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Review

Bibliometric Analysis and Benchmarking of Life Cycle Assessment of Higher Education Institutions

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Abstract: Higher Education Institutions (HEI), such as Universities and Institutes worldwide, are making efforts and setting goals to assess and minimise their environmental impacts, and to become more sustainable. Life Cycle Assessment (LCA) has been considered a powerful approach to deal with environmental impacts of products and services. Thus, in this paper, a bibliometric analysis was carried out to benchmark the sustainability of HEI in terms of key areas, impacts, and barriers. Results indicate that, although some HEI are concerned with sustainability, LCA has not been systematically adopted in their assessments, and the main focus is on the calculation of carbon emissions. The lack of available internal information and managing commitment are the main barriers to adopting LCA in HEI. In the few cases where LCA was considered, it was observed that differences in scopes, functional units, intensities, and data reliability hamper comparisons, and lead to biased conclusions. In the end of the paper, the results of some Portuguese HEI are provided and discussed, showing the need for a better understanding of environmental assessment results.

Keywords: life cycle assessment; higher education institutions; carbon footprint; environmental assessment

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1. Introduction

The relevance of sustainability issues requires novel educational approaches regarding all frameworks from Agenda 2030. In particular, climate change has been identified as a considerable challenge for sustainability. In fact, since the 1800s, anthropogenic activities have been identified as the primary driver of climate change, primarily due to the burning of fossil fuels (coal, oil, and natural gas) [1]. It is well known that Anthropocene is becoming increasingly destructive, and the inaction of the past generations is compromising Earth in many different ways [2,3]. Higher Education Institutions (HEI) cannot avoid this challenge and, in fact, they may play a leading role. Several initiatives have been proposed in the past years to deal with the Education for Sustainable Development (ESD), some more successful than others. A good example is "The Declaration of Talloires", which was planned to promote the commitment to environmental sustainability in universities worldwide [4].

With efforts over time, self-review and self-learning processes have expanded the knowledge of institutions for sustainable education, measuring aspects of the social and financial dimensions, resource management, and strengthening institutions [5]. Moreover, the commitment of HEI to environmental goals is critical for achieving sustainability. However, this field still has a long way to go [6,7]. The educational activity is a tangled system involving a wide range of processes and materials that are relevant to sustainability goals. The sustainability assessment of HEI is a complex problem, usually requiring large amounts of data, which is generally spread within different internal services and departments [8,9].

One of the most recommended and powerful tools developed in the past years to address environmental issues is Life Cycle Assessment (LCA), which provides a holistic approach to evaluate products, processes, or services [10]. LCA framework allows examining the environmental impacts of a product (or service) from the extraction of raw materials, production, use, and final disposal—from cradle to grave. Moreover, LCA provides a methodology for evaluating system-changing aspects to put life cycle thinking into continuous improvement. Many examples are already available in the literature combining the LCA approach with campus learning experiences. It has been noted the active role that university campuses have played in reducing greenhouse gas emissions, managing waste, and raising awareness in the academic community [11]. Some approaches to increase the awareness of the entire academic community using real examples, in Portugal, are provided by [12].

As aforementioned, many activities and processes occurring in HEI may influence the environment. Thus, sustainability in educational *campi* has become a priority [13]. The availability of reliable environmental data is one of the most relevant barriers in higher education institutions that hinder the LCA in these organisations. The inconsistency and lack of comparability in LCA analyses are other flaws. In addition, there is a lack of integration of LCA into the decision-making process and strategic planning in HEI.

On the other hand, sustainability assessment tools (SAT) are commonly used to facilitate the assessment and reporting practices, and to provide benchmarking for HEI [14]. A recent study involving 19 SAT showed that the focus has been on assessing campus operations (34.48%). The same research indicated that only 42.1% of the SAT used impact indicators, while all the others used performance indicators to pursue environmental evaluation. The use of performance indicators instead of impact indicators leads to poor environmental sustainability assessment [14]. The misuse of these indicators drives an urgent need for innovation in LCA education, and research aiming at democratising, standardising, and educating institutions for valid environmental and social concerns [15]. In addition, HEI have an institutional duty to educate their community by offering technical bases for Environment, Social, and Governance (ESG) management.

Some of the pioneer environmental studies of HEI used different methodologies in a very unclear way. One of the most recent worldwide platforms is The Times Higher Education Impact Ranking (THEIR), which comprised 1406 universities from 106 countries and regions in 2022. This ranking evaluates the performance of universities related to the United Nations (UN) Sustainable Development Goals (SDG) across four main areas: research, stewardship, outreach, and education. This system aims to rank HEI based on their performance in the top four SDG. However, the system does not assess environmental impact indicators, which may be considered a drawback for the subsequent use of LCA.

Following the need for a systematic change due to academic and scientific knowledge shared by HEI, several initiatives have been developed to assess, monitor, and compare some key performance indicators (KPI). In particular, some HEI are making efforts to calculate the carbon footprint (CF), which is a metric for evaluating sustainability in terms of greenhouse gas (GHG) emissions [16].

In this context, the present review aims to discuss the evolution over time of LCA application in HEI, and to identify its current practices, trends, and gaps. Therefore, this paper provides a bibliometric analysis on the application of LCA in HEI, to identify patterns, best practices, and key challenges faced by universities when applying life cycle assessment. This analysis is followed by the benchmarking of HEI in terms of carbon intensity. Finally, a brief overview of the environmental assessment of HEI in Portugal is provided to understand its relevance in terms of the international context.

2. Methodology

The methodology adopted in this paper is divided into four main steps, as illustrated in Figure 1.

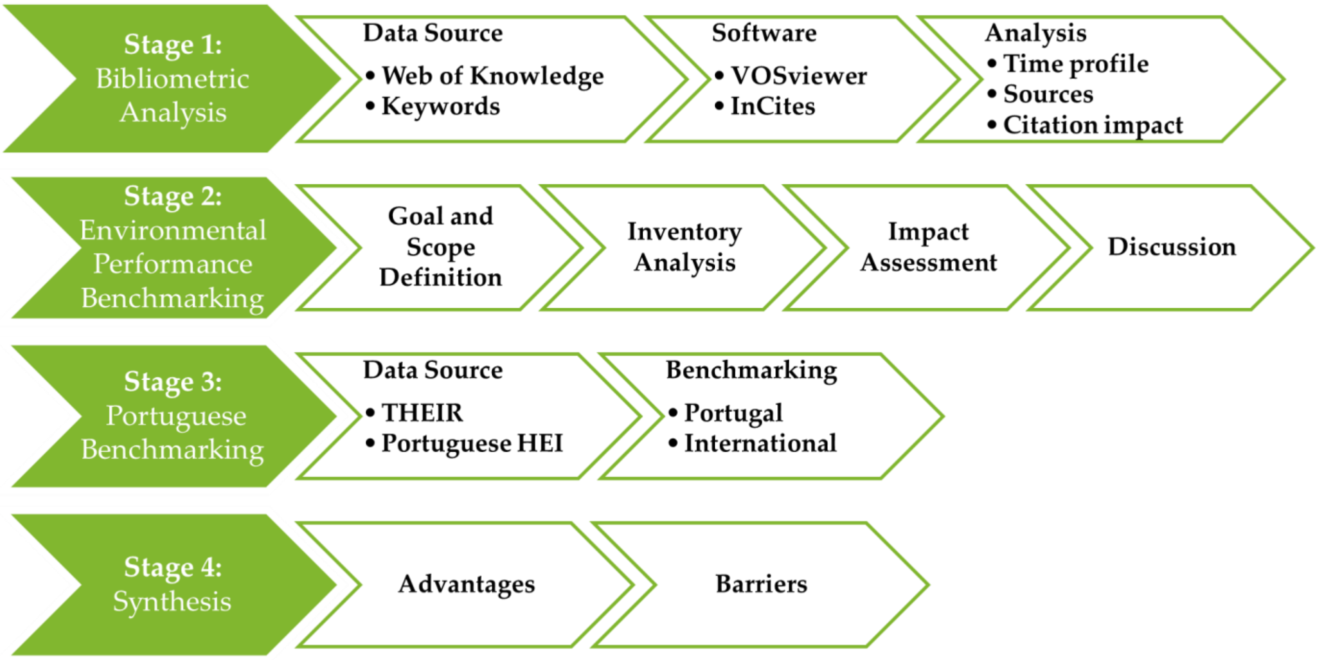

Figure 1. Adopted study approach [17].

Step 1 consisted of the bibliometric analysis and involved data selection, collection, and pre-processing. The Web of Science (WoS) was the selected database. WoS is a paid-access platform owned by Clarivate that provides access to various databases, including multiple journals, and covers several thematic areas. Although other platforms were available, such as Scopus, the WoS was chosen because it provides the most in-depth citation per source. Another advantage of using WoS is the availability of a large volume of scientific literature published in the past.

In Step 2, the discussion about the environmental performance of HEI is made according to the four steps of LCA, provided by ISO 14040 [17], and considering key areas in HEI [18]: buildings, energy, transport, climate, food, soil, air, water, and waste.

Step 3 consisted of the review of the environmental performance of Portuguese HEI, and the comparison with the international context. For this review, the websites of the main HEI were searched for information, reports, and repositories.

Finally, Step 4 summarised the information gathered from the literature and highligthed the main advantages but also the main barriers to the adoption of LCA in HEI.

3. Bibliometric Analysis

Bibliographic mapping tools may be used to visualise the structure of the literature over time. The approach adopted in this paper has three different stages, as described in the following paragraphs.

Stage 1 involved data selection, collection, and pre-processing. The Web of Science (WoS) was the selected database. The WoS is a paid-access platform owned by Clarivate that provides access to various databases, including multiple journals, and covers several thematic areas. All fields with the keywords *life cycle assessment* were searched to determine new trends and research areas associated with LCA in HEI. The following keywords were considered for the titles of the publications: *sustainab** (or) *environment**. In addition, the location was necessary, so the terms *campus* (or) *universit** were included. The asterisk was necessary because of its capability to use each word's correlated parties (e.g., *sustainab** comprised sustainable and sustainability). Then, the pre-processing allows the removal of duplicate and irrelevant references. The review focussed on the period from 2012 to 2022.

Stage 2 was responsible for the extraction, normalisation, and mapping processes. This stage refined the search and provided a reliable assessment of available peer-reviewed articles. The articles were refined by type to include only peer-reviewed journal articles. InCites Benchmarking & Analytics is a web-based research evaluation tool used in this work. This tool was responsible for assessing some indicators related to institutional productivity, citation impacts, tracking cooperation activity, identifying prominent researchers, highlighting strengths, and identifying potential areas.

Stage 3 involved analysing, visualising, and interpreting the gathered data by applying a series of analyses to extract meaningful knowledge, such as network analysis, temporal analysis, and geospatial analysis. The VOSViewer software, version 1.6.18, was used, a text-mining tool commonly used in scientific mapping to show massive bibliometric studies, and construct and visualise networks. This tool included co-occurrence, co-citation analysis, bibliometric coupling features, and illustrating connections and relatedness via distance-based nodes [17,19]. The normalising step assigned a weight to each term based on its importance in the corpus, and applied (when it is possible) a mapping algorithm to the entire network. Normalization of data will form the relationships between the selected units of analysis with lines. The size and spacing of the nodes and the interconnecting lines depict the most often-used terms in the graphic. The keywords are grouped into several clusters based on a text-mining algorithm.

Following the above procedure, the initial combined search yielded 333 publications from the WoS Core Collection (Identification). Only online accessible articles in English were accepted, resulting in 321 entries from all over the world (Screening I). A detailed verification was carried out in the "Title" of the selected ones, resulting in 67 articles within the preselect scope of this study (Screening II). Thirty-seven articles were removed because they did not directly connect to our central inquiry issues; most were based on LCA methodologies, which partially outlined procedures taken on *campus*. Then, the "Abstract" funnel separated the last 30 articles (Included). This search was conducted on 5 May 2022. Figure 2 summarises the refining of the papers in the WoS database.

Figure 2. Refining of papers in the WoS database.

Figure 3 shows the temporal tendencies and the countries of the studies in this bibliometric analysis to identify the status of the current publication regarding LCA on HEI *campi*. Until the end of 2022, 2021 was the peak year of LCA-HEI-related publications. It is noted that the present work was carried out in the first half of 2022. Hence, if the trend continues, the number of publications in 2022 may surpass the last year.

Although the refined analysis led to 30 articles, only 13 countries were identified in Figure 3 due to the international collaborations in some papers. Regarding the sources of the studies, Spain was responsible for about 33% of the publications. China was the second one, corresponding to 20%. The list continues with Germany, Canada, Saudi Arabia, and Singapore. Most publications are from northern countries, such as Germany, the USA, and the Czech Republic. According to WoS, the activity remains based on the environmental sciences (50%), green and sustainable science and technology (40%), and environmental engineering and studies (23%). Important to mention the reference to civil, materials, and environmental engineering words in almost all publications; however, multidisciplinarity is becoming a trend in the most recent documents.

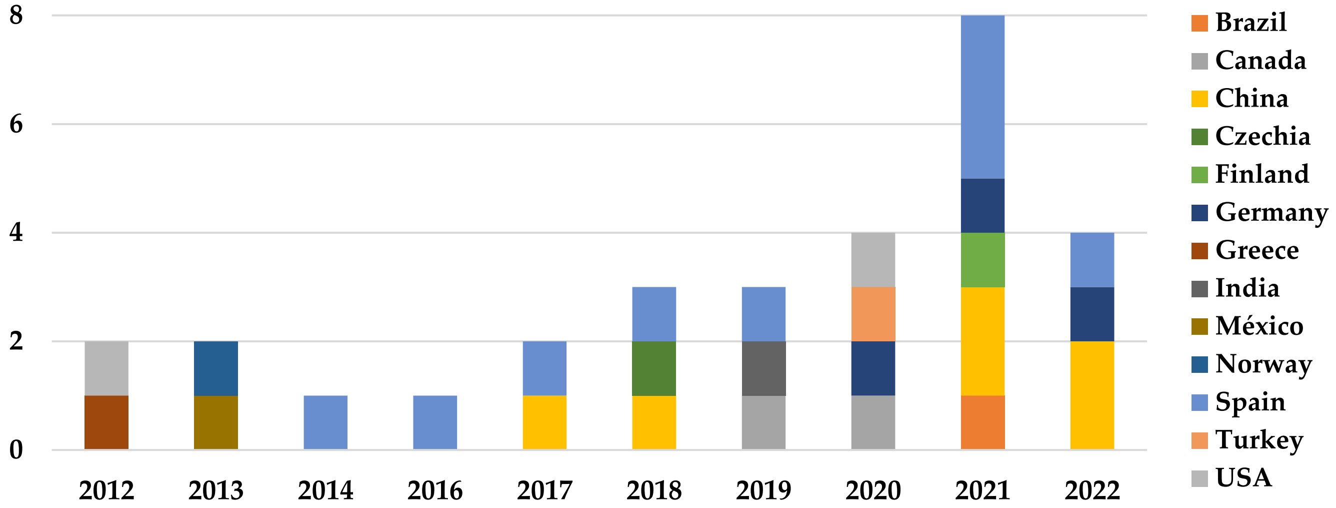

Figure 3. The number of publications of LCA on HEI *campi* from 2012 to 2022.

Furthermore, co-citation analysis was used to identify which publishers can be considered more influential, as shown in Table 1. In this case, Elsevier obtained 38% of the works as a publisher, followed by Springer Nature with 31%. Emerald, MDPI, and Parlar also contributed significantly (8% each).

Table 1. Top sources of LCA on-campus research.

Source	Publisher	Citations	Citation Score
Journal of Cleaner Production	Elsevier	218	9.44
Sustainability	MDPI	34	3.47
Sustainable Cities and Society	Elsevier	14	7.31
The International Journal of Life Cycle Assessment	Springer	12	5.55
Frontiers of Engineering Management	Springer	12	1.52
International Journal of Sustainability in Higher Education	Emerald	8	3.46
Environmental Sciences Europe	Springer	7	6.66
Science of The Total Environment	Elsevier	3	7.84
Fresenius Environmental Bulletin	Parlar	3	0.48
Bioresources	n/a	3	1.92
Environmental Impact Assessment Review	Elsevier	2	5.08
Energy Sustainability and Society	Springer	1	3.09
Sustainable Production and Consumption	Elsevier	1	4.93

In terms of scientific journals, the top thirteen journals are listed in Table 1. The *Journal of Cleaner Production* stands out as the more relevant source of LCA-HEI works, followed by *Sustainability*. On the other hand, when dealing with the citations, Elsevier obtained 74.8% of all verified databases, followed by MDPI and Springer with 10.7% and 10.1%, respectively.

The citation impact of a set of documents is calculated by dividing the total number of citations by the total number of publications. The average ratio of times cited per document in this bibliometric study was almost 7.9 ($\cong$15.15/1.92), indicating a good number of scientific dissemination inside the WoS database. The WoS category normalised citation impact is determined by dividing an actual citation count by an expected citation rate for publications with the same document type, year of publication, and topic area. Figure 4 shows that the normalised citation impact profile varies significantly, comparing the top ten countries. Important to mention that Singapore had the most significant normalised citation impact (measured by the radius of the dots), followed by Germany and the USA. However, it is observed that these countries had a significantly reduced number of papers.

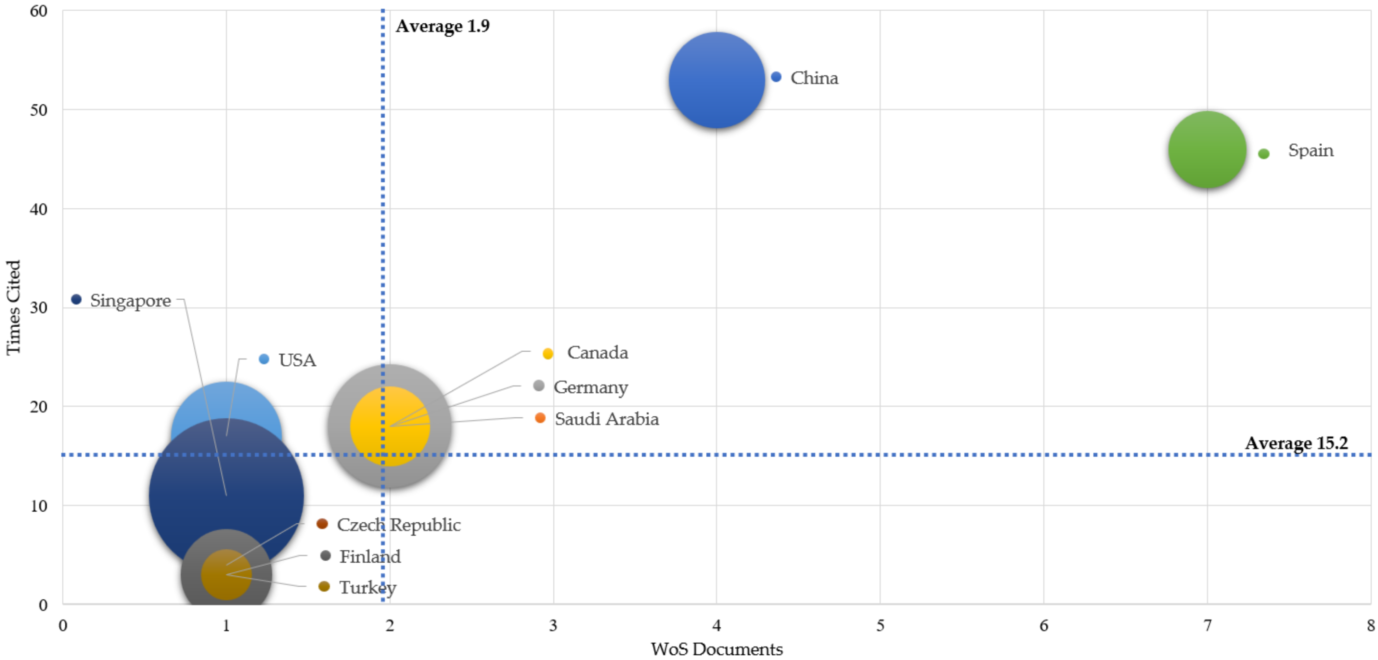

Figure 4. Normalised citation impact profile for the top 10 countries.

The co-occurrence of phrases and keywords was analysed using the VOSViewer software, version 1.6.18, and no normalisation method was selected in the software. The minimum number of occurrences chosen was two due to our limited number of samples. In addition, the weights chosen were the links, and the scores were average publications per year. The line variation was 1.0. We also chose the attraction and repulsion factors of VOSviewer in order to allow better visualisation of the links between the data. However, these factors are only for aesthetic purposes. As the keywords were adequately allocated, it was possible to determine which topics are more frequent and how they are related (i.e., co-occurrence of all keywords). About 219 keywords were founded in this case, but only 50 appeared at least twice, and these were used to create the network graph, as indicated in Figure 5.

The keyword co-occurrence graph shows some interesting trends, while the main keywords were "sustainability", "carbon footprint", management, performance, and LCA variations. In addition, it is observed that the most recent publications (in yellow) introduce the keywords "university carbon footprint" and "zero emissions university".

The main findings enabled by this bibliometric analysis will be discussed further in the following sections of the paper.

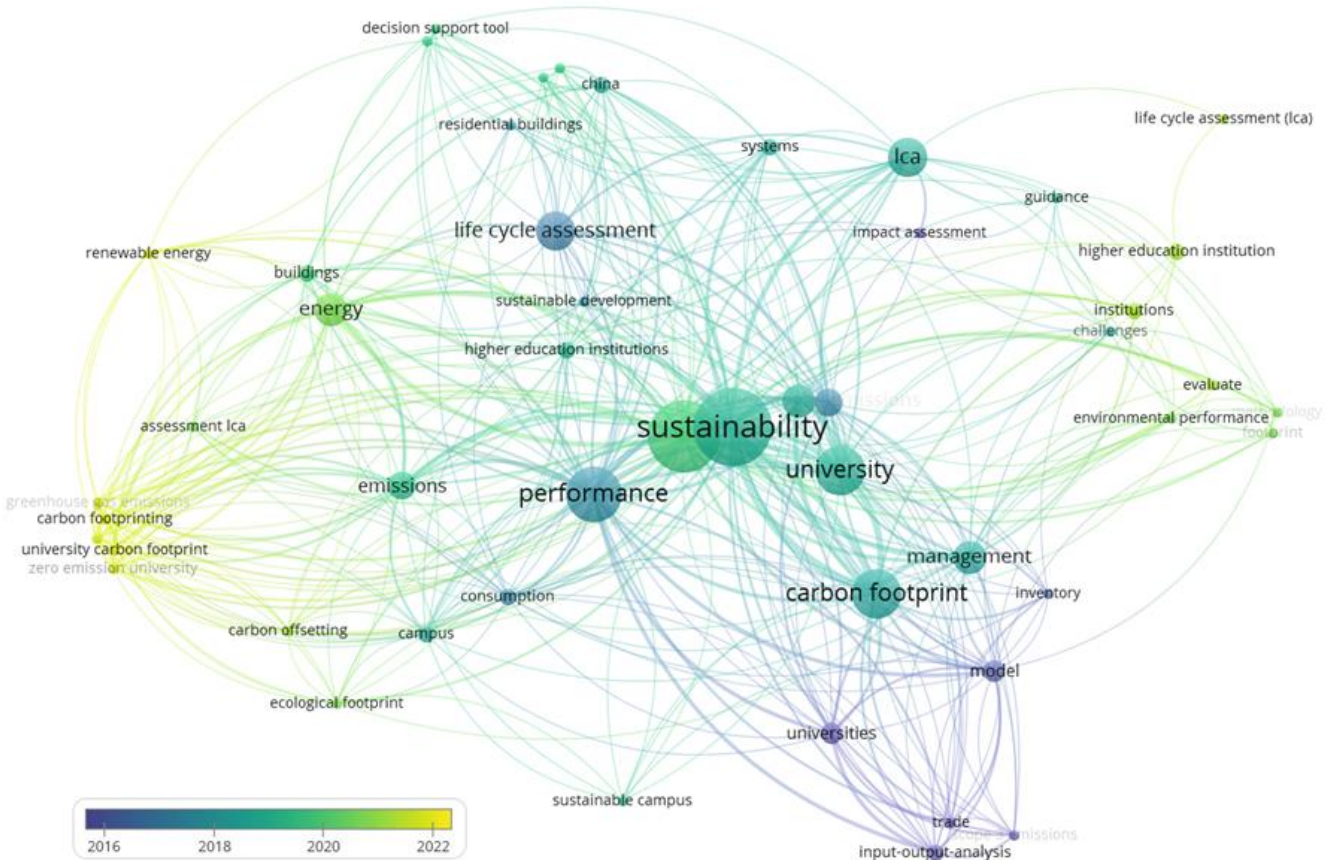

Figure 5. Bibliometric co-occurrence analysis by temporal profile.

4. Carbon Performance Benchmarking

Comparing the performance among the HEI requires transparent models as more and more HEI estimate their GHG emissions to show the carbon footprint (CF). This approach reveals HEI strategies and provides more precise comparisons among HEI. Evaluating similarities or differences in HEI's primary GHG emissions can help concentrate goals, strategies, and policies to reduce emissions [16]. The CF has been used to specify some of the environmental impacts of an HEI operation. However, no other environmental impact is usually considered, such as the emission of particulates, eutrophication potential, or others.

However, a few HEI calculate specific environmental impacts by following the ISO 14040 guidelines [17]. This is usually made to find operational "hotspots" within the main activities of HEI: the provision of teaching and research services. For this purpose, mass and energy balances must be carried out. In addition, data quality and reliability should be ensured by HEI.

Nevertheless, different criteria are used to organise all environmental loads and system boundaries in the calculations. This situation does not allow appropriate comparisons, making it challenging and almost impossible to compare among HEI. Some aspects contributing to the discrepancy of results are, for instance, the use of different methodologies, populations of varying sizes, the adoption of different functional units (FU), different carbon sources, and offset procedures, among others [20,21].

The following paragraphs discuss the main sources of discrepancy according to the different stages of a life cycle analysis. Then, a tentative benchmarking is provided of the carbon intensity of HEI, followed by a discussion.

4.1. Goal and Scope Definition

Scope defines the boundaries of a study and determines what will be included and excluded from the analysis. In the application of a Life Cycle Assessment to HEI, the scope is essential for decision-making as it:

- Defines the system being analyzed, ensuring a consistent and comprehensive evaluation;
- Determines the data and information required, ensuring the reliability and accuracy of the results;
- Guides the choice of impact categories, methods, and data sources, ensuring the relevance and completeness of the results;
- Helps to identify trade-offs and uncertainties, allowing for informed decision-making based on the strengths and limitations of the study;
- Communicates the study's purpose and results to stakeholders, enhancing transparency and credibility.

Therefore, a well-defined and appropriate scope is crucial for a meaningful and useful LCA in a HEI, and for supporting evidence-based decision-making. In addition, this allows the objectives to be outlined within each of the key areas of the study.

The selected papers (#30) were analysed to identify the key areas included in each work, as summarized in Table 2.

Table 2. Key areas in LCA-on-campus research.

Ref.	Country	Year	Building	Energy	Transport	Climate	Food	Soil	Air	Water	Waste
[22]	USA	2020	✓	✓	✓	✓				✓	✓
[23]	China	2020	✓	✓		✓			✓		
[24]	Spain	2017	✓	✓	✓	✓			✓	✓	✓
[25]	Spain	2016	✓	✓	✓		✓		✓	✓	✓
[26]	China	2018	✓	✓	✓	✓					✓
[27]	USA	2012		✓		✓					✓
[28]	China	2017		✓	✓		✓		✓	✓	✓
[29]	Germany	2020	✓	✓		✓					
[30]	Greece	2012	✓	✓		✓					✓
[31]	Spain	2018	✓	✓	✓	✓		✓			
[32]	Spain	2021	✓	✓		✓					
[33]	Spain	2022	✓	✓		✓					
[34]	Spain	2019	✓	✓	✓	✓	✓	✓	✓	✓	✓
[35]	Spain	2021	✓	✓	✓	✓			✓	✓	✓
[36]	Czechia	2018		✓	✓	✓		✓			
[37]	Brazil	2021	✓	✓	✓	✓	✓	✓	✓	✓	✓
[38]	Turkey	2020		✓	✓					✓	✓
[39]	China	2020	✓	✓	✓		✓	✓	✓	✓	
[40]	Spain	2021	✓	✓	✓					✓	✓
[41]	Germany	2022	✓	✓	✓	✓					✓
[42]	China	2021		✓	✓	✓				✓	
[43]	Canada	2019		✓		✓					
[44]	China	2022	✓	✓	✓	✓	✓	✓		✓	✓
[45]	Spain	2014	✓	✓	✓	✓					✓
[46]	México	2013	✓	✓	✓	✓				✓	✓
[47]	India	2019	✓	✓	✓	✓					✓
[48]	Canada	2020	✓	✓	✓	✓				✓	✓
[49]	Germany	2021	✓	✓	✓	✓	✓				✓
[50]	Finland	2021	✓	✓	✓	✓	✓				✓
[20]	Norway	2013				✓					
Total			23	29	22	25	8	6	8	14	20

It is observed that 29 out of 30 studies (96.7%) considered "energy" in the LCA of HEI. The main reason for this is that "energy" is often the dominant factor contributing to the environmental performance of HEI. Surprisingly, only one article covered all key areas [34]. On the other hand, most articles covering "buildings" also tackled "energy", as these two areas are often correlated due to the intrinsic relation between buildings and energy consumption. Buildings, which refer to construction and operational flows, were mentioned in 76.7% of the papers. Climate had 83.3%, and corresponded to all GHG studies and assessments, most of which used carbon footprints.

In the area of "buildings", it was observed that some papers calculated environmental burdens over the entire life cycle of some facilities with Building Information Modelling (BIM) and other digital platforms (e.g., [43]). In addition, it was perceived that smaller universities might quickly lower their environmental impacts due to less infrastructure and mobility requirements. The area of "transport" was addressed in 73.3% of the papers due to its correlation with all other areas. A significant variety of mobility on campus, and the necessity to include this in the LCA process was also observed. "Food", "soil", and "air" were the lesser studied areas, mainly because of the difficulty in finding the environmental data, corresponding to 26.7%, 26.7%, and 20%, respectively.

Another relevant area is "waste", which has been considered in 66.7% of the works. In this case, a driving force for implementing a circular economy on campus was evident—most HEI focussed on avoiding plastic and adopting alternative materials. The relevance of "responsible consumption" is clear since many HEI declare to evaluate several waste flows (electronic equipment, paper, chemicals, and others) concerning their hazardous potential. In addition, in the area of "air", most HEI focussed on GHG emissions; other emissions, such as NO_X, SO_X, and other volatiles, received much lower attention.

4.2. Inventory Analysis

In general, the LCA of HEI involves the collection of huge amounts of different types of data, particularly when different buildings, services, and infrastructures are considered within the boundaries of the study.

Many different data sources were identified in the reviewed literature, but the most cited database was Ecoinvent. However, other databases from different countries were also considered, such as OKO-BAUDAT (Germany) and BCBPMQ (Canada).

4.3. Impact Assessment

The present study showed that 90% of the HEI used LCA to investigate the CF, using indicators such as Global Warming Potential (GWP), measured in tons of CO_2 equivalent (CO_2,e). Furthermore, this indicator seemed to be a good KPI, mainly when normalised per student, or even m^2. Only 10% of the works adopted LCA to evaluate the Ecological Footprint (EF), measured in global hectares (gha), responsible for interconnecting many other footprints. The EF is a site-specific indicator that considers aspects such as the kind of place (rural, suburban, or urban), the scope (university, city, region, or nation), and the normative behaviour of the people. In addition, the EF is essential for environmental-educational purposes for the students and other stakeholders.

Regarding the approaches followed for LCA, almost all papers mentioned the standards directly related to LCA, environmental management, and carbon management, such as ISO 14001, ISO 14040, ISO 14044, and ISO 14072 [17,51–53]. In this review, comprising 14 studies from 14 countries, 24 HEI conducted relevant LCA research related to campus operations.

Most reviewed articles mentioned one of the impact assessment methodologies: Hybrid LCA (HLCA), Process Analysis (PA), Benchmarking (BEN), Building Information Modelling (BIM), and Life Cycle Cost (LCC), with a share of 23%, 53%, 13%, 3%, and 7%, respectively. PA was the primary approach observed because of its rigour and the possibility of collecting data from distinct databases. The HLCA was the category that mixed at least two methodologies. In addition, the environmental impact methods most mentioned were the CML and ReCiPe.

An alternative approach, such as the Social-Organisational Life Cycle Assessment (SO-LCA), was perceived as a good and transversal approach because of its entanglement with several main sustainability issues. This social-organisational LCA has the potential to assist HEI in detecting hotspots, lowering their social imprint, and promoting awareness among academics. These functionalities contribute to the knowledge, progress, human values, and sustainability these HEI represent. The Product Social Impact Life Cycle Assessment

(PSILCA) was the central database used to account for the social aspects of products with transparency. It is observed that the reviewed works focussed on environmental assessment. At the same time, life cycle costs and social impacts received much less attention.

In most cases, the objective was only to study the emission of GHG, and about 46.7% of the studies followed the guidance of the Greenhouse Gas Protocol and its scopes [54]. GHG Protocol is one of the most disseminated guidelines for assessing CF worldwide [54]. The use of the GHG Protocol taxonomy involves:

- Scope 1: Direct GHG emissions from the generation of electricity, physical or chemical processing, transportation in the value chain, and fugitive emissions;
- Scope 2: Indirect GHG emissions from the purchased electricity;
- Scope 3: Indirect emissions from all relevant activities in the value chain.

The literature review showed that the easiest way to estimate the carbon footprint is to focus on Scope 1 and 2 because of the availability of data regarding energy production or purchase.

However, when Scope 3 is considered, its contribution may vary from 20% to 80% of all GHG emissions in the HEI because of its multiple and multidisciplinary working areas (e.g., laboratories, libraries, and administration) [48]. In addition, given the importance of Scope 3 to HEI, its adoption is essential to ensure that HEI are carrying out more robust inventories.

Other approaches were also mentioned, depending on the goals and priorities of each study. For instance, at least 7% of the studies used Life Cycle Cost (LCC) assessment to evaluate economic impacts alongside environmental impacts. The review also encountered mentions to the Environmental Management and Audit Scheme, fuzzy assessments, analytic hierarchy processes, and the use of BIM [23,24,27].

In terms of the use of software, the world market leading software, GaBI and SimaPro, were referred to in four articles close to buildings and energy areas, in which their databases seemed more accurate and reliable [22,29,33,37]. In addition, OpenLCA, a free software, was used by 23% of the works, revealing its preference for scientific approaches. It is noted that most researched articles did not reveal the adopted software. Despite its limitation, the Neighbourhood Evaluation for Sustainable Territories (NEST) tool was considered in 7% of the works.

4.4. Benchmarking

Albeit the variability in terms of LCA assumptions and adopted approaches observed in the reviewed papers, an attempt was made to benchmark the carbon intensity of HEI, considering different functional units (FU), as illustrated in Table 3.

Table 3. LCA in HEI regarding carbon intensity.

Functional Unit (FU)	Ref.	Year	Country	Adopted Method	GHG Scopes	Product System	Carbon Intensity (ton CO_2,e/FU·year)
Square meter	[26]	2018	China	PA		Multistorey building	1.61
	[30]	2012	Greece	PA		Office building	0.63
	[41]	2022	Singapore	PA	1, 2 & 3	*Campi*	0.13
	[41]	2022	Germany	PA	1, 2 & 3	*Campi*	0.12
	[23]	2020	China	HLCA		Teaching building	0.12
	[32]	2021	Spain	PA		*Campi*	0.03
Total	6		5	2	2	Mean value	0.44
Student	[42]	2019	Canada	BEN	1, 2 & 3	Mean of 10 *campi*	4.90
	[50]	2013	Norway	LCC	1, 2 & 3	*Campi*	4.60
	[22]	2020	USA	HLCA	1, 2 & 3	*Campi*	4.40
	[44]	2014	Spain	LCC	1, 2 & 3	Multistorey building	1.87
	[34]	2019	Spain	PA		Two office building	0.46
	[25]	2016	Spain	PA		*Campi*	0.25
Total	6		4	4	4	Mean value	2.75

Table 3. *Cont.*

Functional Unit (FU)	Ref.	Year	Country	Adopted Method	GHG Scopes	Product System	Carbon Intensity (ton CO_2,e/FU·year)
User	[49]	2021	Finland	HLCA	1, 2 & 3	Five office building	5.14
	[48]	2021	Germany	BEN	1, 2 & 3	Mean of 20 Global HEI	4.47
	[45]	2013	México	PA	1, 2 & 3	Multistorey building	1.46
	[35]	2021	Spain	HLCA		*Campi*	1.22
	[31]	2018	Spain	PA		*Campi*	0.84
	[46]	2019	India	PA	1, 2 & 3	*Campi*	0.81
	[38]	2020	Turkey	PA	1, 2 & 3	*Campi*	0.76
	[24]	2017	Spain	HLCA	1, 2 & 3	Three multistorey building	0.24
Total	8		7	3	6	Mean value	1.87

Table 3 shows the variability of the values obtained in several HEI worldwide, considering three different FU categories. One of the difficulties in analysing these results is due to the adoption of different assessment methods. In this case, PA was used in about 55% of the studies, mainly from Spain. This country had 30% of participation in these results. The articles that comprehended more information were related to *campi* approaches (50%), followed by office and multistorey buildings, with 20% of each. On the other hand, about 60% of the environmental assessments considered all scopes in the GHG Protocol.

Concerning the values of carbon intensity, the mean value of emissions related to the FU normalized by students achieved the higher value (2.75 tons of CO_2,e/student.year), followed by the value related to the FU normalized by users (1.87 tons of CO_2,e/user.year). The mean value of emissions per square meter is 0.44 tons of CO_2,e/m^2.year. However, an extended interval of values is observed for all cases.

4.5. Discussion

A huge effort was required to benchmark the reviewed works due to their singularities and internal differences, such as dimension or culture, product system considered, and functional units. Moreover, some boundary conditions differ, such as the number of students and workers, or the geographical area and city location. Hence, the following discussion is based on only 20 articles from the total number of papers reviewed, due to comparability reasons.

Regarding the product system, 36.7% of the studies were related to *campi*, with all facilities considered in the calculation. On the other hand, 36.7% of the studies included several facilities, such as libraries, offices, classrooms, or even departments or faculties. This part was closely related to civil engineering management of the construction and usage phases, most accounting for the cost assessment.

Almost 26.7% of the cases included partial operations inside HEI activities, such as the comparison between remote and face-to-face classes [37], and one Chinese study [39] comparing composters spread over several parts of the campus facilities.

Most of the selected studies (65%) did not make any scenario or even some trend analysis with the environmental indicators. A few studies assumed some scenarios to facilitate decision-making, most related to targets of carbon emissions reductions and finding the hotspots correctly in the processes. Regarding the FU, about 20% of the studies considered the number of students, 23% considered users, followed by intensity indicators per square meter (13%).

A significant part of reviewed works considered the entire facilities of the university as the product system in LCA. However, there were some exceptions in which the scope was limited to specific buildings or processes. An interesting example is provided by [27], where the authors used LCA to compare the environmental impacts of a paper report with an e-report, thus focusing on only one aspect of the HEI activity. On the other hand, some authors, inspired by the pandemic situation, used LCA to compare the impacts of physical classes with online classes [37].

Another factor contributing to this situation is that HEI have different core activities with different specificities and arrangements. Thus, the different authors chose the frontiers and product systems according to the facilities and operational parts considered in the analysis. The most common objects of assessment were classrooms and office buildings, but laboratories, residences, and canteens were also considered. In [46], the author considered the human breath process for the LCA calculation. In addition, functional units and intensity indicators varied among the reviewed works, causing additional difficulties in the comparison.

In general, assessing the life cycle of organisations is more challenging than assessing the life cycle of products or services. Some important steps in LCA may be more challenging to define (e.g., FU or system boundaries).

The main findings from this literature review are summarized in Table 4 by key areas.

Table 4. Overview of the main conclusions in each key area.

Areas	**Main Findings**
Building	Most of the impacts are mainly in material production; Concrete and steel as the most poignant materials; Rehabilitation strategies are effective in harm reduction.
Energy	Present in all environmental assessments; Primary energy is a priority for investment; Increasing green buildings to improve eco-efficiency
Transport	Compact layout and concentrated functions are good characteristics; Suburban *campi* are penalised by mobility; Activities that contribute the most to environmental impacts; Transport services have a very significant social impact; Air transport should be avoided due to its vast impact.
Climate	Scope 1 and 2 are widely used, Scope 3 is the highest emission scope; The most equivalent gases used in GHG accounting are CH4 and NO2.
Food	People typically consume more food when working from home; Only considered in over 50% of the footprint literature; Main impacts occur the most in distinct geographies; Most hotspots are related to cow meat.
Soil	The EF is an excellent indicator in this area; Its LCA is limited by land use behaviour and assumptions; Growth of biomaterials to produce energy; The carbon sequestration market is increasing.
Air	Impacts are sometimes underestimated; Inclusion of particulates and other volatile contaminants.
Water	Decisive on ecological footprint assessment; Environmental performance indicators demand water efficiency; Growth of technological options for alternative water management
Waste	Plenty of types are generated on *campi* due to its operations; Opportunities coming from circular economy awareness; Municipal solid waste represents almost 60% of all waste generated; Logistical problems are a major bottleneck.

5. Portuguese Benchmarking

In the following paragraphs, a brief overview of Portuguese HEI (P-HEI) is provided to compare such performances with international values in the context of sustainability assessment.

5.1. The Case Study of the University of Coimbra

The University of Coimbra (UC) is one of the most sustainable universities in the world according to Times Higher Education Impact Ranking (THEIR), occupying 26th place in the fourth edition. The participation of UC in international rankings has allowed identifying areas for improvement, both in terms of performance and instruments for monitoring performance. This ranking is the main SAT at UC due to its international coverage and sustainable goals. The ranking interacts with the strategy and quality of the management framework to organise environmental management. However, the ranking has some drawbacks, such as the fact that only the three best SDG are evaluated, plus the 17th SDG, which creates voids that need to be filled with other tools such as the Global Reporting Initiative guidelines and national legislation.

UC is committed to achieving carbon neutrality by 2027, and sustainability reports have been published to monitor the progress toward this goal. However, since UC is one of the oldest universities in Europe (730 years old in 2020) and with a colossal patrimony, developing such reports is challenging. In 2020, the university comprised about 25,722 students and 3379 employees (including professors, researchers, and technical staff), distributed in three *campi* around the city. The management of 29,728 people (or users) is challenging. The oldest part of the university, Polo I, is located in the city centre and includes the Faculties of Law, Arts, and Humanities, and the Physics, Chemistry, Mathematics, and Architecture Departments. Polo II entails all other departments from the Faculty of Science and Technology (e.g., civil engineering, mechanical engineering, informatics engineering, electrical and computer engineering, chemical engineering, and others). The faculties of medicine and pharmacy are located in Polo III, and other departments are located in other parts of the city (e.g., the faculty of economics and the faculty of sports sciences and physical education). In addition, apart from the different departments and respective labs, the patrimony of UC comprehends different libraries, museums, canteens, residencies for students, sports facilities, and many other buildings for academic services. The historic area of UC, classified as a World Heritage Site by UNESCO, adds up to a total of 452.5 m^2 of facilities and 64,180 m^2 of built area.

The quantification of GHG emissions has been calculated according to the GHG Protocol, entailing Scopes 1 and 2. This quantification considers all *campi*, buildings, and infrastructures described before, and has been evaluated since 2020. According to the Sustainability Report 2020 [55], the quantification of GHG per FU is illustrated in Figure 6 for the different locations. The functional unit is normalized by the user, entailing students, professors, researchers, and all other employees.

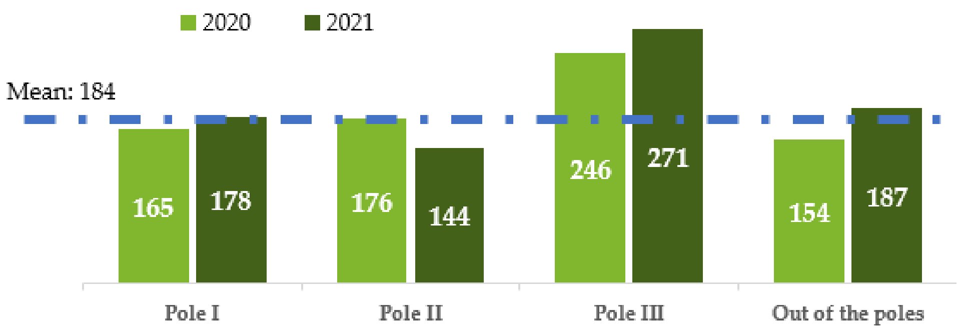

Figure 6. Carbon footprint, in $kgCO_2$,e per user [21].

Considering the results in Table 3 and comparing them with the values in Figure 6, it could lead to the conclusion that UC has a lower carbon intensity concerning other international HEI. However, these results may be explained by the lack of Scope 3 in UC calculations, which obviously would increase the values in Figure 6. Hence, any comparison made upon these values may lead to biased conclusions.

5.2. Carbon Performance of Other Portuguese HEI

Recently, a survey was carried out to monitor several aspects of sustainability in P-HEI [56]. When asked about governance, in about 29 answers, eight HEI indicated that they did not report sustainability. In most cases, it was indicated that the strategic plan of each university was connected to sustainability. Attempts are currently being made to create awareness and disseminate relevant information, indicating that HEI is starting to demonstrate attention to these concerns. However, it should be highlighted that most HEI do not have a dedicated budget for this subject, which could play a role in the absence of comprehensive and consistent sustainability strategies [56].

Taking into account the Portuguese HEI that are reporting carbon emissions, the respective carbon footprints are provided in Table 5. It is possible to observe that the UC value is much lower when compared to the University of Lisbon (UL). The main difference may be due to UL's consideration of Scope 3. Moreover, not only the values are referring to different periods, but also the considerable variation in campus facilities, location, and activities hinder the direct comparison of these values.

Table 5. P-HEI Carbon Footprint in the past decade (ton CO_2,e).

Ref.	P-HEI	Product System	Scope	Years												
Functional Unity: User·Year				2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
[57]	UL	*Campi*	1, 2 & 3								1.6	1.6	1.5			1.6
[58]	UMinho	*Campi*	1, 2 & 3	0.2	0.3	0.3	0.3	0.3	0.4							0.3
[59]	NOVA	*Campi*	1 & 2												0.2	0.2
[21]	UC	*Campi*	1 & 2										0.2	0.2	0.2	0.2

In general, most assessments revealed a lack of standard data, such as the system boundaries, the operating system, and even the functional units. The consideration of Scope 3 in the assessment by the University of Minho (UMinho) in 2015 shows the long path Portuguese HEI need to walk in this direction, enlarging the evaluation process and covering the majority of their activities.

It is worth mentioning that, in the Portuguese context, SAT are currently used to evaluate academic and community sustainability in HEI. The most common example is the *Times Higher Education Ranking*, used by the University of Coimbra.

However, this SAT does not consider a life cycle approach for environmental evaluation. In fact, like at the international level, the LCA topic in HEI management is underrated and not really explored. Currently, assessments and comparisons are based on international SAT, and there is no concern about revealing the environmental footprint of HEI, with all parameters and priorities that the international standards require.

6. Synthesis and Further Development

The literature review provided in this paper allowed identifying some highlights regarding the adoption of LCA by HEI. In most cases, HEI does not use LCA methods to evaluate their environmental impacts; among the reviewed works, only a few HEI considered LCA in the past decade.

Most HEI are reporting "sustainability" using several SAT tools, and the calculation of the CF seems to be the most popular indicator [14]. Nevertheless, the adoption of different data sources, scopes, and methods does not allow the establishment of robust benchmarks [60]. In addition, other impact categories, such as air emissions and noise, receive much less attention when discussing LCA on HEI. However, to become more sustainable, HEI must identify main hotspots that could later help the management of some crucial environmental factors, which may be achievable by applying LCA.

Implementing LCA should be seen as a collaborative effort amongst the numerous partners participating in HEI [15]. A socially conscious HEI considers stakeholder behaviour and perception to better understand their expectations and priorities, which are then used as an educational tool to improve ecological education.

Moreover, LCA provides a comprehensive and data-driven approach to monitoring, enabling HEI to track the environmental impact of their activities and supply chain. This may aid HEI to identify opportunities for improvement, to engage stakeholders, and to demonstrate accountability for internal and external reporting requirements. Overall, LCA is essential in helping HEI to achieve their sustainability goals, and to maintain a competitive edge in rapidly evolving management.

However, the implementation of LCA in the assessment of HEI is a challenging process, and some of the barriers to the adoption of LCA are summarized in Table 6.

Table 6. Main barriers to the adoption of LCA in HEI.

Barriers	
Data collection and management	LCA requires data from multiple sources and in different formats, making data collection and management a significant challenge; Ensuring the quality and accuracy of the data can be difficult and requires a significant effort.
Complex algorithms	The algorithms may be computationally intensive, especially for large datasets, and may require specialised knowledge to implement effectively
Time and resource constraints	Calculating the LCA for large datasets can be a time-consuming process and may require significant computational resources; It can pose a challenge for organisations with limited time and resources;
Data quality issues	The accuracy of the LCA depends on the quality of the data being used; Inaccurate data may result in incorrect results, undermining the tool's usefulness;
Privacy concerns	Privacy laws and regulations may restrict the use of personal information in the LCA calculation, making it challenging to implement in practice; Ensuring the privacy and security of sensitive data can be a significant challenge.
Integration with existing systems	Integrating the LCA into systems and processes is complex and requires some changes; It can pose a challenge for organisations with existing IT infrastructure and processes.
Lack of standardisation	There is no standardised procedure for applying LCA to HEI, leading to variability and inconsistent results across different assessments and preventing HEI from comparing their performances.

Data quality and availability are undoubtedly the main concerns in the LCA of HEI. In fact, one of the most critical aspects of conducting a reliable LCA in HEI is the availability of reliable databases with internal and external information. Combining complementary LCA methods is crucial to deal with the system's complexity. Considering economic and social criteria allows better management of resources, and fosters sustainability. Moreover, it is essential to improve data reliability. An accurate life cycle assessment of environmental loads, with appropriate scenarios and projections, is also essential to fight against greenwashing. In addition, to improve decision-making, optimisation processes and multi-criteria decision approaches, such as the Analytic Hierarchy Method, are required [20,25,46].

7. Conclusions

This study aimed to review the application of LCA in the assessment of the sustainability of HEI. It was possible to conclude that most HEI do not use LCA to calculate their environmental footprints, and the most common approach relies on assessing GHG emissions and carbon footprint.

The number of publications on LCA in HEI is growing steadily in the past decade, mostly from developed countries. In the studied database, Europe had 46% of scientific articles published.

Data quality and availability are undoubtedly the main concerns in the reviewed articles. In fact, one of the most critical aspects of conducting a reliable LCA in HEI is the availability of reliable databases with internal and external information. Moreover, it is crucial to understand the role of the HEI manager in overcoming these questions.

The most critical areas identified in the LCA of HEI are related to the energy consumption of buildings and other resources (e.g., potable water); however, these are relatively easy to quantify internally. On the other hand, the main difficulties in quantifying impacts are related to processes that have unclear boundaries, such as the mobility of students and staff, the provision of food, and other materials.

Since the emission of GHG was the main indicator addressed by most studies, an initial set of benchmarks was attempted to focus on this indicator and consider different functional units. For instance, the mean value of GHG emissions per student is about 2.75 tons of CO_2,e/student.year, but the interval of values is wide (0.25 to 4.90 CO_2,e/student·year). This wide variability is mainly due to the adoption of different scopes and assessment procedures.

Finally, a brief overview of the performance of Portuguese HEI was provided. In terms of GHG emissions, the values of Portuguese HEI are in line with international values. Overall, the values provided in this article may be used considering the approximations made in each study to avoid biased conclusions.

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References

1. Intergovernmental Panel on Climate Change. *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Shukla, P.R., Skea, J., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., et al., Eds.; Intergovernmental Panel on Climate Change: Geneva, Switzerland, 2022.
2. Steffen, W.; Broadgate, W.; Deutsch, L.; Gaffney, O.; Ludwig, C. The Trajectory of the Anthropocene: The Great Acceleration. *Anthr. Rev.* **2015**, *2*, 81–98. [CrossRef]
3. Almond, R.; Grooten, M.; Petersen, T. *WWF Living Planet Report 2020—Bending the Curve of Biodiversity Loss*; WWF: Gland, Switzerland, 2020.
4. Association of University Leaders for a Sustainable Future. The Talloires Declaration: 10 Point Action Plan. 1990. Available online: http://ulsf.org/wp-content/uploads/2015/06/TD.pdf (accessed on 30 December 2022).
5. Dodds, F.; Schneeberger, K.; Ullar, F.; Le Blanc, D. *Review of Implementation of Agenda 21 and the Rio Principles—Sustainable Development in the 21st Century Project*; United Nations Department of Economic and Social Affairs: New York, NY, USA, 2012.
6. Lozano, R.; Ceulemans, K.; Alonso-Almeida, M.; Huisingh, D.; Lozano, F.J.; Waas, T.; Lambrechts, W.; Lukman, R.; Hugé, J. A Review of Commitment and Implementation of Sustainable Development in Higher Education: Results from a Worldwide Survey. *J. Clean. Prod.* **2015**, *108*, 1–18. [CrossRef]
7. Tilbury, D. Higher Education for Sustainability: A Global Overview of Commitment and Progress. *High. Educ. Commit. Sustain. Underst. Action* **2011**, *4*, 18–28. [CrossRef]
8. Tauchen, J.; Brandli, L.L. A Gestão Ambiental Em Instituições de Ensino Superior: Modelo Para Implantacão Em Campus Universitário. *Gestão E Produção* **2006**, *13*, 503–515. [CrossRef]
9. Wuebbles, D.J.; Fahey, D.W.; Hibbard, K.A.; Dokken, D.J.; Stewart, B.C.; Maycock, T.K. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*; United States Global Change Research Program: Washington, DC, USA, 2018; Volume 1.
10. Remmen, A.; Jensen, A.A.; Frydendal, J. *Life Cycle Management—A Business Guide to Sustainability*; UNEP: Nairobi, The Republic of Kenya; SETAC: Pensacola, FL, USA; LCI: Baton Rouge, LA, USA, 2007; ISBN 9789280727722.
11. Jaglan, A.K.; Cheela, V.R.S.; Vinaik, M.; Dubey, B. Environmental Impact Evaluation of University Integrated Waste Management System in India Using Life Cycle Analysis. *Sustainability* **2022**, *14*, 8361. [CrossRef]
12. Ferreira, J.G.; de Matos, M.; Silva, H.; Franca, A.; Duarte, P. Sustainable Campus: The Experience of the University of Lisbon at Ist. *Sustainability* **2021**, *13*, 8050. [CrossRef]
13. Alaloul, W.S.; Altaf, M.; Musarat, M.A.; Javed, M.F.; Mosavi, A. Systematic Review of Life Cycle Assessment and Life Cycle Cost Analysis for Pavement and a Case Study. *Sustainability* **2021**, *13*, 4377. [CrossRef]
14. Findler, F.; Schönherr, N.; Lozano, R. Assessing the Impacts of Higher Education Institutions on Sustainable Development—An Analysis of Tools and Indicators. *Sustainability* **2018**, *11*, 59. [CrossRef]
15. Caeiro, S.; Ang, L.; Ham, S.; Martins, R.; Elizabeth, C.; Aldaz, B. Sustainability Assessment and Benchmarking in Higher Education Institutions—A Critical Reflection. *Sustainability* **2020**, *12*, 543. [CrossRef]
16. Valls-Val, K.; Bovea, M.D. Carbon Footprint in Higher Education Institutions: A Literature Review and Prospects for Future Research. *Clean Technol. Environ. Policy* **2021**, *23*, 2523–2542. [CrossRef]
17. *ISO 14040*; Environmental Management—Life Cycle Assessment—Principles and Framework. International Organization for Standardization: Geneva, Switzerland, 2006.
18. Van Eck, N.J.; Waltman, L. *Visualizing Bibliometric Networks*; Springer: Berlin/Heidelberg, Germany, 2014; ISBN 9783319103778.

19. Van Eck, N.J.; Waltman, L. Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping. *Scientometrics* **2010**, *84*, 523–538. [CrossRef]
20. Li, Z.; Chen, Z.; Yang, N.; Wei, K.; Ling, Z.; Liu, Q.; Chen, G.; Ye, B.H. Trends in Research on the Carbon Footprint of Higher Education: A Bibliometric Analysis (2010–2019). *J. Clean. Prod.* **2021**, *289*, 125642. [CrossRef]
21. Da Silva, P.P.; Rocha, F.; Gervásio, H.; Quina, M.; Deda, D. *Relatório de Sustentabilidade 2021*; Universidade de Coimbra: Coimbra, Portugal, 2021.
22. Clabeaux, R.; Carbajales-Dale, M.; Ladner, D.; Walker, T. Assessing the Carbon Footprint of a University Campus Using a Life Cycle Assessment Approach. *J. Clean. Prod.* **2020**, *273*, 122600. [CrossRef]
23. Xue, Z.; Liu, H.; Zhang, Q.; Wang, J.; Fan, J.; Zhou, X. The Impact Assessment of Campus Buildings Based on a Life Cycle Assessment-Life Cycle Cost Integrated Model. *Sustainability* **2020**, *12*, 294. [CrossRef]
24. Lo-Iacono-Ferreira, V.G.; Torregrosa-López, J.I.; Capuz-Rizo, S.F. Organizational Life Cycle Assessment: Suitability for Higher Education Institutions with Environmental Management Systems. *Int. J. Life Cycle Assess.* **2017**, *22*, 1928–1943. [CrossRef]
25. Lo-Iacono-Ferreira, V.G.; Torregrosa-López, J.I.; Capuz-Rizo, S.F. Use of Life Cycle Assessment Methodology in the Analysis of Ecological Footprint Assessment Results to Evaluate the Environmental Performance of Universities. *J. Clean. Prod.* **2016**, *133*, 43–53. [CrossRef]
26. Kumanayake, R.; Luo, H. Life Cycle Carbon Emission Assessment of a Multi-Purpose University Building: A Case Study of Sri Lanka. *Front. Eng. Manag.* **2018**, *5*, 381–393. [CrossRef]
27. Ingwersen, W.W.; Curran, M.A.; Gonzalez, M.A.; Hawkins, T.R. Using Screening Level Environmental Life Cycle Assessment to Aid Decision Making: A Case Study of a College Annual Report. *Int. J. Sustain. High. Educ.* **2012**, *13*, 6–18. [CrossRef]
28. Liu, H.; Wang, X.; Yang, J.; Zhou, X.; Liu, Y. The Ecological Footprint Evaluation of Low Carbon Campuses Based on Life Cycle Assessment: A Case Study of Tianjin, China. *J. Clean. Prod.* **2017**, *144*, 266–278. [CrossRef]
29. Horn, R.; Ebertshäuser, S.; Di Bari, R.; Jorgji, O.; Traunspurger, R.; von Both, P. The BIM2LCA Approach: An Industry Foundation Classes (IFC)-Based Interface to Integrate Life Cycle Assessment in Integral Planning. *Sustainability* **2020**, 6558. [CrossRef]
30. Gaidajis, G.; Angelakoglou, K.; Aktsoglou, D. Assessing the Global Warming Potential of a Typical University Office-Workstation Using Life Cycle Assessment. *Fresenius Environ. Bull.* **2012**, *21*, 2326–2330.
31. Leon, I.; Oregi, X.; Marieta, C. Environmental Assessment of Four Basque University Campuses Using the NEST Tool. *Sustain. Cities Soc.* **2018**, *42*, 396–406. [CrossRef]
32. Arias, A.; León, I.; Oregi, X.; Marieta, C. Environmental Assessment of University Campuses: The Case of the University of Navarra in Pamplona (Spain). *Sustainability* **2021**, *13*, 8588. [CrossRef]
33. Bueno, G.; de Blas, M.; Pérez-Iribarren, E.; Zuazo, I.; Torre-Pascual, E.; Erauskin, A.; Etxano, I.; Tamayo, U.; García, M.; Akizu-Gardoki, O.; et al. Dataset on the Environmental and Social Footprint of the University of the Basque Country UPV/EHU. *Data Br.* **2022**, *41*, 107847. [CrossRef]
34. Gamarra, A.R.; Herrera, I.; Lechón, Y. Assessing Sustainability Performance in the Educational Sector. A High School Case Study. *Sci. Total Environ.* **2019**, *692*, 465–478. [CrossRef]
35. Bueno, G.; de Blas, M.; Pérez-Iribarren, E.; Zuazo, I.; Torre-Pascual, E.; Erauskin, A.; Etxano, I.; Tamayo, U.; García, M.; Akizu-Gardoki, O.; et al. The Environmental and Social Footprint of the University of the Basque Country UPV/EHU. *J. Clean. Prod.* **2021**, *315*, 128019. [CrossRef]
36. Kubová, P.; Hájek, M.; Třebický, V. Carbon Footprint Measurement and Management: Case Study of the School Forest Enterprise. *BioResources* **2018**, *13*, 4521–4535. [CrossRef]
37. Silva, D.A.L.; Giusti, G.; Rampasso, I.S.; Junior, A.C.F.; Marins, M.A.S.; Anholon, R. The Environmental Impacts of Face-to-Face and Remote University Classes during the COVID-19 Pandemic. *Sustain. Prod. Consum.* **2021**, *27*, 1975–1988. [CrossRef]
38. Isildar, G.Y.; Morsali, S. Environmental Footprint Assessment of University Campuses among Developed and Developing Countries Including a Case from Turkey. *Fresenius Environ. Bull.* **2020**, *29*, 1114–1120.
39. Zhang, C.; Yang, X.; Yi, M.; Yang, Y.; Chen, Y. Assessing the Efficiency and Sustainability of Three Eco-Campus Systems in Northwestern China Using a Comprehensive Evaluation Framework. *Energy Rep.* **2022**, *8*, 187–204. [CrossRef]
40. Erauskin-Tolosa, A.; Bueno, G.; Etxano, I.; Tamayo, U.; García, M.; de Blas, M.; Pérez-Iribarren, E.; Zuazo, I.; Torre-Pascual, E.; Akizu-Gardoki, O. Social Organisational LCA for the Academic Activity of the University of the Basque Country UPV/EHU. *Int. J. Life Cycle Assess.* **2021**, *26*, 1648–1669. [CrossRef]
41. Helmers, E.; Chang, C.C.; Dauwels, J. Carbon Footprinting of Universities Worldwide Part II: First Quantification of Complete Embodied Impacts of Two Campuses in Germany and Singapore. *Sustainability* **2022**, *14*, 3865. [CrossRef]
42. Alghamdi, A.; Haider, H.; Hewage, K.; Sadiq, R. Inter-University Sustainability Benchmarking for Canadian Higher Education Institutions: Water, Energy, and Carbon Flows for Technical-Level Decision-Making. *Sustainability* **2019**, *11*, 2599. [CrossRef]
43. Liu, Q.; Wang, Z. Green BIM-Based Study on the Green Performance of University Buildings in Northern China. *Energy. Sustain. Soc.* **2022**, *12*, 12. [CrossRef]
44. Alvarez, S.; Blanquer, M.; Rubio, A. Carbon Footprint Using the Compound Method Based on Financial Accounts. the Case of the School of Forestry Engineering, Technical University of Madrid. *J. Clean. Prod.* **2014**, *66*, 224–232. [CrossRef]
45. Güereca, L.P.; Torres, N.; Noyola, A. Carbon Footprint as a Basis for a Cleaner Research Institute in Mexico. *J. Clean. Prod.* **2013**, *47*, 396–403. [CrossRef]

46. Kulkarni, S.D. A Bottom up Approach to Evaluate the Carbon Footprints of a Higher Educational Institute in India for Sustainable Existence. *J. Clean. Prod.* **2019**, *231*, 633–641. [CrossRef]
47. Alghamdi, A.; Hu, G.; Haider, H.; Hewage, K.; Sadiq, R. Benchmarking of Water, Energy, and Carbon Flows in Academic Buildings: A Fuzzy Clustering Approach. *Sustainability* **2020**, *12*, 4422. [CrossRef]
48. Helmers, E.; Chang, C.C.; Dauwels, J. Carbon Footprinting of Universities Worldwide: Part I—Objective Comparison by Standardized Metrics. *Environ. Sci. Eur.* **2021**, *33*, 30. [CrossRef]
49. El Geneidy, S.; Baumeister, S.; Govigli, V.M.; Orfanidou, T.; Wallius, V. The Carbon Footprint of a Knowledge Organization and Emission Scenarios for a Post-COVID-19 World. *Environ. Impact Assess. Rev.* **2021**, *91*, 106645. [CrossRef]
50. Larsen, H.N.; Pettersen, J.; Solli, C.; Hertwich, E.G. Investigating the Carbon Footprint of a University—The Case of NTNU. *J. Clean. Prod.* **2013**, *48*, 39–47. [CrossRef]
51. *ISO 14001*; Environmental Management Systems—Guidelines for a Flexible Approach to Phased Implementation. International Organization for Standardization: Geneva, Switzerland, 2019.
52. *ISO 14044*; Environmental Management—Life Cycle Assessment — Requirements and Guidelines. International Organization for Standardization: Geneva, Switzerland, 2006.
53. *ISO 14072*; Environmental Management—Life Cycle Assessment—Requirements and Guidelines for Organizational Life Cycle Assessment. International Organization for Standardization: Geneva, Switzerland, 2014.
54. Ranganathan, J.; Corbier, L.; Bhatia, P.; Schmitz, S.; Gage, P.; Oren, K. *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*; World Business Council for Sustainable Development: Geneva, Switzerland, 2012.
55. Da Silva, P.P.; Rocha, F.; Gervásio, H.; Quina, M.; Jorge, S.; Amaral, A.R.; Deda, D. *Relatório de Sustentabilidade 2020*; Universidade de Coimbra: Coimbra, Portugal, 2021.
56. Rede Campus Sustentável. *Primeiro Diagnóstico Sobre Implementação Da Sustentabilidade No Ensino Superior Em Portugal—Análise Dos Resultados de Um Inquérito*; Rede Campus Sustentável: Lisbon, Portugal, 2021; ISBN 9789893332474.
57. Living Laboratory for Sustainability Sustentabilidade No Campus @Ciências. Available online: https://ciencias.ulisboa.pt/pt/pegada-carbonica-campus-campo-grande (accessed on 15 February 2023).
58. Ramisio, P. Relatório de Sustentabilidade. Available online: https://www.uminho.pt/PT/uminho/Informacao-Institucional/RelatoriosSustentabilidade/RelatoriodeSustentablidade2015.pdf (accessed on 15 February 2023).
59. Universidade NOVA de Lisboa Organizational Sustainability. Available online: https://sustainability.unl.pt/focus_areas/organizational-sustainability/ (accessed on 15 February 2023).
60. Berzosa, A.; Bernaldo, M.O.; Fernández-Sanchez, G. Sustainability Assessment Tools for Higher Education: An Empirical Comparative Analysis. *J. Clean. Prod.* **2017**, *161*, 812–820. [CrossRef]