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Measuring and monitoring the transition to the circular economy of universities: CExUNV

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ABSTRACT

The circular economy (CE) has been identified as a critical strategy to contribute to sustainable development and the achievement of the Sustainable Development Goals of the 2030 Agenda, being one of the biggest challenges for society in general and organisations in particular. Hence, various methods have been developed in recent years to measure the level of circularity of organisations, such as methodologies, indicators, metrics and CE tools.

Universities, as education, research and community service organisations, play a key role in the promotion of and transition to the CE. Therefore, they require methods that enable them to quantify and monitor their level of circularity. However, it has been shown that CE methods developed for organisations are not suitable for such complex institutions, and, to date, no sector-specific methods have been developed.

In this context, it has become necessary to develop a useful method to quantify and monitor the current level of circularity, assess its progress and facilitate decision-making on circularity that addresses the specific needs of this type of organisation. Thus, a set of 82 CE indicators and their metrics, specific to universities, has been proposed. They have been implemented in an Excel spreadsheet tool called CExUNV, in order to promote and facilitate their use. In addition, 41 improvement actions have been suggested to guide and assist universities in their progress towards CE.

1. Introduction

In recent decades, the circular economy (CE) — an economic model that aims to reduce the amount of waste and minimise the extraction of raw materials by keeping products, components and materials in use for as long as possible — has gained global attention. The CE is considered vital for addressing current environmental, economic and social challenges and plays a key role in the achievement of the Sustainable Development Goals (SDGs) set by the 2030 Agenda (United Nations, 2015), as noted by Schroeder et al. (2019) and Serrano-Bedia and Perez-Perez (2022). Hence, at the European level, the New CE Action Plan (COM 98, 2020) has been positioned at the core of the European Green Deal (COM 640, 2019).

To implement the CE in our society effectively, its approach must be extended to the community level, which is crucial. In this regard, universities, renowned for their capacity to generate knowledge and technology, play a key role in shaping public awareness of the CE and influencing consumer behaviour, driving the CE transition from theory to reality (Nunes et al., 2018). Moreover, universities have a strong effect on future managers in industries and countries (Disterheft et al., 2012; Lozano García et al., 2006). In fact, SDG4 "Quality Education" (United Nations, 2015) recognises the importance of education in promoting sustainable development, the implementation of the CE and the transition towards a more environmentally friendly economy and society (Obrecht et al., 2022). Thus, it can be stated that universities play an essential role in promoting environmental education and raising awareness in society of the need to implement more circular economic models.

Nevertheless, to act as a driving force for change in society, universities themselves should set an example by implementing circular models in all their areas of influence, which involves more than just adopting practices on campus (Deda et al., 2022). This implies the integration of CE into the institutional culture. Accordingly, if universities want to implement circular approaches in all their areas of action, they require approaches that effectively assess their current degree of implementation of the CE and their transition towards more circular models. In this context, the purpose of the study is to determine how universities can measure their circularity.

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2. Background

To date, at the university level, indicators to assess environmental and sustainable performance have been proposed, considering the university approach and the specificities of these institutions. Some of the most recent ones are, among others, the UI GreenMetric (2022) ranking, which proposes a set of indicators to assess and rank universities worldwide according to their environmental commitment and performance; and the Impact ranking (THE, 2022), which proposes a set of qualitative indicators to assess universities against the United Nations' Sustainable Development Goals. Additionally, there is the diagnosis of environmental sustainability in Spanish universities (GESU, 2021), which is a questionnaire that includes a series of qualitative indicators to measure sustainability. Furthermore, some literature has focused on assessing the environmental performance of universities, such as Lo-Iacono-Ferreira et al. (2018), who proposed KPIs to analyse the environmental performance of universities; or Valls-Val and Bovea (2022), who designed a Carbon Footprint calculation tool for universities, among others. However, although some of them are linked to certain aspects of the CE and could be included in the measurement of circularity, they have not been specifically designed for that purpose. This could affect their ability to provide an accurate and meaningful assessment of the level of circularity.

Nevertheless, Qu et al. (2021) proposed a theoretical framework of university activities related to CE that could provide many benefits for promoting the transition to CE, but they did not propose indicators to measure this transition to CE. Moreover, Mendoza et al. (2020) advanced a CE decision support framework to help universities identify opportunities and develop an action plan for the implementation of a CE; yet they highlighted the need to define indicators to monitor circularity. Thus, the need to develop specific circular economy indicators for universities is stressed.

CE indicators have been developed for the three key levels of the CE: the micro level (organisations), the meso level (eco-industrial parks) and the macro level (city/regional/national) (Geng and Doberstein, 2008; Yuan et al., 2006). However, universities have a particular idiosyncrasy that complicates the direct implementation of such indicators. On the one hand, university campuses are commonly known as "small cities" due to their dense populations and diverse ranges of activities (Jakimiuk et al., 2023), but with an organisational character. On the other hand, their complex structure makes it difficult to identify their activities, products and services, in contrast with industrial or production organisations (Lo-Iacono-Ferreira et al., 2018).

At the macro level, CE is attracting particular interest, and, in recent years, several frameworks have emerged for monitoring the progress of the CE, using a set of territorial CE indicators. At the European level, the European Commission has set up a common CE monitoring framework (Eurostat, 2023), and national frameworks have also emerged, such as GREP (BMUB, 2016) in Germany, FBAN (PBL, 2018) in the Netherlands, EEEC (MITECO, 2020) in Spain and 11KI (SDES, 2021) in France, among others. Further, some CE frameworks have been developed at the international level, such as BS 8001 (BSI, 2017) in the United Kingdom, CHCEIS (NDCR, 2017) in China or FPSMS (Government of Japan, 2018) in Japan, among others. Nevertheless, these macro indicators are not suitable for measuring the level of circularity of universities, as they are designed considering the specific characteristics and challenges of regions. Universities have a more limited scope and scale, as well as a particular context and activities, so indicators need to be adapted or developed specifically for universities.

At the micro level, since there is no common and standardised framework of CE indicators for organisations, several authors have identified the need to adapt these macro-level indicators to the micro level. For example, Ibáñez-Forés et al. (2022) analysed the applicability and adaptability of indicators proposed by eight macro frameworks for organisations and proposed a set of 34 micro indicators, while Rincón-Moreno et al. (2021) analysed the adaptability of Eurostat indicators at the micro level and proposed a set of 14 indicators also for organisations, among others. Moreover, there has been a significant growth in the review of CE indicators at the micro level: De Oliveira et al. (2021) and De Pascale et al. (2021) identified 20 and 28 organisational CE indicators, respectively; Franco et al. (2021) and Kravchenko et al. (2019) identified 58 and 250 CE indicators, respectively, and associated them with circularity strategies; and Saidani et al. (2019) identified 20 sets of CE indicators and developed an Excel-based tool to facilitate the selection of appropriate indicators according to the specific user's needs and requirements, among others. These reviews highlight that, to date, a wide variety of CE indicators have been proposed, but they are heterogeneous. Furthermore, it can be noted that most CE indicators concentrate on material flows (Moraga et al., 2019; Vinante et al., 2021). Hence, they are mainly focused on production organisations and are often not applicable or adaptable to universities, since they need multidimensional indicators to measure CE in its totality, including their main areas and activities.

Apart from this, also at the micro level, CE tools have emerged, which are tools capable of measuring the level of CE implementation of organisations automatically and can be classified into quantitative and qualitative types, according to their measurement basis. Quantitative CE tools (CTI Tool, 2020; MCI, 2017; Vayona and Demetriou, 2020) mainly focus on inflows and outflows of organisations, and are thus not directly applicable to universities, as they have a productive focus. Meanwhile, qualitative CE tools (CAS2.0, 2021; CE-Diagnosis, 2017; CircularTRANS, 2020; Inedit, 2020; MATChE, 2021) include other aspects of circularity related to business management, shared use, symbiosis and some social aspects. However, Valls-Val et al. (2023c) analysed the adequacy of qualitative CE tools for universities, concluding that they do not consider the specific characteristics of universities and are therefore not valid for decision-making.

Against this background, the need to measure the level of circularity for universities is identified. Although sustainability and CE are interrelated, they do not have the same focus; they have different concepts and objectives, with a more specific focus on CE. Hence, the use of specific circularity indicators enables a more precise approach, a better understanding of progress and a more detailed evaluation of practices and policies related to the circular economy at the university. Nevertheless, to date there are no suitable indicators to measure the circularity of universities: macro indicators have a wider focus and scale than is necessary for universities; micro indicators are not suitable in terms of scale or operational structure; and no specific indicators have been identified. As a result, the lack of research on the development of circularity indicators in the university context is highlighted as a major research gap in this field.

Consequently, on the basis of the research gap identified, the aim of this study is to develop a set of indicators to measure the level of circularity of universities. These indicators consider the multidimensionality and principles of CE, the structural and organisational complexity of universities and the specificities and needs of these institutions. Moreover, these indicators are modelled in a CE tool, CEx-UNV, capable of capturing potentials for improvement, detecting incorporated improvements and thus increasing the circular performance in an efficient, focused and rapid manner.

3. Materials and methods

The methodological procedure adopted in this study was based on the four main stages shown in Fig. 1, including a case study.

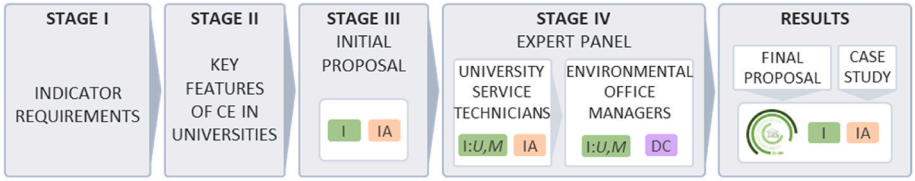

Fig. 1. Methodology.

3.1. Stage I. Setting indicator requirements

The aim of this stage was to establish the requirements for the definition of the CE indicators. The proposed indicators should measure the level of circularity objectively and, at the same time, consider the specificities and needs of each particular case. Thus, the following requirements were considered essential:

- A **set** of indicators rather than a single one, given the complexity involved in the CE.
- Indicators should cover the **6Rs** of the CE: Rethink, Refuse, Reduce, Reuse, Repair and Recycle (Dung and Hong, 2021).
- Indicators should be **suitable** for universities.
- Indicators should consider all the dimensions and **specific characteristics** of a university.
- Indicators should be applicable to **different organisational units**, i.e., the university as a whole or the university broken down into faculties, as these units have defined limits and can remain consistent throughout the assessment (Lo-Iacono-Ferreira et al., 2017).
- Indicators should preferably be **quantitative**, since, as Valls-Val et al. (2022) have already concluded, qualitative indicators are more subjective, and university environmental office managers prefer quantitative indicators that are more objective.
- Indicators should help any university to **identify areas of high improvement potential**, and thus increase the performance of the CE efficiently, precisely and rapidly.
- Indicators should be able to **monitor the evolution of circularity behaviour** by comparing results over different years.
- Indicators should be able to **detect innovations** related to the CE; i.e., they should be capable of detecting circularity-related strategies applied by universities.
- Their **units** should be **standardised** to facilitate the comparison of the circularity over time.
- Indicators should be **easy to calculate** in order to promote their use.

3.2. Stage II. Identifying the key features of CE in universities

The aim of this stage was to identify the specific characteristics (idiosyncrasies) and key aspects of circularity in universities, as one of the requirements of the indicators was to consider all dimensions of the CE in universities.

Universities are academic institutions of higher education and research that provide academic degrees in different disciplines, which differ in size, specialisation and focus. However, there are essential functions common to most university institutions, including education (teaching, academic degrees, etc.), research (research projects to generate new knowledge and solve problems), knowledge transfer (lectures, seminars, workshops and courses play an important role in the diffusion of knowledge and its practical application in society), administration and management (budget management, strategic planning, maintenance, etc.), as well as community services (volunteering, art exhibitions, concerts, sports facilities, etc.).

To identify the key aspects of circularity in universities, the websites and various documents such as the Environmental Statements or Sustainability Reports of the five Spanish universities best positioned in the UI GreenMetric (2022) were analysed. Moreover, interviews were conducted with environmental office managers of four Spanish universities in which information was requested on the circularity strategies currently being implemented or planned for the short or medium term. Additionally, the circularity strategies related to waste management analysed by Valls-Val et al. (2023b) and the circularity strategies related to public procurement analysed by the same authors (Valls-Val et al., 2023a) were also considered.

Following this review, it was noted that the meaning of CE for universities is aligned with the general objectives and principles of CE, but with a specific focus on the academic landscape and the impact that this type of institution can have on society and the environment. Circularity in universities implies a comprehensive commitment that integrates practices that minimise waste, maximise resource efficiency, promote education and awareness in terms of circularity, encourage innovation and research in areas related to CE, and generate collaborations to promote CE locally and globally. Hence, the most relevant areas for action in the circularity of universities are as follows. First, *research, teaching* and *awareness-raising*, which constitute the fundamental activities of universities, were highlighted, as well as *employment*, since universities generate significant employment, ranging from management or administration to teaching and research. Second, inputs (*purchases, energy and water*) and management of major assets (*furniture and computer equipment*) were highlighted, given that universities are large buyers, both in terms of the quantity and variety of goods and services they acquire (Thurston and Eckelman, 2011). Third, *transport* was identified, given the frequent daily commuting to and from campuses. Finally, outputs were identified, encompassing *waste management*, as universities are large waste generators and the adoption of sustainable waste management on university campuses has great potential for adoption by society at large (Gursoy Haksevenler et al., 2022), and their *environmental impact*, as they play an important role in sustainable development and the fight against climate change (Cordero et al., 2020).

3.3. Stage III. Initial proposal

A group of well-trained researchers conducted a comprehensive iterative process to propose the CE indicators. The initial proposal was made by considering the proven experience in CE application of the researchers, the aforementioned requirements (Stage I), the specific characteristics of circularity in universities (Stage II), the UI GreenMetric (2022) indicators and the review of organisational CE methods conducted in the background research. To this end, firstly, they carried out a brainstorming activity to identify indicators. Subsequently, through a series of collaborative work sessions, the proposal was repeatedly revised through multiple rounds of discussion, analysis and revision. During this process, the indicators were refined and improved, and the most appropriate units and metrics were proposed for each indicator. This process of constant improvement was repeated until a list of standardised, adaptable and comparable indicators was achieved.

Besides the list of indicators, the group of researchers also formulated a list of improvement actions to be applied in the areas where the university can improve its level of circularity. These actions were proposed on the basis of the previous knowledge acquired and the strategies identified in Stage I.

Finally, the proposed CE indicators were rechecked to determine if they were included in a broader indicator. If it was determined that an indicator was encompassed within a broader one, it was removed from the sample. For example, the indicator "toilets/showers with water-saving systems" was initially proposed, but this indicator was also reflected in the indicator "water consumption: m^3/user", and it was therefore decided to reassign it as an improvement action.

3.4. Stage IV. Expert panel

The initial proposal made in Stage III was checked by an expert panel composed of university managers at two different levels:

- **University service technicians.**

Verification of the suitability of indicators and their metrics and of the improvement actions. To this end, meetings were conducted with eight technicians from different services in the universities associated with the various key areas identified in Stage II, as they were the people who have the best information on each field/category. Specifically, the consultation was carried out with staff from the IT service, the technical office of works and projects, the research office, the procurement and tendering office, the environmental office and research groups related to sustainability and CE.

Individual, face-to-face meetings were conducted with each of the technicians, in which the initial proposal of indicators related to their expert field was shown to them and they were asked for feedback. In the interview, an evaluation template was used to assess the suitability of each indicator, including its description, unit and metrics. Also, a space for free comments was used to collect additional observations. Furthermore, the staff were asked whether they considered it necessary to include any indicator in the sample that had not been incorporated in the initial proposal.

Next, they were shown the initial proposed improvement actions and asked for feedback, as well as which actions they thought could be incorporated into the sample that had not been considered.

Finally, the research team adjusted the proposal based on the feedback from the service technicians. To this end, comments on the suitability of the indicators and additional comments were considered, reformulating those that were not optimal in accordance with the suggestions of the technicians. Also, new indicators or strategies proposed by the technicians were included. In this way, a second proposal was defined, which was consulted in the next stage with the environmental office managers.

- **Environmental office managers.**

These experts were asked to verify the suitability and the adequacy of the indicators, units and metrics proposed in the previous verification and to consider the difficulty in obtaining the data necessary to calculate them. For this purpose, a questionnaire was designed in the Qualtrics platform (Qualtrics, 2023), following the structure shown in Fig. 2 for each indicator (description, unit and metric). For each indicator, respondents had to answer the questions following the order and structure shown in Fig. 2.

The survey was sent by email to the 50 Spanish public universities, addressed to the manager of the environmental or sustainability office at each university, since they were responsible for the management of environmental issues and the integration of CE. Once a response rate of 10% (5 universities) was achieved, the results were analysed and a common pattern was observed. Hence, the results of the survey were analysed and modified based on the following criteria:

- Indicators that some universities indicated were "already being measured" were considered valid criteria.
- Indicators that no university was measuring yet were categorised based on the level of intensity of data collection required for their calculation. To obtain this level, a score was assigned to the survey responses: "Already measured" (5), "Easy" (4), "Medium" (3), "Difficult" (2) and "Not suitable" (1). Next, the average score for each indicator was calculated and, based on this score, they were classified into three categories:
  - o *Low level* (Indicators calculated with data that are easily accessible): Those that scored 4–5. No modifications were made to them.
  - o *Medium level* (Indicators calculated with currently available data but difficult to collect because they were not monitored): Those that scored 3. A series of recommendations for their measurement were proposed.
  - o *High level* (Indicators calculated with currently unrecorded data). Those that scored 1–2. For these cases, changes were made in their writing and/or unit and/or metric, some clarification was added where necessary and recommendations for their measurement were proposed.

4. Results

Following the methodology described in Fig. 1, the key areas of CE in universities were identified. Next, an initial proposal was developed, which included a total of 94 quantitative indicators (with their units and metrics) and 47 improvement actions. Then, after the first consultation, a proposal that included a total of 84 indicators with their units and metrics and 57 improvement actions was made. Finally, the final proposal (which is detailed below) was formulated.

4.1. Final proposal

4.1.1. Indicators

The final proposal of indicators along with their units and metrics was made based on the initial proposal (Stage III) and the expert panel consultation results (Stage IV). The proposal is presented in Table 1 and includes 82 indicators, grouped into the 12 areas identified in the review as the most representative of the CE in universities (research, teaching, employment, awareness, purchases, energy, water, furniture, IT equipment, transport, waste and environmental impact).

Some indicators, those directly related to circularity, were taken directly from the UI GreenMetric (2022). In order to facilitate the comparability of the indicators, the metrics of other indicators in the UI GreenMetric (2022) were adapted (marked with an A in the UI column of Table 1). The remaining indicators were proposed on the basis of the review of methods for measuring the level of circularity carried out in

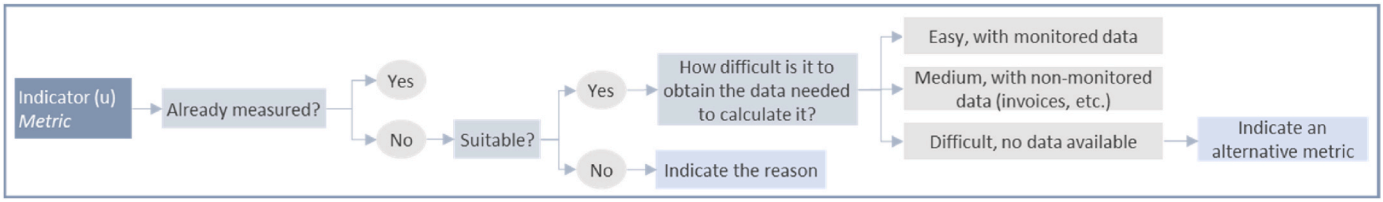

Fig. 2. Structure of the Qualtrics questionnaire.

Table 1
Proposed CE indicators for universities.

Category	Code	Indicator	Unit	Metrics	Trend[b]	UI[l]	6R[m]
Research	RC01	Funding obtained by CE-related projects	%	€ CE-related projects/€ total projects	+	A	R1
	RC02	Funding obtained by CE-related pre-/post-doctoral contracts	%	€ CE-related contracts/€ total contracts	+		R1
	RC03	CE-related papers published	%	No. of CE-related papers/No. of total papers	+		R1
	RC04	CE-related conference papers	%	No. of CE-related conferences/No. of total conferences	+		R1
	RC05	CE-related priority patents	%	No. of CE-related priority patents/No. of total priority patents	+		R1
	RC06	CE-related theses defended	%	No. of CE-related thesis defended/No. of total thesis defended	+		R1
	RC07	CE-related start-ups driven by the university[a]	%	No. of CE-related start-ups/No. of total start-ups financed	+		R1
Teaching	TC01	Degrees with competences in CE	%	No. of degrees with competences in CE/No. of total degrees	+		R1
	TC02	CE-related TFG and TFM defended	%	No. of CE-related TFG and TFM/No. of TFG and TFM defended	+		R1
	TC03	TFG/TFM/Thesis awards related to CE	No./user	No. of CE-related awards/No. of TFG/TFM/Thesis students	+		R1
	TC04	Events/workshops organised with CE criteria[a]	%	No. of events with EC criteria/No. of total events	+		R1
	TC05	CE extracurricular courses for students	Access ratio	No. of places offered/No. of students	+	A	R1
	TC06	CE training for Administrative and Services staff (AS staff)	No./user	No. of places offered/No. of AS staff	+	A	R1
	TC07	CE training for Teaching and Researching staff (TR staff)	No./user	No. of places offered/No. of TR staff	+	A	R1
Employment	EM01	Employment related to CE work	No.	No. of new CE-related jobs created	+		R5
	EM02	AS staff with CE training	%	No. of AS with CE training/No. of AS staff	+		R1
	EM03	TR staff with CE training	%	No. of TR with CE training/No. of TR staff	+		R1
Awareness	AW	CE awareness-raising actions[c]	No.	No. of actions in the year	+	A	R1
Purchases	PU01	Tenders including CE criteria	%	No. of tenders with CE criteria/No. of total tenders	+		R2
	PU02	Tender technicians with CE training	%	No. of tender technicians with CE training/No. of total tender technicians	+		R1
	PU03	Office supplies purchase[d]	€/user	€ in purchases of office supplies/No. of AS + TR staff	–		R3
	PU04	Paper purchase ratio	kg/user	Kg of paper purchased/No. of AS + TR staff	–		R3
	PU05	Paper print ratio	No./user	No. of paper prints/No. of AS + TR staff	–		R3
	PU06	Recycled paper ratio	%	kg. of recycled paper purchased/kg. of paper purchased	+		R6
Energy	EN01	Electricity consumption	kWh/user	total kWh (purchased + self-generated)/No. of people	–	S	R3
	EN02	Energy qualification of buildings	kWh/m^2	total kWh (electricity + natural gas)/m^2 built area	–		R3
	EN03	Self-production of electricity	%	kWh self-generated/total kWh (purchased + self-generated)	+	S	R6
	EN04	Self-production efficiency	kWh/m^2	kWh self-generated/m^2 used	+		R3
	EN05	Natural gas consumption	kWh/user	kWh consumed/No. of people	–		R3
	EN06	Building closures during holiday periods	%	(No. of total closure days +0.5 No. of partial closure days)/365	+		R3
	EN07	Buildings with IACS (Integrated Automation and Control System)	%	m^2 of buildings with CE IACS/m^2 built area	+	S	R1
Water	WA01	Water consumption[e]	m^3/user	m^3 consumed (purchased + reused)/No. of people	–		R3
	WA02	Reused water[e]	m^3	m^3 reused	+		R4
	WA03	Green areas designed with CE criteria[f]	%	m^2 designed with CE criteria/m^2 of green areas	+		R3
Furniture	FU01	Furniture purchase	No./user	No. of items of furniture purchased/No. of people	–		R3
	FU02	Circularity criteria in tender documents[g]	%	0.5 % mandatory CE-criteria +0.5 % weight of CA of CE-criteria	+		R2
	FU03	Furniture per employee	No./user	No. of items office furniture/No. of AS + TR staff	–		R3
	FU04	Repair of furniture[h]	%	No. of items repaired furniture/No. of repairable items of furniture	+		R5
	FU05	Valorisation of unusable furniture[i]	%	No. of items valorised furniture/No. of unusable items of furniture	+		R6
IT equipment	IT01	IT equipment purchase	No./user	No. of IT equipment items purchased/No. of people	–		R3
	IT02	Circularity criteria in tender documents[g]	%	0.5 % mandatory CE-criteria +0.5 % weight of CA of CE-criteria	+		R2
	IT03	Computers (fixed or laptop) per employee	No./user	No. of computers for employees/No. of AS + TR staff	–		R3
	IT04	Screenshots per employee	No./user	No. of screenshots for employees/No. of AS + TR staff	–		R3
	IT05	Laptop lending to employees[a]	No./user	No. of computers lendable to employees/No. of AS + TR staff	+		R1
	IT06	Printer sharing per employee	No./user	No. of printers for employees/No. of AS + TR staff	–		R3
	IT07	IT equipment in computer classrooms	No./user	No. of computers for students/No. of students	+		R1
	IT08	Laptop lending to students[a]	No./user	No. of computers lendable to students/No. of students	+		R1
	IT09	Period for renewal of IT equipment	year	Minimum years after which renewal can be requested	+		R5
	IT10	University maintenance of IT equipment	%	No. of computers with university maintenance/No. of computers	+		R5
	IT11	Repair of IT equipment[h]	%	No. of repaired items of IT equipment/No. of repairable items of IT equipment	+		R5
	IT12	Valorisation of obsolete IT equipment[i]	%	No. of valorised items of IT equipment/No. of obsolete items of IT equipment	+		R6

(*continued on next page*)

Table 1 (*continued*)

Category	Code	Indicator	Unit	Metrics	Trend[b]	UI[l]	6R[m]
Transport	TR01	Commuting in private vehicle	%	No. of people commuting in private vehicle/No. of people	–	S	R3
	TR02	Commuting by public transport	%	No. of people commuting by public transport/No. of people	+		R1
	TR03	Commuting by bicycle or on foot	%	No. of people commuting by bicycle or on foot/No. of people	+		R1
	TR04	Parking places for private vehicles	No./user	No. of parking places/No. of people	–		R3
	TR05	Car park surface	%	m^2 of park surface/m^2 total area	–	S	R3
	TR06	Electric vehicle charging stations[a]	%	No. of electric vehicle charging stations/No. of parking places	+		R1
	TR07	Self-renewable electric vehicle charging stations[a]	%	No. of self-renewable/No. of electric vehicle charging stations	+		R6
	TR08	Vehicle fleet	No./user	(No. of university vehicles +0,5 electric vehicles)/No. of AS + TR staff	–	A	R3
	TR09	Bicycle lending[a]	No./user	No. of lendable bicycles/No. of people	+		R1
	TR10	Bicycle parking	No./user	No. of bicycle parking places/No. of people	+		R1
	TR11	Cycle lane inside the university	%	m^2 of bike lane/m^2 total area	+		R1
	TR12	Financial assistance for public transport[a]	€/user	€ in public transport assistance/No. of students	+		R1
	TR13	Frequency of arrival of public transport on campus	min	Arrival time average for public transport	+	A	R1
	TR14	Public transport connectivity	%	No. of connected neighbourhoods/No. of total neighbourhoods	+	A	R1
	TR15	University's own car-sharing service[a]	%	No. of people using the service/No. of people in private vehicle	+		R1
	TR16	Telework[a]	%	Permitted teleworking hours per week/working hours per week	+		R3
Waste	WT01	Non-hazardous waste generation	kg/user	kg of non-hazardous waste generated/No. of people	–	A	R3
	WT02	Hazardous waste generation	kg/user	kg of hazardous waste/No. of people in areas with hazardous waste	–	A	R3
	WT03	Toner waste generation	No./user	No. of toner waste generated/No. of AS + TR staff	–		R3
	WT04	Paper recycling rate	kg/user	kg of paper recycled/No. of people	+		R6
	WT05	Packaging recycling rate	kg/user	kg of packaging recycled/No. of people	+		R6
	WT06	Glass recycling rate	kg/user	kg of glass recycled/No. of people	+		R6
	WT07	Food waste[a]	kg/user	kg of food waste generated/No. of people	–		R3
	WT08	On-site composting[a]	%	Kg of food waste composted on-site/kg of food waste generated	+		R6
	WT09	Recycling collection points[j]	No./m^2	No. of recycling collection points/m^2 built area	+		R6
	WT10	Separate collected fractions	No.	No. of separate collection fractions (paper, packaging, batteries, etc.)	+		R6
	WT11	Drinking water sources[a]	No./m^2	No. of water-drinking sources in the campus/m^2 built area	+		R3
	WT12	Second-hand goods exchange platform[k]	No.	No. of transactions/exchanges made in the year	+		R4
Environmental impact	EI01	Carbon Footprint (Scope 1 + 2)	tCO2eq/per.	Use the CO2UNV tool (Valls-Val and Bovea, 2022)	–		R3
	EI02	Carbon Footprint (Scope 3)	tCO2eq/per.	Use the CO2UNV tool (Valls-Val and Bovea, 2022)	–	S	R3
	EI03	Carbon Footprint offsetting (Scope 1 + 2)	%	Use the CO2UNV tool (Valls-Val and Bovea, 2022)	+		R1

People include students and AS and TR staff.

[a] If the service is not available, the value of the indicator is 0.

[b] Trend that the indicators should follow in their evolution to improve the CE: (+) indicates that the value should increase, (−) indicates that the value should decrease.

[c] Includes awareness-raising campaigns on various topics (waste, mobility, energy, etc.) in which the principles of circularity are integrated.

[d] Includes basic office supplies (pens, pencils, folders, correctors, etc.) purchased with university funds.

[e] Reused water includes rainwater, water from university reservoirs, recirculated grey water for sanitary purposes, water used for cleaning swimming pools, etc.

[f] Areas with circularity criteria are those in which native species are planted, gravel is used or any other element that enables the reduction of water consumption.

[g] Circularity criteria are those related to the use of reused and reusable material, repair, minimisation of materials, etc. (including Eurostat GPP criteria (European Commission, 2023)).

[h] Repairable means those items which are repairable because replacement components are available and by repairing them the functionality of the item is not lost.

[i] Unusable/obsolete means that they are not repairable or, after repair, do not meet the requirements to be used effectively in a university environment. Valorisation includes the donation to organisations that can make use of them or their management by recycling companies.

[j] Points are defined as the number of locations where separate collection containers are located. These points may include containers of different types of waste.

[k] A service that promotes the reuse of furniture, office material, etc. Users can bring items they do not use instead of discarding them, and other users can take advantage of them.

[l] Relationship between indicators and UI GreenMetric indicators: S (same indicator), A (adapted indicator).

[m] Relationship between indicators and the 6Rs: R1 (rethink), R2 (refuse), R3 (reduce), R4 (reuse), R5 (repair), R6 (recycle).

the background research. Further, observe that the 6Rs were also considered, as indicated in the last column of Table 1.

It should be noted that all indicators were defined to be calculated with annual data, in such a way that if they are calculated for different years, universities can monitor the evolution of their level of circularity over time and analyse the effects of the implementation of improvement actions. Thus, CExUNV enables the analysis of the evolution of CE through a comparison of the results of indicators over different years. This comparative approach provides a detailed and comprehensive overview of CE progress, identifying areas where significant

improvements have taken place and areas that require further attention for improvement.

Regarding the units for each indicator, a standardisation process was applied in order to establish a common basis for measurement and to obtain values that could be evaluated and compared in different situations. Wherever possible, the percentage unit (%) was used. Where this was not possible, functional units were used; i.e., the total value was divided by the functional united affected. For example, for indicators related to teaching, the equivalent number of students was used (defined as a full-time student by Lo-Iacono-Ferreira et al. (2017)); for indicators related to consumption, the number of people was used (full-time students + Administration and Services staff + Teaching and Research staff), among others.

The indicators were implemented in an Excel spreadsheet, the CExUNV, in which all the indicators were calculated using the data entered by the user in the activity data spreadsheet (which can be found in Fig. S2 of the Supplementary Material). If the indicators are calculated for several years, their evolution is shown on a colour scale: green, when an indicator improves its value; yellow, when it remains equal; red, when its value worsens; and grey, when it has not been calculated, as shown in Fig. 3.

In addition, it should be noted that, since universities are large and complex organisations, the process of collecting information is time-consuming and constitutes one of the biggest obstacles to measuring circularity. Thus, for indicators with medium and high levels of data collection, a set of recommendations have been proposed in order to simplify the data collection process (which have been incorporated as comments in the activity data sheet and are shown in Table S1 of the Supplementary Material). As can be seen, most of these recommendations focused on the implementation of an effective and efficient Data Management System.

Finally, in order to use the proposal accurately and to ensure their proper application, the following guidelines should be taken into account:

- In terms of indicator metrics, the difference between CE-related and total items consists of their contribution or connection to the principles of the CE in the university context. CE-related items include those that are aligned with the principles of minimising waste, maximising resource efficiency, promoting education and awareness of circularity, encouraging innovation and research in areas related to the CE, as well as generating collaborations to promote the CE locally and globally.
- Regarding the scope, include in the evaluation everything that depends directly on the management of the university (operational control), and exclude everything over which the university has no control. For example, the purchase of materials made by employees as part of their research projects and not included in the university's tenders should be excluded.
- Whenever possible, it is advisable to carry out the evaluation disaggregated by functional units (faculties) rather than for the university as a whole, since this makes it easier to identify areas and actions for improvement.
- Regarding the data, whenever possible, they should be primary data with material units (kg, kW, etc.) and compiled from monitored and reliable sources. When not possible, data from secondary sources can be used. If the data cannot be obtained, please indicate this using the following acronyms:
  - **DIC (Data Inadequately Collected)**: data that were being collected, but not in the appropriate form to be able to calculate the proposed indicator. This may be due to limitations on how the data were collected or insufficient quality of the information to differentiate between CE-related and non-CE-related items (highlighted in blue in the Excel spreadsheet).
  - **NCD (Not Collected Data)**: data that were not being collected in any way, and are thus not available in the information system (highlighted in grey in the Excel spreadsheet).
- The indicators were designed to monitor the circularity of the university itself. In the case of a comparison with other universities, both universities must have similar characteristics, mainly in terms of areas of knowledge.

4.1.2. Improvement actions

The proposal of improvement actions was made based on the strategies identified in Stage II and their subsequent improvement in Stage IV. This is presented in Table 2 and consists of a set of 41 measures grouped into the 12 areas of circularity defined previously.

4.2. Case study

The set of indicators proposed to measure the level of circularity in universities was applied to a Spanish public university, in order to test them. The case study is a public university with approximately 15,000 students and 2500 staff, offering teaching in areas such as natural sciences, social sciences, legal sciences, humanities, health sciences and engineering and technology. The indicators were calculated for the years 2017 and 2022, in order to observe the evolution over a 5-year horizon.

Firstly, the data needed to calculate the indicators reported in Table 1 were collected, requesting the information from managers and technicians from different services, departments and offices in the university. These data were introduced into the CExUNV tool (as shown in Fig. S1 and Fig. S2 of the Supplementary Material). As a result, the report spreadsheet shown in Fig. 3 was obtained, including the indicators described in Table 1. The report shows the indicators classified by areas. For each indicator the value for the two years of analysis is shown, as well as their evolution (last column) indicated by a colour scale (green, indicators that have improved; yellow, indicators that have remained; red, indicators that have worsened; blue or grey, indicators that have not been possible to calculate). In addition, the last column indicates whether the data has been obtained with public data (*P*) or has been estimated (*E*) using the data listed in Table S2 of the supplementary material, or if the indicator is 0 because the service is not available (*NA*).

As shown Figs. 3 and 75% of the proposed indicators can currently be measured. In the case of these indicators, 55% have improved, 25% have worsened, and 20% have remained the same when comparing results for 2017 with those of 2022. The areas that improved most are environmental impact followed by purchases and waste. In contrast, a negative trend was observed in terms of energy and IT equipment. So, future improvement actions should be focused on these two areas.

Regarding the 25% of indicators that could not be measured, due to the current lack of effective data management systems, they are mainly focused on research, teaching, employment, awareness and furniture, which pertain (except furniture) to areas where there is no material flow. For these indicators a set of recommendations for data collection were proposed (see Table 3). As can be seen, most of them are related to an efficient data management system and annual surveys. This is because the process of collecting information was a time-consuming task, as the university's systems were not prepared for it. Moreover, the data collected had to be submitted to a refinement process to adapt them to the format and units required. Hence, a proper centralisation and monitoring of data in an organisation as complex as a university is essential.

In summary, in the context of the case study, it was not possible to determine a uniform trend in terms of the evolution of their circularity, as it varied according to the category of the analysis, showing both improvement and worsening. The analyses of the evolution of the CE, nevertheless, enables the university to identify areas that require special attention.

Thus, it can be concluded that the proposal is useful to measure the

UNIVERSITY CIRCULARITY REPORT

RESEARCH

		2017	2022	EV
RC01	Funding obtained by CE-related projects	DIC	DIC	
RC02	Funding by CE-related pre/post doctoral contracts	DIC	DIC	
RC03	CE-related papers published	0.00%	1.21%	E
RC04	CE-related conference papers	0.00%	14.04%	E
RC05	CE-related priority patents	DIC	DIC	
RC06	CE-related theses defended	0.56%	4.67%	E
RC07	CE-related start-ups driven by the university	DIC	DIC	

TEACHING

		2017	2022	EV
TC01	Degrees with competences in CE	DIC	DIC	
TC02	CE-related TFG and TFM defended	0.67%	1.47%	E
TC03	TFG/TFM/Thesis awards related to CE	DIC	DIC	
TC04	Events organised with CE criteria	NCD	NCD	
TC05	CE extracurricular courses for students	DIC	DIC	
TC06	CE training for AS staff	0.047	0.070	
TC07	CE training for TR staff	0.015	0.006	

EMPLOYMENT

		2017	2022	EV
EM01	Employment related to CE work	NCD	NCD	
EM02	AS staff with CE training	DIC	DIC	
EM03	TR staff with CE training	DIC	DIC	

AWARENESS

		2017	2022	
AW	CE awareness-raising actions	DIC	DIC	

ENERGY

		2017	2022	EV
EN01	Electricity consumption	907.80	917.26	
EN02	Energy qualification of buildings	83.53	82.95	
EN03	Self-production of electricity	1.08%	4.88%	
EN04	Self-production efficiency	270.50	182.55	
EN05	Natural gas consumption	255.88	281.30	
EN06	Building closures during holiday periods	33.29%	32.60%	
EN07	Buildings with IACS	100.0%	100.0%	

PUIRCHASES

		2017	2022	EV
PU01	Tenders including CE criteria	DIC	DIC	
PU02	Tender technicians with CE training	DIC	DIC	
PU03	Office supplies purchase	11.38	5.27	
PU04	Paper purchase ratio	7.39	5.63	
PU05	Paper print ratio	DIC	14.0981	
PU06	Recycled paper ratio	26.15%	30.59%	

IT EQUIPMENT

		2017	2022	EV
IT01	IT equipment purchase	0.78	1.24	
IT02	Circularity criteria in tender documents	DIC	DIC	
IT03	Computers (fixed or laptop) per employee	3.35	3.67	
IT04	Screenshots per employee	1.66	2.03	
IT05	Laptop lending to employees	0	0	NA
IT06	Printer sharing per employee	0.77	0.81	
IT07	IT equipment in computer classrooms	0.26	0.32	
IT08	Laptop lending to students	0.0061	0.0015	
IT09	Period for renewal of IT equipment	7	7	
IT10	University maintenance of IT equipment	59.20%	41.23%	
IT11	Repair of IT equipment	DIC	DIC	
IT12	Valorisation of obsolete IT equipment	100%	100%	E

WATER

		2017	2022	EV
WA01	Water consumption	3.08	3.50	
WA02	Reused water	0.00	354.43	
WA03	Green areas designed with CE criteria	DIC	DIC	

FURNITURE

		2017	2022	EV
FU01	Furniture purchase	2.45	2.21	
FU02	Circularity criteria in tender documents	DIC	DIC	
FU03	Furniture per employee	DIC	DIC	
FU04	Repair of furniture	DIC	DIC	
FU05	Valorisation of unusable furniture	100.00	100.00	E

TRANSPORT

		2017	2022	EV
TR01	Commuting in private vehicle	37.22%	NCD	
TR02	Commuting in public transport	41.13%	NCD	
TR03	Commuting by bicycle or on foot	21.66%	NCD	
TR04	Parking places for private vehicles	0.251	0.247	
TR05	Car park surface	7.92%	7.92%	E
TR06	Electric vehicle charging stations	2	14	
TR07	Self-renewable electric vehicles charging stations	0	0	
TR08	Vehicle fleet	0.0018	0.0010	
TR09	Bicycle lending	0.004	0.008	
TR10	Bicycle parking	DIC	DIC	
TR11	Cycle lane inside the university	0.67%	0.67%	
TR12	Financial assistance for public transport	0	0	NA
TR13	Frequency of arrival of public transport on campus	30	30	
TR14	Public transport connectivity	100.0%	100.0%	
TR15	University's own car-sharing service	NCD	0	
TR16	Telework	0%	40%	

WASTE

		2017	2022	EV
WT01	Non-hazardous waste generation	0.134	0.038	P
WT02	Hazardous waste generation	5.662	2.627	P
WT03	Toner waste generation	0.895	0.233	P
WT04	Paper recycling rate	2.399	2.463	P
WT05	Packaging recycling rate	0.782	1.048	P
WT06	Glass recycling rate	0.201	0.166	P
WT07	Food waste	NCD	NCD	
WT08	On-site composting	0	0	
WT09	Recycling collection points	264	292	P
WT10	Separate collected fractions	10	10	P
WT11	Drinking water sources	37	69	
WT12	Second-hand goods exchange platform	0	0	NA

ENVIRONMENTAL IMPACT

		2017	2022	EV
EI01	Carbon Footprint (Scope 1+2)	0.473	0.057	
EI02	Carbon Footprint (Scope 3)	0.217	0.209	
EI03	Carbon Footprint offsetting (Scope 1+2)	0.12%	1.51%	

Fig. 3. Report of the case study.

Table 2
Proposed circularity actions for universities.

Category	Proposed action
Research	- Provide central laboratory services (shared equipment). - Develop a guide of recommendations/protocol in the laboratory considering the principles of the CE.
Teaching	- Offer CE training courses. - Promote the integration of CE principles in degree programmes.
Employment	- Increase repair and maintenance work, thereby increasing jobs.
Awareness	- Create a unit, office or service of a technical-administrative nature that is specifically dedicated to CE issues. - Setting measurable CE targets. - Create repair spaces in the campus (repair cafés).
Purchases	- Establish centralised purchasing. - Develop a procurement guide or protocols that include CE principles. - Use multi-post envelopes to reduce paper consumption. - Develop a paper purchasing guide.
Energy	- Integrate the energy in the IACS (Integrated Automation and Control System) system in the buildings. - Integrate a centralised air-conditioning management system. - Integrate a centralised indoor lighting management system. - Consider actions to reduce electricity consumption (energy-saving lamps, presence detectors, reduce sockets on workbenches, dimming/adjustment of light intensity, separate window lighting line, etc.). - Energy improvement actions (Window insulation, more efficient boilers, improved building envelopes, etc.).
Water	- Integrate the water in the IACS (Integrated Automation and Control System) system in the buildings. - Integrate an irrigation management system. - Sinks/showers with water-saving systems (push buttons, detectors, valves to reduce the flow, etc.). - Reuse of grey water (sinks) for toilets. - Toilet tanks with water-saving systems (dual flush, efficient urinal flushes, etc.). - Teaching and research laboratories with water-saving systems (recirculation, energy-saving dishwashers, etc.).
Furniture	- Standardisation and centralisation of furniture to facilitate maintenance. - Generate a proper inventory (updated and digitised). - Use traceable labels to know the location of each element.
IT equipment	- Standardisation and centralisation of IT equipment to facilitate maintenance. - Generate a proper inventory (updated and digitised). - Use traceable labels to know the location of each item of equipment. - Implement the remote classroom (enables reduction of computers in study rooms). - Offer laptop lending service for employees and students.
Transport	- Actions to reduce the use of private vehicles (VAO spaces, reduction of parking spaces, etc.). - Offer bicycle support services (repair facilities, inflators, etc.). - Agreement with public transport companies. - Develop an annual commuting survey. - Monitor the work trips (distance, means of transport, etc.). - Reducing commuting (enabling teleworking, grouping teaching into four days, etc.).
Waste	- Quantify and characterise waste. - Increase selective collection fractions (medicines, oils, etc.) and points or containers. - Provide information on clean/green/recycling points.
Environmental impact	- Finance reforestation projects annually.

Table 3
Recommendations for data collection.

Category	Code	Recommendation to obtain the required data
Research	RC01 RC02 RC05 RC07	Register the *item** in the DMS, indicating in a checkbox whether they are linked to any SDG or CE principle (sustainable consumption, waste management, secondary raw materials, water reuse or circular business models). * *Item*: research projects for RC01, pre-post contracts for RC02, patents for RC05, start-ups driven by the university for RC07
Teaching	TC01	Distribute a survey to the heads of each degree programme, asking them about the relationship with any SDG or CE principle. Subsequently, new degree programmes should indicate this relationship. Register this information in the DMS.
	TC03	Register the awards in the DMS, detailing the criteria and requirements for obtaining them. Then, carry out an analysis of the requirements.
	TC04	Incorporate the events in the DMS, detailing the criteria and bases used for their realisation. Subsequently, carry out an analysis of these criteria to determine whether they include aspects related to circularity, such as the use of reusable stands or the consideration of non-material souvenirs, among others.
	TC05	Enter the courses offered for students in the DMS, detailing the subject, date and places offered. Subsequently, filter the courses by subject.
Employment	EM01	Conduct an annual survey with the head of each department or service, asking if the number of jobs has increased due to work related to CE: repair, waste reduction, etc. These answers will be stored in the DMS.
	EM02 EM03	Conduct an annual survey with staff* on the courses taken during the year and stored them in the DMS. * AS staff for EM02, and TR staff for EM03
Awareness	AW	Enter the awareness conferences/actions in the DMS, indicating the date, subject and people attending. Then, filter them by subject.
Purchases	PU01	Register the tenders in the DMS, linking the corresponding tender documents and breaking down the criteria by category (technical, economic, sustainability, etc.). The study by Valls-Val et al. (2023a) can be taken as an example.
	PU02	Conduct an annual survey with technicians that carry out tenders on sustainable/circular public procurement courses taken during the year and stored the responses in the DMS.
Water	WA03	Introduce a plan of the green areas in the DMS, indicating the type of species planted.
Furniture	FU02	Same as *PU01*.
	FU03	Register all furniture in the DMS, indicating type, location and assignment. Update annually the location and status of equipment, and use traceable tags to show the current location of each item. This database should enable the average number of items of furniture per employee to be extracted.
	FU04	Incorporate the furniture store in the DMS, registering incoming and outgoing furniture, as well as repairs carried out.
IT equipment	IT02	Same as *PU01*.
Transport	TR10	Register in the DMS a dynamic campus map showing the different parking places by type (car, high occupancy vehicle, bicycle or electric scooter).
Waste	WT07	Weigh the organic matter container daily and enter it into the DMS.

level of circularity of universities, and the analysis of annual evolution helps to identify priority areas for improvement.

5. Conclusion

Given the proven importance of universities in leading the transition towards the CE and the lack of approaches to measure their level of circularity, it was considered necessary to design CE indicators for universities. To this end, a set of 82 CE indicators with their corresponding units and metrics has been proposed and modelled in the CExUNV. The indicators proposed, in contrast to other indicators and CE tools, are all quantitative and consider the key features and characteristics of the universities. The CExUNVl also enables the analysis of the evolution of circularity over time and suggest a number of improvement actions. Hence, it can be concluded that the proposal is a useful approach to identify hotspots from a CE perspective and to analyse the effect that improvement actions have on CE.

To verify the proposal, a case study has been used, and the results have shown that the proposal is suitable for universities, can be adapted to any case study and the evolution analysis can help them to identify priority areas for improvement actions. Furthermore, it should be noted that the process of collecting information was a time-consuming task, which highlights the importance of establishing effective monitoring and data management systems in universities.

With regard to future developments, the proposal could be developed into an open-source online version with a friendly interface, which would be capable of storing data for various years, and simulate different improvement actions, thereby facilitating the evaluation. Finally, it would be interesting to export the results in a report in pdf format.

CRediT authorship contribution statement

Karen Valls-Val: Writing – original draft, Resources, Methodology, Investigation, Conceptualization. **Valeria Ibáñez-Forés:** Writing – review & editing, Methodology, Investigation, Conceptualization. **María D. Bovea:** Writing – review & editing, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

BMUB, 2016. German Resource Efficiency Programme (ProgRess) 124.
BSI, 2017. Framework for implementing the principles of the circular economy in organizations. Br. Stantards Inst.
CAS2.0, 2021. Circularity Assessment Score 2.0. Circular Business Academy [WWW Document]. URL. https://www.circularbusiness.academy/circularity-assessment-score/.
CE-Diagnosis, 2017. Circular Economy Diagnostic Questionnaire. TECNUN. Escuela de Ingeniería. Universidad de Navarra [WWW Document]. URL. https://economiacircular.wixsite.com/economiacircular/cuestionario.
CircularTRANS, 2020. Mondragón University [WWW Document]. URL https://www.mondragon.edu/circulartrans.
COM 640, 2019. The European Green Deal. Communication from the Commission to the European Parliament. the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions.
COM 98, 2020. A new circular economy action plan for a cleaner and more competitive Europe. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions.
Cordero, E.C., Centeno, D., Todd, A.M., 2020. The role of climate change education on individual lifetime carbon emissions. PLoS One 15 (2), 1–23. https://doi.org/10.1371/journal.pone.0206266.
CTI Tool, 2020. WBSCD Circular-IQ [WWW Document]. URL. https://ctitool.com/.
de Oliveira, C.T., Dantas, T.E.T., Soares, S.R., 2021. Nano and micro level circular economy indicators: Assisting decision-makers in circularity assessments. Sustain. Prod. Consum. 26, 455–468. https://doi.org/10.1016/j.spc.2020.11.024.
De Pascale, A., Arbolino, R., Szopik-Depczyńska, K., Limosani, M., Ioppolo, G., 2021. A systematic review for measuring circular economy: the 61 indicators. J. Clean. Prod. 281 https://doi.org/10.1016/j.jclepro.2020.124942.
Deda, D., Barros, M.V., Rigueiro, C., Ribau Teixeira, M., 2022. From linear to circular ideas: an educational contest. Sustain. Times 14, 11207. https://doi.org/10.3390/su141811207.
Disterheft, A., Ferreira Da Silva Caeiro, S.S., Ramos, M.R., De Miranda Azeiteiro, U.M., 2012. Environmental Management Systems (EMS) implementation processes and practices in European higher education institutions - Top-down versus participatory approaches. J. Clean. Prod. 31, 80–90. https://doi.org/10.1016/j.jclepro.2012.02.034.
Dung, N.T.P., Hong, T.H., 2021. Circular economy policies of some Asian countries and recommendations for Vietnam. In: Proc. Int. Conf. Emerg. Challenges Bus. Transform. Circ. Econ. (ICECH 2021), vol. 196, pp. 486–494. https://doi.org/10.2991/aebmr.k.211119.045.
European Commission, 2023. EU GPP Criteria [WWW Document]. URL. https://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm.
Eurostat, 2023. Circular Economy, Monitoring Framework. European Comission [WWW Document]. URL. https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework.
Franco, N.G., Almeida, M.F.L., Calili, R.F., 2021. A strategic measurement framework to monitor and evaluate circularity performance in organizations from a transition perspective. Sustain. Prod. Consum. 27, 1165–1182. https://doi.org/10.1016/j.spc.2021.02.017.
Geng, Y., Doberstein, B., 2008. Developing the circular economy in China: challenges and opportunities for achieving "leapfrog development.". Int. J. Sustain. Dev. World Ecol. 15, 231–239. https://doi.org/10.3843/SusDev.15.3:6.
GESU, 2021. Diagnosis of Environmental Sustainability in Spanish Universities: 2021 Report. CRUE-Sustainability-GESU.
Government of Japan, 2018. Fundamental Plan for Establishing a Sound. Material-Cycle Society.
Gursoy Haksevenler, B.H., Kavak, F.F., Akpinar, A., 2022. Separate waste collection in higher education institutions with its technical and social aspects: a case study for a university campus. J. Clean. Prod. 367, 133022 https://doi.org/10.1016/j.jclepro.2022.133022.
Ibáñez-Forés, V., Martínez-Sánchez, V., Valls-Val, K., Bovea, M.D., 2022. Sustainability reports as a tool for measuring and monitoring the transition towards the circular economy of organisations: proposal of indicators and metrics. J. Environ. Manag. 320, 115784 https://doi.org/10.1016/j.jenvman.2022.115784.
Inedit, 2020. Self-assess. Inedit Innova [WWW Document]. URL. https://circular.ineditinnova.com/index/es.
Jakimiuk, A., Matsui, Y., Podlasek, A., Koda, E., Goli, V.S.N.S., Voběrková, S., Singh, D. N., Vaverková, M.D., 2023. Closing the loop: a case study on pathways for promoting sustainable waste management on university campuses. Sci. Total Environ. 892, 164349 https://doi.org/10.1016/j.scitotenv.2023.164349.
Kravchenko, M., Pigosso, D.C., McAloone, T.C., 2019. Towards the ex-ante sustainability screening of circular economy initiatives in manufacturing companies: consolidation of leading sustainability-related performance indicators. J. Clean. Prod. 241, 118318 https://doi.org/10.1016/j.jclepro.2019.118318.
Lo-Iacono-Ferreira, V.G., Capuz-Rizo, S.F., Torregrosa-López, J.I., 2018. Key Performance Indicators to optimize the environmental performance of Higher Education Institutions with environmental management system – a case study of Universitat Politècnica de València. J. Clean. Prod. 178, 846–865. https://doi.org/10.1016/j.jclepro.2017.12.184.
Lo-Iacono-Ferreira, V.G., Torregrosa-López, J.I., Capuz-Rizo, S.F., 2017. Organizational life cycle assessment: suitability for higher education institutions with environmental management systems. Int. J. Life Cycle Assess. 22, 1928–1943. https://doi.org/10.1007/s11367-017-1289-8.
Lozano García, F.J., Kevany, K., Huisingh, D., 2006. Sustainability in higher education: what is happening? J. Clean. Prod. 14, 757–760. https://doi.org/10.1016/j.jclepro.2005.12.006.
MATChE, 2021. Making the Transition to Circular Economy. Technical University of Denmark [WWW Document]. URL. https://www.matche.dk/.
MCI, 2017. Material Circularity Indicator. Ellen MacArthur Foundation [WWW Document]. URL. https://www.ellenmacarthurfoundation.org/resources/apply/material-circularity-indicator.
Mendoza, J.M.F., Gallego-schmid, A., Azapagic, A., 2020. Implementation of a circular economy at universities. In: Handbook of the Circular Economy, pp. 439–451.
MITECO, 2020. España Circular 2030. Estrategia Española de Economía Circular.
Moraga, G., Huysveld, S., Mathieux, F., Blengini, G.A., Alaerts, L., Van Acker, K., de Meester, S., Dewulf, J., 2019. Circular economy indicators: what do they measure? Resour. Conserv. Recycl. 146, 452–461. https://doi.org/10.1016/j.resconrec.2019.03.045.
NDCR, 2017. Chinese Circular Economy Development Evaluation Indicator System [WWW Document]. URL. https://ec.europa.eu/newsroom/env/items/618580/en.
Nunes, B.T., Pollard, S.J.T., Burgess, P.J., Ellis, G., de los Rios, I.C., Charnley, F., 2018. University contributions to the circular economy: professing the hidden curriculum. Sustain. Times 10. https://doi.org/10.3390/su10082719.
Obrecht, M., Feodorova, Z., Rosi, M., 2022. Assessment of environmental sustainability integration into higher education for future experts and leaders. J. Environ. Manag. 316, 115223 https://doi.org/10.1016/j.jenvman.2022.115223.
PBL, 2018. Circular economy: what we want to know and can measure. Framework and baseline assessment for monitoring the progress of the circular economy in the Netherlands. , PBL Policy Report. PBL Publication Number: 3217.

Qu, D., Shevchenko, T., Saidani, M., Xia, Y., Ladyka, Y., 2021. Transition towards a circular economy: the role of university assets in the implementation of a new model. Detritus 17, 3–14. https://doi.org/10.31025/2611-4135/2021.15141.

Qualtrics, 2023. Qualtrics.xm [WWW Document]. URL https://www.qualtrics.com/ (accessed July.28.2023).

Rincón-Moreno, J., Ormazábal, M., Álvarez, M.J., Jaca, C., 2021. Advancing circular economy performance indicators and their application in Spanish companies. J. Clean. Prod. 279, 123605 https://doi.org/10.1016/j.jclepro.2020.123605.

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., Kendall, A., 2019. A taxonomy of circular economy indicators. J. Clean. Prod. 207, 542–559. https://doi.org/10.1016/j.jclepro.2018.10.014.

Schroeder, P., Anggraeni, K., Weber, U., 2019. The relevance of circular economy practices to the Sustainable Development Goals. J. Ind. Ecol. 23, 77–95. https://doi.org/10.1111/jiec.12732.

SDES, 2021. Key Indicators for Monitoring the Circular Economy. France.

Serrano-Bedia, A.M., Perez-Perez, M., 2022. Transition towards a circular economy: a review of the role of higher education as a key supporting stakeholder in Web of Science. Sustain. Prod. Consum. 31, 82–96. https://doi.org/10.1016/j.spc.2022.02.001.

THE, 2022. Impact Rankings 2023. Times Higher Education [WWW Document]. URL. https://www.timeshighereducation.com/impactrankings.

Thurston, M., Eckelman, M.J., 2011. Assessing greenhouse gas emissions from university purchases. Int. J. Sustain. High Educ. 12, 225–235. https://doi.org/10.1108/14676371111148018.

UI GreenMetric, 2022. Overall Rankings 2022 [WWW Document]. URL. https://greenmetric.ui.ac.id/rankings/overall-rankings-2022.

United Nations, 2015. Transforming Our World: the 2030 Agenda for Sustainable Development [WWW Document]. URL. https://sdgs.un.org/2030agenda.

Valls-Val, K., Bovea, M.D., 2022. Carbon footprint assessment tool for universities: CO2UNV. Sustain. Prod. Consum. 29, 791–804. https://doi.org/10.1016/j.spc.2021.11.020.

Valls-Val, V., Ibáñez-Forés, V., Bovea, M.D., 2022. How can organisations measure their level of circularity? A review of available tools. J. Clean Prod. 354, 131679.

Valls-Val, K., Ibáñez-Forés, V., Bovea, M., 2023a. Diagnosis of sustainable public procurement in Spanish universities. Application to catering services. In: Proceesings from the 27th International Congress on Project Management and Engineering (Donostia – San Sebastián, pp. 1078–1090. https://doi.org/10.61547/3427. July 2023.

Valls-Val, K., Ibáñez-Forés, V., Bovea, M.D., 2023b. Diagnosis de estrategias de circularidad implementadas en universidades y vinculadas con la jerarquía de residuos. In: Actas Del X Simposio Iberoamericano de Ingeniería de Residuos "Hacia La Circularidad y El Residuo Cero" (Castellón de La Plana, Junio 2023), pp. 980–987.

Valls-Val, K., Ibáñez-Forés, V., Lo-Iacono-Ferreira, V.G., Capuz-Rizo, S.F., Bovea, M.D., 2023c. Adequacy of existing circular economy assessment tools for higher education institutions. Sustain. Prod. Consum. 39, 399–413. https://doi.org/10.1016/j.spc.2023.05.011.

Vayona, A., Demetriou, G., 2020. Towards an operating model for attribution in circular economy. In: Proc. - 16th Annu. Int. Conf. Distrib. Comput. Sens. Syst. DCOSS, pp. 490–495. https://doi.org/10.1109/DCOSS49796.2020.00082, 2020.

Vinante, C., Sacco, P., Orzes, G., Borgianni, Y., 2021. Circular economy metrics: literature review and company-level classification framework. J. Clean. Prod. 288, 125090 https://doi.org/10.1016/j.jclepro.2020.125090.

Yuan, Z., Bi, J., Moriguichi, Y., 2006. The circular economy: a new development strategy in China. J. Ind. Ecol. 10, 4–8. https://doi.org/10.1162/108819806775545321.