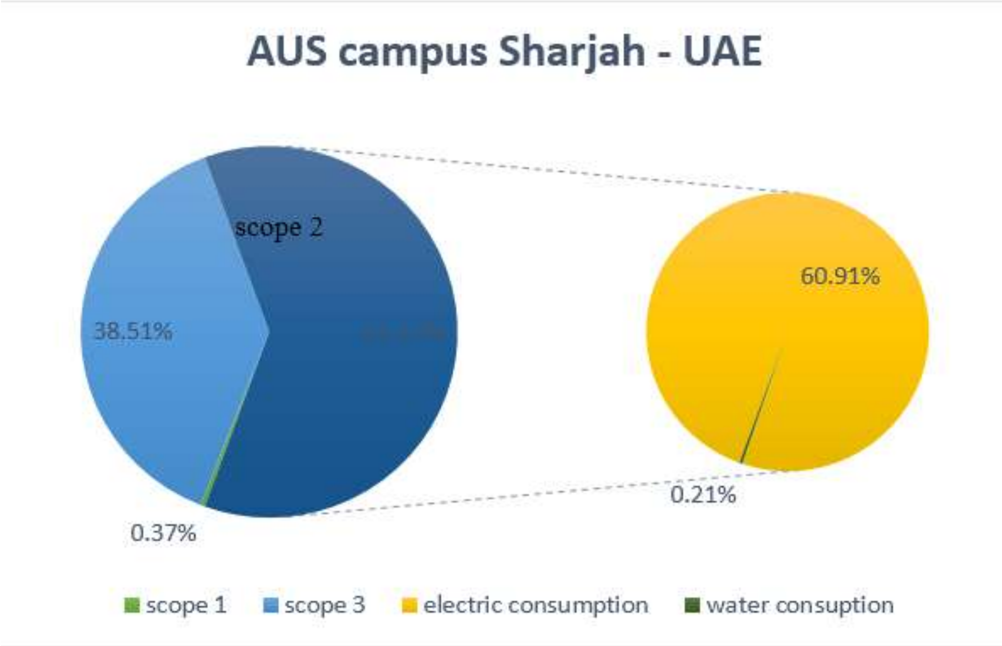

Fig. 6 Distribution of Carbon Footprint (CFP) scopes of emissions in AUS Sharjah

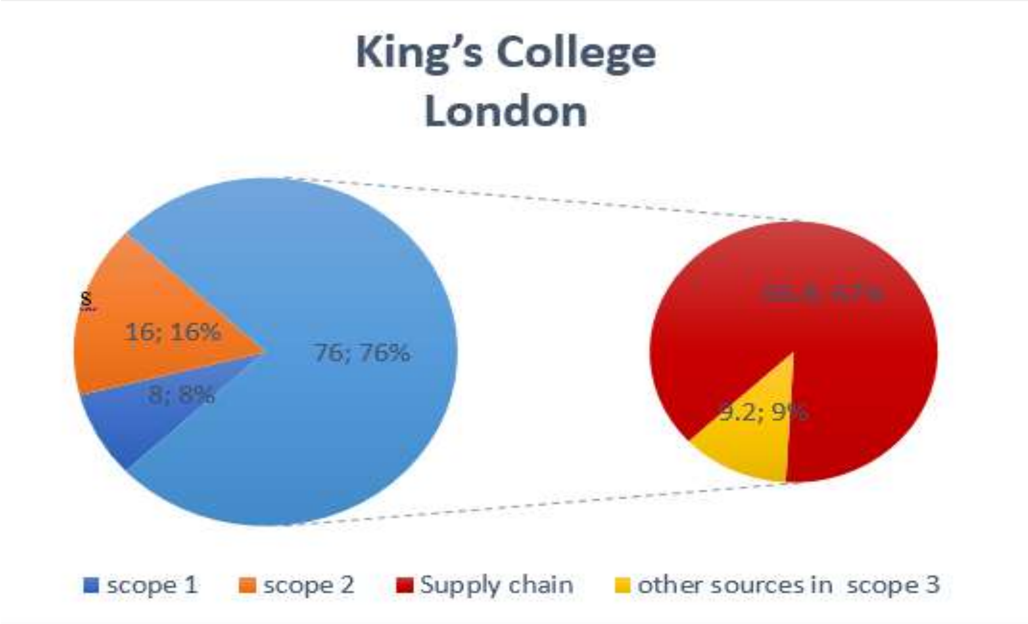

Fig. 7 Effect of Carbon Footprint (CFP) scopes and supply chain on emissions at King's College London

So as an example, for reducing emissions counted on scope 2 then reducing electric consumption is the focus, and here are some of the effects possible solutions to start with. Using motion sensors inside all units inside the campus will allow using electricity for lighting efficiently and only when needed. Change normal light pulps into energy-saving light bulbs. Switch to an energy-saving appliance. Study the possibility of using renewable energy such as implementing solar panels/solar heaters on buildings' roofs. And for emissions under scope 3, where the main factor is supplying chain so here are some of the effects possible solutions to start with. Implement an active procurement policy where the organization can highlight its intention to reduce its associated climate impact. Choose vendors with sustainable environmental awareness with ecological practices. Request emission factors from service providers. Reducing waste generation and management of solid waste is in the following order: recycle, reuse, gasification، and finally landfill (Tim, and Rana, 2022).

And above all, a general way for CFP reduction is to continuously monitor and visually display the consumption impact to make everyone feels that he will have a significant role, also training programs, sustainability campaigns and workshops are necessary, and Informational signs and posters around campus are required. This will improve the knowledge of the campus population of students, staff, faculty، and even visitors and educate them how to reduce their consumption of electricity, and waste generation (Loyarte, *et al.*,2020).

CONCLUSION

We can conclude that the expression ‘carbon footprint’ is a measure of the total CO2 emissions caused directly and indirectly during the whole lifecycle and the accumulated activity associated with a product or any human activity. The metric tonnes of MTCO2eq emission and intensity from the Scopes 1, 2, and 3 sectors under the three scenarios are compared in Figs. 2

and 3. In the case of educational buildings, it's clear that scope 2 of the calculation methodology is the section with the highest CFP value. Electrical and water consumption are the main contribution sections in the CFP for university and campus buildings and activities. So, the study may introduce advice for all decision-makers in the different universities to enhance the possible strategies for reductions. It is strongly recommended that the universities under investigation implement the reduction strategy if it has a role in achieving the environmental pillar of their countries and their commitments to the Paris Agreement regarding reducing global warming. Finally, the recommendations for future research are based on the study's findings. This might include suggestions for how to further investigate the differences in carbon footprints between different campuses or how to implement sustainability initiatives in a more effective and efficient way.

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مراقبة البصمة الكربونية والتخفيف من حدتها في مباني التعليم العالي

أحمد ماهر عبد البصير [١]– **معتز محمد كامل** [٢]– **نهى دنيا** [١]– **هاجر نوار** [٣]
١) قسم الهندسة البيئية، كلية الدراسات العليا والبحوث البيئية، جامعة عين شمس، مصر ٢) طالب دراسات عليا بقسم الهندسة البيئية، كلية الدراسات العليا والبحوث البيئية، جامعة عين شمس، مصر
٣) قسم العلوم الأساسية البيئية، كلية الدراسات العليا والبحوث البيئية، جامعة عين شمس، مصر

المستخلص

تبحث مقالة المراجعة هذه في الأبحاث السابقة حول مراقبة وتقليل البصمة الكربونية للكلية (CFP). تم استخدام نهج التحليل التلوي لمراجعة طرق مختلفة. تركز نطاق العمل على البيانات المنشورة المتاحة لمواقع الحرم الجامعي المختلفة: حرم BITS Pilani (في الهند)، وحرم AUS في الشارقة (في الإمارات العربية المتحدة) ، و King's College London (في المملكة المتحدة) ، وSt. جامعة (في الولايات المتحدة). جامعة كليمسون، الولايات المتحدة الأمريكية يساهم استهلاك الكهرباء بنسبة كبيرة من CFP ، حيث يستهلك حرم الجامعة الأمريكية ٥٨٧٧٣ ميجاوات ساعة من الكهرباء سنويًا، أي ما يعادل ٦١٪ من إجمالي الانبعاثات. في جامعة كليمسون، بلغت الانبعاثات الناتجة عن توليد الكهرباء ٣٨٧١٨ مليون طن من ثاني أكسيد الكربون المكافئ، وفي حرمBITS جامعة بيلاني، ١٦٥٠٠ مليون طن من ثاني أكسيد الكربون المكافئ. يشير هذا إلى أن استهلاك الكهرباء قد تحسن بشكل كبير عندما يتعلق الأمر بتخفيض CFP. تشير النتائج إلى أنه على الرغم من إحراز بعض التقدم ، لا يزال هناك مجال كبير للتحسين. تسلط الورقة الضوء على القيود والتحديات التي تواجه الأساليب الحالية وتقدم رؤى وتوصيات للبحث في المستقبل. تُعد المراجعة مصدرًا مفيدًا للمعلمين والباحثين وواضعي السياسات. تنص منهجية الحساب على أنه بالنسبة للمباني التعليمية، يحتوي القسم الثاني على الحد الأقصى لقيمة CFP ، في حين أن استهلاك الكهرباء والماء هما المساهمان الرئيسيان.

الكلمات المفتاحية: المراقبة، التخفيف، البصمة الكربونية، المرافق التعليمية، التأثير المناخي.