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Review

Decarbonization in Higher Education Institutions as a Way to Achieve a Green Campus: A Literature Review

Liziane Araújo da Silva, Ana Regina de Aguiar Dutra and José Baltazar Salgueirinho Osório de Andrade Guerra *

Center for Sustainable Development (Greens), University of Southern Santa Catarina (UNISUL), Palhoça 88137-270, SC, Brazil
* Correspondence: jose.baltazarguerra@animaeducacao.com.br

Abstract: Reducing the carbon footprint (CF) helps to meet the targets of the sustainable development goals (SDGs), with emphasis on SDG 13, which seeks urgent measures to combat climate change and its impacts. Higher Education Institutions (HEIs) or universities, as organizations engaged in education, research, and community service, play an important role in promoting sustainable development. Thus, HEIs are increasingly interested in practices to reduce their CF, in addition to training professionals for this worldwide need. CF reduction is a tool to assess the sustainability and decarbonization of a campus that aligns with Green Campus (GC) initiatives. The objective of this study is to carry out a literature review of the current situation of CF reduction practices in HEIs and the move toward a greener campus, identifying the main sources of emissions according to the GHG Protocol and classification by scope. This article sought to identify the HEIs/universities with already-implemented decarbonization initiatives through the elaboration of a table. This study was based on a portfolio of 33 articles published up to February 2022 that analyze the CFs of HEIs and the implementation of green initiatives. Differences were identified in the methodology and data used by each university. The results show that the main reason for this is the lack of standardization regarding the time metric (year, semester), functional unit (student, employee, area), limitation of data collection (scope 1, 2, 3), and sources of emission and emission factors, mainly about Scope 3 (sometimes not considered in the calculations). However, despite the differences, the search for standardization was observed in the studied articles, as well as the expectation of reduction in the CF of HEIs over time. It also identified the efforts of HEIs in implementing green initiatives aimed at decarbonizing their campuses. It can be concluded that the CF of HEIs requires improvements and solutions to a series of challenges, including the definition of emission sources representative of Scope 3, the creation of a robust database of emission factors, and the development of tools and methodologies—with greater standardization—that cover the needs of the type of institution globally, and that can be used comparatively as an effective model by other HEIs.

Keywords: carbon footprint; universities; green campus; sustainable development goals

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1. Introduction

The 2030 Agenda for Sustainable Development, adopted in September 2015 by 193 UN Member States, comprises 17 goals and 169 global action targets, mostly covering the environmental, economic, and social dimensions of sustainable development, in an integrated and interrelated way. Among SDGs is goal 13, which brings the need for urgent action to fight climate change and its impact on life on Earth. Much has been said and written about this harsh reality and its effects, and also about the need for a switch in the way climate change is perceived, mitigated, and adapted [1]. However, the concern regards the immediate symptoms of a deeper problem, rather than the fundamentals that provide solutions to that problem. The basic level for dealing with any situation is linked to education; it is at this level that we gain an understanding of the relationships between humans and the environment around us, where we learn the intricate connections that each of our activities creates between the environment and living and non-living things [2–4].

Thus, the fact that the global community is engaged in achieving SDGs means that there is an unparalleled opportunity for universities regarding teaching and research, and the execution of activities linked to external stakeholders and society [5]. Universities, regardless of an existing formal sustainable development policy, show engagement with environmental sustainability policies or procedures in one way or another [5,6]. Understanding the environment and sustainability practices at universities is of great relevance, as students are powerful agents of change in their communities [7]. Hence, universities or Higher Education Institutions (HEIs) play an important role in promoting sustainability and should strive to be an example of a sustainable organization [8]. An HEI is a social institution that has society as its principle and its reference for norms and values. HEIs, besides reflecting the knowledge and social relations, also enable changing the ways of seeing, understanding, and producing beyond the present, with future visions and new actions [9].

The main factor that contributes to climate change is global warming, which is measured by the concentration of greenhouse gas (GHG) emissions released into the atmosphere; thus, to achieve the goals of SDG 13, we need urgent measures, such as removing these gases from the atmosphere. GHG emissions are an alarming problem, causing not only rising temperatures but also dramatic natural disasters like floods, hurricanes, droughts, and many more. For organizations that want to contribute to achieving the goal of climate neutrality, the first step is to determine their current environmental performance in terms of carbon footprint (CF). Then, based on an updated analysis of the situation—that is, calculations of the generated environmental impact—they can propose action plans to reduce or even offset their GHG emissions. Therefore, calculating, tracking, and reporting CFs in HEIs is the starting point for achieving more sustainable educational institutions [10]. There are examples in the literature where different HEIs calculated their carbon emissions or attempted to contribute to climate change [11]. Accounting for carbon emissions and reporting them reflects due diligence and can serve several purposes, including making efforts to increasingly reduce these emissions [12].

Carbon Footprint (CF) is a very useful decision-making tool that allows organizations to measure and communicate the effect of their activities on the environment [13]. Also, it is an effective tool for exercising a higher degree of control over activities that affect the environment. In addition, this tool provides a baseline for assessing the effect of future mitigation efforts [14]. Therefore, reducing the CFs of HEIs and training professionals along this path is an extremely important process for committing to achieve the reduction of GHG emissions into the atmosphere, according to the 2030 agenda goals. There are different international standards for calculating organizations' CF. Among them, the most outstanding regulatory frameworks mentioned in the literature are the GHG Protocol (2004), ISO 14064-1 (2006) and ISO/TR 14069 (2013), PAS 2050 (2011), and PAS 2060 (2014). Although they were initially applied to check the requirements for quantifying GHG emissions within organizations under the Kyoto Protocol (2008), their use is currently spreading to other types of organizations that are voluntarily interested in calculating and reporting their CF, as is the case of HEIs [10].

HEIs are usually made up of several buildings intended for classrooms, laboratories, offices, cafeterias, and residences, among others. Some have power plants, transportation circuits, water systems, or health services, depending on the number of students. Any of these activities has emission sources that contribute to a CF and need to be identified and quantified. This task can become very complicated, depending on the type and size of the HEI [10] (Valls-Val & Bovea, 2021). Considering the heterogeneous structure of most HEIs, it is important to develop a campus sustainability approach applicable to institutions of all types, sizes, and different structures [1,15]. Therefore, as a preliminary step for calculating the CFs of HEIs, it is necessary to understand the activities that contribute to climate change by creating a GHG emissions inventory [16].

Santovito and Abiko (2018) suggest how to prepare the GHG inventory; they have identified some relevant emission sources, which lead to a better vision of opportunities for GHG mitigation. However, after reading the selected articles, there is still no specific standard methodology for preparing the inventory and calculating HEIs' GHG emissions because each institution has its peculiarities. [17] This same literature shows examples of HEIs' efforts to make their campuses a greener space by developing several actions towards decarbonization. The so-called Green Campus Initiatives (GCIs) are being established at HEIs as a strategy to promote sustainable development (SD). They are focused on implementing a sustainable infrastructure, reducing environmental impacts and economic costs, and raising students' awareness of the SD concept itself. GCI models cover HEIs' sustainability initiatives, which focus on meeting the goals set by the Talloires Declaration and SDGs [18].

For Pereira Ribeiro et al. (2021), the Green Campus (GC) concept is holistic, where mental awareness and action become an integral part of HEIs' daily activities. A GC can be achieved by implementing GCIs, which focus on HEIs' environmental, economic, and social issues. Much more than a portfolio of projects and programs related to environmental issues, GCIs should be at the core of all campus activities [19]. Although there is no single model for operating a GC, in this context the term "greening" refers to actions intended to minimize adverse socio-environmental impacts [2,18,20]. The actions resulting from GCIs can be divided into different categories depending on the expected outcome. These categories are mainly related to keeping university resources and minimizing negative impacts at the socio-environmental and economic levels [18]. One example of a Green Campus analyzed in this study was the model presented by Gu et al. (2018), who examined Keele University, located in North Staffordshire, England. This was the first campus assessment through the analysis of the environmental footprint structure. The method contributed to the evaluation of the CF and sustainable development, and for policymakers interested in establishing GC. [21]

Campus "greening", or a sustainability campus, considers the operational aspects, based on environmental impacts, and the educational aspect, based on society education [22]. Currently, GC gives more emphasis to the dissemination of sustainable ideas and education due to their high social impact [23,24]. However, the environmental impacts and resource efficiency of universities themselves cannot be ignored, as there are more than 13,000 universities worldwide and the number is still growing, especially in developing countries with greater environmental problems [25]. Due to their high complexity and strong interdependencies, a GC that focuses on a single system usually does not work well. However, most efforts toward GC have sometimes been fragmented, focusing on a single area such as waste management. This lack of integrated efforts can lead to the inefficient implementation of a program's goals.

Based on this brief contextualization, and given the topic's great relevance, this article intended to review the selected literature for checking existing gaps, identifying pertinent concepts and protocols, and finding HEIs that have already implemented green initiatives successfully, thus serving as examples for other HEIs. Existing university inventories regarding CF reduction in HEIs were the subjects sought for trying to exemplify and answer the initial question: **which CF reduction initiatives, already existing at HEIs, contribute to building a Green Campus?**

2. Methodological Procedures

The literature review sought to meet the requirements of robustness, depth, and transparency in the research. The research question guided the selection of articles focused on the evaluation of the CFs of HEIs aiming at GCIs (Green Campus Initiatives) to identify what information should be extracted. The keywords used in the search were *carbon footprint*, *higher education*, and *green campus*. We identified 228 articles in English from the combination of these keywords. The chosen publication period was between 2017 and 2022, with search results up to February 2022. Of the 228 articles found in the initial search, we selected 33 articles through eligibility criteria for a more detailed review of the topic, since the articles should specifically address CF reduction and green initiatives at HEIs/universities. The research methodology had four distinct steps, as described in Figure 1.

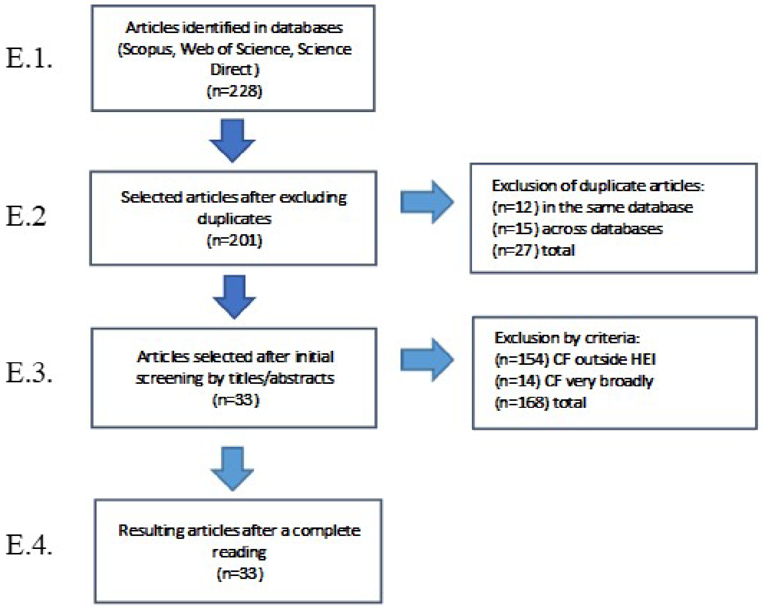

Figure 1. Stages of article selection.

2.1. Step 1 (E1)—Searches for Articles in Databases

In this initial step, we sought to identify the literature related to the theme in general, through the keywords "carbon footprint, higher education, and green campus" and whose content was included in open access articles, in English, through the search in the databases Scopus, Web of Science, and Science Direct.

2.2. Step 2 (E2)—Exclusion of Duplicate Articles

From step 1, 228 articles on the topic were located. Step 2 consisted of excluding duplicate articles, which reduced the result to 221 articles.

2.3. Step 3 (E3)—Exclusion of Articles from the Eligibility Criteria

Step 3 consisted of selecting, through the pre-defined eligibility criteria (see Table 1), the literature specifically focused on the theme, that is, articles that dealt with CF or the reduction in the CFs of HEIs or universities, with characteristics of a GC, and aiming to obtain the necessary content to answer the research question. This selection was carried out by reading the titles, abstracts, and parts of the articles, resulting in 33 articles for analysis in this research.

Table 1. Eligibility criteria: criteria that determine whether the article found, through the keywords in the databases, will be included or excluded from the final analysis in the search. (E3).

Eligibility Criteria—(Inclusion and Exclusion)		
Type of Criterion	**Criterion for Inclusion**	**Criterion for Exclusion**
Focus (relevant to PP)	CF at Universities/HEIs as a way to achieve GC.	CF outside Universities/HEIs, fragmented or very general.
Object of Study	Universities/HEIs that reduce their CF and characterize a GC.	Other organizations and institutions.
Type of Study	Article; review.	Other articles in conferences, and conference abstracts.

Table 1. *Cont.*

Eligibility Criteria—(Inclusion and Exclusion)		
Type of Criterion	**Criterion for Inclusion**	**Criterion for Exclusion**
Access	Free access articles.	Close access.
Quality	Impact factor equal or above 2; with more than 10 citations, at least for articles between 2017 and 2018; peer-reviewed (in ABS journals)	Publications before 2017, and with a lower impact factor in the period.
Theoretical framework	Universities/HEIs and GC, within the context of the CF scenario.	Universities/HEIs and GC, outside the context of the CF scenario.
Unit of Analysis	Models at HEIs.	Models outside HEIs/Universities.

2.4. Step 4 (E4)—Selection of Final Articles

Step 4 consisted of the full reading of the 33 selected articles (see Table 2). From this reading, it is possible to work on the creation of Table 3 for general and comparative analysis of the contents, followed by the systematization of knowledge.

Table 2. Selection of articles by database (E1).

Database	Keywords and Boolean Operators	1st Search	Exclusion: Duplicates in the Base	Exclusion: Duplicates across Bases	Exclusion: Eligibility Criteria	The Selection at Each Base
SCOPUS	"carbon footprint" AND "higher education" = 22 "carbon footprint" AND "green campus" = 03 (−1) * "carbon footprint" AND "higher education" AND "green campus" = 01 (−1) *	26	(−2) = 24	(−01)	(−08)	15
WEB OF SCIENCE	"carbon footprint" AND "higher education" = 86 "carbon footprint" AND "green campus" = 05 (−1) * "carbon footprint" AND "higher education" AND "green campus" = 01 (−1) *	92	(−2) = 90	(−10)	(−69)	11
SCIENCE DIRECT	"carbon footprint" AND "higher education" = 97 "carbon footprint" AND "green campus" = 09 (−4) * "carbon footprint" AND "higher education" AND "green campus" = 04 (−4) *	110	(−8) = 102	(−04)	(−91)	07
Total number of articles		228	(−12) = 216	(−15) = 201	(−168)	33

(* Duplicates in the base).

Table 3. Mapping of articles and related universities/HEIS.

Título do Artigo/DOI *	Autor(s)	Temática/Objetivo	Universidade (Estudo/Estudada)	Escopo(s)
A longitudinal assessment of the energy and carbon performance of a Passivhaus university building in the UK. https://doi.org/10.1016/j.jobe.2021.103353	Sepideh S. Korsavi, Rory V. Jones, PeterA. Bilverstone, Alba Fuertes. (2021)	Certificação Passivhaus no Reino Unido.	The Enterprise Center (TEC), edifício universitário do Reino Unido.	1, 2
Arranging university semester date to minimize annual CO_2 emission: A UK university case study. https://doi.org/10.1016/j.isci.2021.103414	Zihao Li, Wei Sun, Yue Xiang, Camilla Thomson, Gareth Harrison. (2021)	Investigar um modelo de sistema de energia multivetorial (MES) em nível de campus.	Universidade de Edimburgo (UoE), campus na Escócia, Reino Unido.	1, 2
Assessment of Carbon Footprint of a Campus with Sustainability Initiatives. https://doi.org/10.35378/gujs.726553	Emre ARTUN. (2021)	Desenvolver uma ferramenta baseada em planilha de cálculo das emissões de carbono.	Universidade Técnica do Oriente Médio (METU-NCC)	1, 2, 3
Assessment of carbon neutrality and sustainability in educational campuses (CaNSEC): A general framework. http://dx.doi.org/10.1016/j.ecolind.2017.01.012	Suresh Jaina, Archit Agarwal, Viveka Jani, Shaleen Singhal, Prateek Sharmaa, Ramesh Jalane. (2017)	Apresentar a estrutura interinstitucional de Neutralidade e Sustentabilidade de carbono em Campus Educacionais (CaNSEC).	Universidade TERI, (TERIU), Nova Delhi, na Índia.	1, 2, 3
Carbon footprint assessment tool for universities: CO_2UNV. https://doi.org/10.1016/j.spc.2021.11.020	KarenVallsÿVal María D. Bovea. (2022)	Apresentar uma ferramenta de avaliação de CF para universidades (CO_2UNV).	Universidade Jaume I, na Espanha.	1, 2, 3
Carbon footprint estimation in a university campus: Evaluation and insights. https://doi.org/10.3390/su12010181	Pablo Yañez, Arijit Sinha, Marcia Vásquez. (2019)	Ilustrar a trajetória para determinação da CF e identificar os estressores.	Universidade de Talca, in Chile.	1, 2, 3
Carbon footprint in Higher Education Institutions: a literature review and prospects for future research. https://doi.org/10.1007/s10098-021-02180-2	Karen VallsÿVal, María D. Bovea. (2021)	Investigar a temática da CF, desde a data de publicação do primeiro quadro de CF (2004), até o presente.	Universidade Jaume I, in Espanha.	1, 2, 3
The carbon footprint of a university campus from Colombia. https://doi.org/10.1080/17583004.2021.1876531	Manuel Varón-Hoyos, José Osorio-Tejada, Tito Morales-Pinzón. (2021)	Medir a CF da UTP, com escopo 3. Estimativa de emissões específicas: deslocamento diário dos membros da universidade.	Universidade Tecnológica de Pereira (UTP), in Colômbia.	1, 2, 3

Table 3. *Cont.*

Título do Artigo/DOI *	Autor(s)	Temática/Objetivo	Universidade (Estudo/Estudada)	Escopo(s)
Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. https://doi.org/10.1186/s12302-021-00454-6	Eckard Helmers, Chia Chien Chang, Justin Dauwels. (2021)	Analisar a CF de 20 universidades.	U Cape Town, RSA; UAM Mexico City; KU Leuven, Belgium U. Pittsburgh PA, USA; TU Johor Bahru, Malaysia; U. Tongji, Shanghai, China; U. Brisbane, Austrália; U. Mankato MN, USA: UCB Birkenfeld, Germany; U. Melbourne, Australia; DeMU, Leicester, GB; UM College Park MD, USA; NTU, Singapore; U. Talca, Chile; U. Potsdam, Germany; U. Cork, Ireland; Yale U. N. Haven CT, USA; U. Lüneburg, Germany; King's College London, GB; ETH Zürich, Suíça.	1, 2, 3
Carbon management in UK higher education institutions: An overview. https://doi.org/10.3390/su131910896	Ebiyon Idundun, Andrew S. Hursthouse, Iain McLellan. (2021)	Revisar a gestão de carbono em relação às IES do UK e a dependência de combustíveis fósseis, através da comparação do CF relatado em 3 universidades.	Universidade de Keele, Staffordshire, UK; Universidade De Montfort, Leicester, UK; Universidade de Leeds, Leeds, UK;	1, 2, 3
Development and evaluation of a method to estimate the potential of decarbonization technologies deployment at higher education campuses. https://doi.org/10.1016/j.scs.2019.101464	William Horan, Rachel Shawe, Richard Moles, Bernadette O'Regan. (2019)	Apresentar um método para estimar o potencial de implantação de tecnologias de descarbonização em nível setorial de HEC para os países.	HEC, in Irlanda.	1, 2, 3
Environmental footprint assessment of green campus from a food-water-energy nexus perspective. https://doi.org/10.1016/j.egypro.2018.09.109	Gu, Yifan, Wang, Hongtao, Robinson, Zoe P., Wang, Xin, Wu, Jiang, Li, Xuyao, Xu, Jin, Li, Fengting. (2018)	Exemplo de avaliação de um campus verde.	Universidade Keele, Inglaterra, in UK.	1, 2, 3

Table 3. *Cont.*

Título do Artigo/DOI *	Autor(s)	Temática/Objetivo	Universidade (Estudo/Estudada)	Escopo(s)
Environmental Impact of Mobility in Higher-Education Institutions: The Case of the Ecological Footprint at the University of A Coruna (Spain). https://doi.org/10.3390/su13116190	José-Benito Pérez-Lopez, Alfonso Orro, Margarita Novales. (2021)	Calcular a CF associada à mobilidade das pessoas na Universidade.	Universidade da Corunha (UDC), in Espanha.	3
Exploring sustainable student travel behavior in The Netherlands: balancing online and on-campus learning. https://doi.org/10.1108/IJSHE-10-2020-0400	Marieke Versteijlen, Bert van Wee, Arjen Wals. (2021)	Estudar a consideração dos estudantes holandeses na decisão de viajar ao campus ou estudar *online*.	Universidade de ciências aplicadas (HAN), in Holanda.	3
Feasibility Assessment of Two Biogas-Linked Rural Campus Systems: A Techno-Economic Case Study. https://doi.org/10.3390/pr8020180	Liqin Zhu, Congguang Zhang. (2020)	Quantificar a entrada, saída e *status* econômico correspondente de dois sistemas de eco-campus rurais para analisar e avaliar a sustentabilidade econômica deles.	Hohai University, Nanjing, China. (Fanjiazhai Middle School, FJZ e Xidazhai Middle School, XDZ, Yangling), China.	1, 2
Incorporating external effects into project sustainability assessments: The case of a green campus initiative based on a solar PV system. https://doi.org/10.3390/su11205786	Heng Shue Teah, Qinyu Yang, Motoharu Onuki, Heng Yi Teah. (2019)	Demonstrar uma estrutura de avaliação da sustentabilidade do projeto que avalia a CF e o custo do ciclo de vida do projeto, e também o efeito externo na comunidade local de uma perspectiva de resiliência a desastres.	Campus Kashiwa da Universidade de Tóquio, in China.	1, 2
Kicking the habit: Rethinking academic hypermobility in the Anthropocene. https://doi.org/10.32674/jis.v11iS1.3845	Max Crumley-Effinger, Blanca Torres-Olave. (2021)	Sobre o privilégio que vêm com a acumulação de capital cultural, social e humano incorporado por trabalhadores acadêmicos.	Loyola University Chicago, in EUA	3
Mapping of sustainability policies and initiatives in higher education institutes. https://doi.org/10.1016/j.envsci.2019.04.015	Rachel Shaweÿ, William Horan, Richard Moles, Bernadette O'Regan. (2019)	Mapear as políticas e iniciativas de sustentabilidade de um número seleto de IES irlandeses e internacionais.	IT de Galway-Mayo (GMIT) IT Sligo (TI Sligo) IT de Limerick (LIT)U. Galway, Irlanda (NUIG) U Maynooth, Irlanda (NUIM) U. Cork (UCC) U. Limerick (UL) U. Recursos Naturais e Ciências da Vida, Viena (BOKU) U. Copenhague Umwelt-Campus Birkenfeld U. Bradford U. de Edimburgo London School of Economics and Political Science (LSE) U. Nottingham U de Bola U. Califórnia Davis (UC Davis)	1, 2, 3

Table 3. *Cont.*

Título do Artigo/DOI *	Autor(s)	Temática/Objetivo	Universidade (Estudo/Estudada)	Escopo(s)
Measuring Carbon Footprint of an Indian University Using Life Cycle Assessment. https://doi.org/10.1016/j.procir.2017.11.111	Kuldip Singh Sangwana, Vikrant Bhakara, Vinti Arorabe, Prem Solankib (2018)	Estimar as emissões de GEE do campus universitário BITS Pilani para o ano letivo de 2014-2015.	Campus da BITS, in Pilani.	1, 2, 3
Modeling energy demand from higher education institutions: A case study of the UK. https://doi.org/10.1016/j.apenergy.2018.09.203	Zia Waduda, Sarah Roystonb, Jan Selbyb. (2018)	Investigar variações no uso de energia entre IES (análise transversal) e mudanças no uso de energia ao longo do tempo (análise temporal), usando UK como estudo de caso.	Universidade de Leeds, in Leeda, UK; Universidade de Sussex, in Brighton, UK.	1, 2
Performance and reduction of carbon footprint for a sustainable campus. https://doi.org/10.35940/ijeat.A2672.109119	Michelle Lim, Gasim Hayder. (2019)	Analisar e reduzir a emissão da CF no entorno do campus a fim de construir um campus sustentável para as gerações futuras.	Universidade Tenaga Nacional (UNITEN), in Malásia.	3
Powering the future university campuses: a mini-review of feasible sources. https://doi.org/10.1016/j.promfg.2019.05.003	Paul A. Adedejia, Stephen Akinlabib, Nkosinathi Madushelea. (2019)	Mini-revisão de fontes de energia renováveis viáveis em ambiente universitário, facilmente avaliáveis para geração de energia.	Universidade de Joanesburgo, in África do Sul.	1
Pros and cons of online education as a measure to reduce carbon emissions in higher education in the Netherlands. https://doi.org/10.1016/j.cosust.2017.09.004	Marieke Versteijlen, Francisca Perez Salgado, Marleen Janssen Groesbeek, Anda Counotte. (2017)	Estudar a contribuição relativa das viagens de estudantes (e funcionários) para as emissões de carbono das IES holandesas e examinar os argumentos a favor e contra a educação *online* como meio de reduzir o impacto de carbono das viagens de estudantes.	Universidade Aberta da Holanda (UAS); Utrecht UAS, Utrecht University, University of Amsterdam, Amsterdam UAS, Erasmus University Rotterdam, Rotterdam UAS, in Netherlands.	3
Quantitative assessment of environmental impacts at the urban scale: the ecological footprint of a university campus. https://doi.org/10.1007/s10668-021-01686-5	C. Genta1, S. Favaro, G. Sonetti1, G. V. Fracastoro, P. Lombardi1. (2021)	Informar o processo decisório de planejamento e avaliar as soluções sociotécnicas implementadas nos ambientes urbanos locais para reduzir o consumo de energia, diminuir os impactos ambientais e melhorar a qualidade de vida dos habitantes do campus.	Politecnico di Torino, in Italy.	1, 2, 3
Reducing carbon emissions: Strathmore University contributions towards sustainable development in Kenya. https://doi.org/10.15249/13-1-173	Lilian Njeri Munene. (2019)	Descrever o impacto econômico e social criado por uma universidade ao tornar suas fontes de energia mais verdes.	Strathmore University, Quênia.	1

Table 3. *Cont.*

Título do Artigo/DOI *	Autor(s)	Temática/Objetivo	Universidade (Estudo/Estudada)	Escopo(s)
Solar powered green campus: A simulation study. https://doi.org/10.1093/ijlct/ctx011	Akshay Suhas Baitule, K Sudhakar. (2017)	Localizar e analisar a viabilidade de desenvolver um campus acadêmico 100% solar fotovoltaico na MANIT—Bhopal, Índia.	Maulana Azad Instituto Nacional de Tecnologia Bhopal, (MANIT—Bhopal)	1
Sustainable well-being challenge: A student-centered pedagogical tool linking human well-being to ecological flourishing. https://doi.org/10.3390/su11247178	Christine Vatovec, Haley Ferrer. (2019)	Analisar 5 comportamentos que podem aumentar a felicidade com pegadas ecológicas mínimas, realizada por estudantes de graduação, durante um semestre.	Universidade de Vermont (UVM), Burlington, USA.	3
The carbon footprint of a UK University during the COVID-19 lockdown. https://doi.org/10.1016/j.scitotenv.2020.143964	Viachaslau Filimonau Y, Dave Archer, Laura Bellamy, Neil Smith, Richard Wintrip. (2020)	Comparar a CF de uma universidade de médio porte do Reino Unido produzida durante o bloqueio do COVID-19 (abril a junho de 2020) com a gerada no respectivo período nos anos anteriores.	Bournemouth University, Talbot Campus, Fern Barrow, Poole, Dorset, UK.	1, 2, 3
The effect of the covid-19 pandemic on mobility-related GHG emissions of the University of Oldenburg and proposals for reductions. https://doi.org/10.3390/su13148103	Angela Gamba, Diana Maldonado, Michael Rowen, Herena Torio. (2021)	Analisar as emissões de GEE relacionadas à mobilidade em um contexto de IES, antes e durante a pandemia de COVID 19.	Universidade de Oldenburg, Germany.	3
The role of EcoCampus in addressing sustainability in UK universities. https://doi.org/10.15302/J-FEM-2017038	Peter Redfern, Hua Zhong. (2017)	Avaliar o desempenho da gestão de carbono das universidades no Reino Unido e na China e relacioná-lo com o nível de aceitação de EMSs nessas universidades.	Nottingham Trent University, Nottingham, UK.	1, 2
Towards a Carbon Neutral and Sustainable Campus: Case Study of NED University of Engineering and Technology. https://doi.org/10.3390/su14020794	Atif Mustafá, Majida Kazmi, Hashim Raza Khan, Saad Ahmed Qazi, Sarosh Hashmat Lodi. (2022)	Calcular e avaliar o impacto e eficácia de várias estratégias de mitigação da CF no contexto de uma IES.	Universidade NED de Engenharia e Tecnologia, no Paquistão.	1, 2, 3
Towards a universal carbon footprint standard: A case study of carbon management at universities. https://doi.org/10.1016/j.jclepro.2017.02.147	Oliver J. Robinson, Adam Tewkesbury, Simon Kemp, Ian D.Williams. (2017)	Descrever elementos-chave para padronizar o processo de CF organizacional. Pesquisa realizada em 31 IES individuais.	Universidade de Southampton, Hampshire, UK.	1, 2, 3

Table 3. *Cont.*

Título do Artigo/DOI *	Autor(s)	Temática/Objetivo	Universidade (Estudo/Estudada)	Escopo(s)
Towards environmental sustainability in Russia: evidence from green universities. https://doi.org/10.1016/j.heliyon.2020.e04719	Ernest Baba Ali, Valery P. Anufriev. (2020)	Investigar o impacto das práticas de gestão do campus na qualidade ambiental entre as universidades russas. Estudo realizado em 16 universidades russas, de 2015 a 2019.	Universidade RUDN, Universidade Perm, Universidade Minin, Universidade Tomsk P., Universidade Altai S., Universidade Don ST, Universidade Gorno AS, Universidade Saint-PSF, Universidade Penza S., Universidade Voronezh S., Polzunov Universidade AST, UniversidadeSVP Russa, Universidade Astrakhan S., Universidade Est. de Tomsk, Universidade Est. de Tver, Universidade Est. De Petrozavodsk.	1, 2, 3

* Accessed on 11 April 2022

3. Results

3.1. Presentation of Results and Table 3

The role of HEIs is fundamental in managing the carbon footprint with the ability to raise public awareness and educate future leaders and provide scientific research and innovative carbon management solutions to combat climate change [26]. Empirical evidence of the interest in tracking and calculating the CFs of HEIs is reflected by the number of documents offering recommendations and guidelines that have recently emerged in the academic literature [12].

Table 3 presents the main results of the 33 selected articles, in alphabetical order, by title, the corresponding authors, the objective of each study, and the university/HEI studied, as well as the reference of the scope achieved. The main classification was based on the scopes defined by the GHG protocol and serves as a guide for readers to identify models of green practices in HEIs.

Among the thirty-three selected articles, the United Kingdom had the largest number of publications in the chosen period, with seven papers. Spain and India came in second, with three publications each. In addition, we noticed that articles on the topic are increasing every year. The year 2021 had the highest number of publications, with 12 articles out of the 33 selected. However, the result for the year 2022 is not conclusive, since the study was finished in February and thus did not include the total number of articles that would be published by the end of the year.

3.2. Greenhouse Gas Protocol (GHGP) and Scopes

Based on the surveyed literature, the most widely used standard for calculating CF is the Greenhouse Gas Protocol (GHGP). GHGP (https://ghgprotocol.org/, accessed on 1 August, 2022) is an internationally accepted standard for GHG accounting and reporting, used by companies and organizations, as it provides a guideline to quantify and report their GHG emissions. GHGP categorizes organizational emissions according to three types of scopes:

- Scope 1 (GHG direct emissions): these emissions come from sources owned or controlled by HEIs; for example, emissions from fossil fuel combustion related to campus buildings and vehicles.
- Scope 2 (GHG indirect emissions from electricity): this includes emissions from purchased electricity, defined as electricity acquired or otherwise brought into the HEI organizational boundary.
- Scope 3 (other GHG indirect emissions): scope 3 is an optional reporting category that allows accounting for all other indirect emissions. Scope 3 emissions are a consequence of HEI activities but stem from sources that are not owned or controlled by them. Some examples of scope 3 activities are the extraction and production of purchased materials, transportation of purchased fuels, and waste processing.

Although GHG emissions are classified into three different types of scopes, attributing and accounting for the full range of emissions of an organization's activities is extremely complex and difficult. While scope 1 and scope 2 emissions are the simplest to assign and calculate, scope 3 emissions are rarely quantified entirely and can vary a lot for different institutions [27].

According to the GHGP itself, reporting Scope 3 emissions is optional. HEIs, in general, can choose which categories they want to report in, which makes it difficult to compare Scope 3 emissions between institutions. Although there are convincing arguments to quantify scope 3 emissions, this scope still does not present a uniform and consistent reports [28]. In addition, there are a limited number of studies with different methodologies for collecting and interpreting data, making it difficult to carry out a valid quantitative description of the CFs of HEIs [29]. However, the literature brings the individual efforts of each HEI to implement, in the best possible way, green initiatives on campuses as a way to achieve sustainability and CF reduction goals, as shown in Table 3.

4. Discussion

Mustafa et al. (2022) emphasize that transforming a university into a sustainable and carbon-neutral campus is a slow and gradual process, and there is still no standard for becoming carbon-neutral and sustainable. However, transforming a university into a carbon-neutral and sustainable campus can become a source of motivation for the local community and relevant stakeholders, spilling over into wider segments of society. Globally, HEIs can achieve neutrality by first calculating their carbon footprint and then designing/implementing carbon mitigation strategies [30].

The main result from the literature review, through data obtained in previous studies, was the identification of HEIs' efforts towards implementing green initiatives aiming at the decarbonization of their campuses, and the achievement of global carbon neutrality goals. The literature points out models that can serve as examples for other HEIs. However, there is a great limitation regarding the standardization of indicators, which hinders the classification by scopes. At this point, there are issues to re-evaluate and improvements to implement to achieve uniform methods that enable its global application in the educational sector. This task is not easy, since we must consider the differences among HEIs, such as campus extension, location, population, and field of operation, among other specifics that generate climate, cultural, and regional distinctions.

4.1. Green Campus Initiatives versus CF Reduction in HEIs

One of the main paths for the construction of a GC has been the CF reduction practices in the HEIs, which also characterize the GCIs, with improvements in lighting, temperature control, better ventilation, and indoor air quality, as well as the practices that contribute for healthy and sustainable environments. It is also necessary to change the mindset on the part of the HEI management to ensure the effectiveness of green practices. Awareness practices in the academic community also play an important and transforming role in this journey.

In the study by Artun (2021), like other universities, GCIs was established at the North Cyprus Campus of the Middle East Technical University (METU) in Ankara, Turkey, and various actions were implemented over the period of its research to make the campus greener. This same author brought important examples of green initiatives implemented in that institution: tree planting, a shuttle bus for staff/students to travel around the campus, promoting bicycles as a means of transport (e.g., bicycle rental, road signs to share the road between pedestrians, bicycles and cars), solid waste reduction and garbage recycling, flea markets to promote the purchase of used goods, the reuse of waste through artistic activities, and efficient practices in the uses of water and electricity [11].

4.2. Main Examples of the Literature Studied

Based on Table 3, there is a balance in the literature regarding the achievement of classification by scopes, where we identified each type of scope in each study. Some studies evaluated CF by combining more than one type of scope, or by analysis and attainment of all three scopes. The range of treatment by HEIs, individually or combined, reached: scope 1, 26 articles; scope 2, 23 articles; and scope 3, 24 articles.

Despite observing a balance of scope treatment in the literature, this does not mean that scope 3 was treated uniformly, as scopes 1 and 2 were. As already mentioned, because it is broader and has its indicators defined by the HEI itself, scope 3 does not show balance in the comparisons between HEIs since it is very difficult to standardize indicators for this scope.

For Idundun et al. (2021), HEIs can do more to improve CF estimates, particularly those associated with scope 3 emissions, and establish standardized models to account for, measure, monitor, and report fossil fuel emissions in collaboration with other stakeholders [31]. According to Redfern and Zhong (2017), policymakers are often reluctant to include scope 3 emissions as part of emission reduction goals due to the difficulty of accurately monitoring the emission flow embedded in traded goods and services, but their importance should not be ignored. The contribution of scope 3 emissions to the overall carbon footprint is significant. In 2012, the first comprehensive CF of the higher education sector was published; using 2005 baseline data, it estimated that combined scope 3 carbon emissions accounted for over 60% of all sector emissions, with construction accounting for nearly 30% [32,33].

There is a strong correlation between the environmental performance of a Higher Education Campus (HEC) and its characteristics, namely climate zone and type of institution. Climatic conditions derived from the location are useful for estimating HEC resource use, especially energy use due to heating and cooling needs. Climatic conditions are also useful for estimating the potential for renewable technologies in HECs since they vary with local weather and geographic conditions. Another important indicator for HEC categorization was the type of institution, particularly its research intensity [34,35].

Another identified fact was that electricity was the highest indicator of impact and generation of GHG emissions in the atmosphere. Therefore, renewable energy was considered an option for GHG reduction. Strathmore University, in Kenya, installed a grid-connected rooftop solar photovoltaic (PV) system designed to provide electricity to the entire University campus for a period of 25 years. The project should increase sustainability efforts through partnerships with global institutions to answer to climate change and carbon emissions, although Africa has the lowest rates of contribution to global warming [36].

Helmers et al. (2021) mentioned that the largest part of a university's GHG emissions impact also refers to energy consumption, in terms of electricity and heat production. The second set of impacts of relatively high relevance is in the area of mobility. This finding was taken from Helmers' survey of 18 different universities around the world, where energy consumption also created the highest impact [29].

According to Helmes et al. (2021) and the Corporate Value Chain report (scope 3), which is on the GHG protocol website, almost all universities that report CO_2 emissions follow a scheme given by the "GHG Protocol Corporate Accounting and Reporting Standard". Although allocating impacts due to this scheme by types of scopes is simple, as already mentioned in a previous topic many universities partially deviate from the scheme and apply individual allocations. The most relevant impact (energy consumption) generally belongs to scope 2; however, large universities are establishing their power plants, such as University College Cork, the University of Cape Town, and Yale University, shifting the impacts from energy production to scope 1 [29].

Today, many universities already have photovoltaic (PV) systems, among them the Nanyang Technological University (NTU), the Environmental Campus (Umwelt-Campus) Birkenfeld of the University of Trier, and the Leuphana University of Lüneburg, who are reallocating part of their impact from energy production from scope 2 to scope 1. In addition, if the university operates its fleet of vehicles, these impacts belong to scope 1, but when using external vehicles for business trips it will be a scope 3 impact. Therefore, as a whole, it is still a challenge to compare the university's CF impacts based on the separation by scopes 1, 2, and 3 due to the GHG Protocol's Corporate Accounting and Reporting Standard [29]. To make carbon management in HEIs worthwhile, it is essential to overcome the barriers of time, cost, and data reliability in assessing GHG emissions by scope.

Even with so many challenges, HEIs can achieve carbon neutrality, as evidenced by the case of Leuphana University Lüneburg in Germany, which reached this goal through the maximum use of modern building technology and the highly sophisticated management of green energy. In this case, the University produces an energy surplus and can almost completely offset its GHG emissions. However, maximum use of technology means a high upstream carbon impact due to the materials used, which can lead to a longer payback time and change carbon performance, an effect that has not been quantified for universities yet. Low or even zero carbon emissions can also be achieved by purchasing carbon certificates, and combining these two forms for reducing or neutralizing the CFs of HEIs: technology and market [29].

Finally, we found several recent studies in different continents which were conducted to assess, estimate, or calculate GHG emissions in HEIs—that is, to track the CFs of HEIs—such as Valls-Val & Bovea (2022), who created a CF assessment tool for universities (CO_2UNV) at

Jaume I University, Spain; Yañez et al. (2020), who estimated the CF at the Talca campus of the University of Talca, Chile; Mustafa et al. (2022), who estimated the CF of NED University, in Pakistan; Gamba et al. (2021), who analyzed the magnitude of mobility-related GHG emissions before and during the COVID-19 pandemic at the University of Oldenburg, Germany; Pérez-Lopez et al. (2021), who calculated the CF associated with people's mobility at the University of La Coruña, Spain; and Li et al. (2021), who investigated the impact of semester schedules on annual CO^2 emissions at the University of Edinburgh campus, Scotland, UK, among others listed in Table 3 [12,13,30,37–39].

5. Conclusions

This study developed a global literature review focusing on the CFs of HEIs, in search of green initiatives to decarbonize a campus. The objective was to identify and point out the main issues addressed, as well as to identify gaps in the reviewed literature. The study analyzed publications on CF reduction in HEIs in the scientific field through searches in the Scopus, Web of Science, and Science Direct databases. It was found that the theme still needs to be deepened by academic research, as well as standardization of calculation models since consumption and impact data are not recorded regularly or are recorded without depth for analysis. There is great relevance in this scientific deepening aligned with the SDGs, especially with the targets for reducing GHG emissions by the year 2030. Thus, it is expected that the organization of data and the standardization of protocols will strengthen the academic cooperation of international organizations, with attention to the growing concerns about climate issues.

We mention some conclusions based on the survey results. The region that published the most on the topic was the United Kingdom. We also identified that 2021 was the year with more publications up to February 2022 among the 33 articles reviewed. From the readings, we noticed the lack of a single method of international standardization for the inventory and calculation of organizations' CF, and hence for HEIs and their specifics. In addition, the time base for calculating the CFs of educational institutions varied across the articles and should be standardized, as it would be advisable to implement mechanisms for keeping annual historical records which would facilitate comparison between HEIs in general analyses. As a practical contribution, we built Table 3, which outlined the objectives of each selected article, identifying the authors and the examined HEI as well as the type of scope reached by each article.

The theoretical contributions focus on concepts such as "carbon footprint" and "green campus", and the organization of the selected articles and their classification by types of scopes achieved, according to GHGP. The article examined the current systematic knowledge on the subject, in three databases, with the most recent publications until February 2022. It also contributed to creating a research agenda, based on the existing gaps in the central theme and the lack of model standardization.

The reviewed articles bring some limitations; one of them is the impossibility of a more precise comparison of scope reach since each study addresses different scopes, making it impossible to analyze the three scopes of GHG emissions equally in each article. It is important to highlight the weaknesses identified in scope 3, which represents a large percentage of GHG emissions, constituting an important source of action to reduce emissions and rigorously visualize the scope of decarbonization in HEIs.

As an agenda for future research, a more detailed study of the subject is suggested, with the inclusion of other data banks. This includes further analysis of the progress of the research area with cooperative networks from different countries and different organizations, as well as studies on new technologies, after the COVID-19 pandemic. Although HEIs may be different in size and function, it would be interesting to have a uniform approach to reducing CFs throughout the education sector in collaboration with the private sector, government(s), and society in general. The COVID-19 pandemic presented opportunities for HEIs to reconsider the model of how education is carried out, taking into consideration possible problems that could arise such as, for example, inequalities associated with the offer of online education and transfer of emissions between work locations for residences [31]. The standardization of two models, protocols, and calculation of CF, as well as the inclusion and better characterization of scope 3 in the inventory of CF assessments, are relevant points for future studies.

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