Transition towards a circular economy: a review of the role of higher education as a key supporting stakeholder in Web of Science

1. INTRODUCTION

In recent decades, the concept of a circular economy (CE) has been gaining attention globally because the intention is to decouple economic development from the consumption of finite resources (Harris et al., 2021). Broadly defined as a restorative and regenerative model that aims to keep products, components, and materials in a closed loop at their highest level of utility and value (Ellen MacArthur Foundation [EMF] 2015), it has emerged as a preferred alternative to the dominant linear take-make-consume-dispose economic model (Haas et al., 2015). The development model of CE has been perceived as a way of achieving more sustainable development (Nikolaou and Tsagarakis, 2021; Korhonen et al., 2018) but with a narrower focus on the economic and environmental dimensions (Mhatre et al., 2021; Pieroni et al., 2019). Against this backdrop, the CE has gained considerable organisational, governmental, and academic attention (Burger et al., 2019; Merli et al., 2018). This is likely to remain the case in the near future (Shekarian, 2020) because the CE can become an accelerator for the targets set in worldwide initiatives towards sustainable development such as those included in the Agenda 2030 (United Nations, 2015). Thus, the CE has the potential to understand and implement new forms of business operations and consumption behaviours and patterns that can help society become more sustainable at low or no energy, material, and environmental cost. From this perspective, moving to a CE plays a vital role to address the Sustainable Development Goals (SDGs) of the Agenda 2030, such as SDG 12 (Dantas et al., 2021) on responsible consumption and production, SDG 9 on industrial development, or SDG 13 on climate action, among others (EMF, 2021). Moreover, the transition to a CE could deliver more jobs, increasing gross domestic product (GDP) and therefore economic growth. It is estimated that the shift to a CE could generate around 700,000 jobs at a net economic benefit of €1.8 trillion in the European Union (EU) by 2030 (McKinsey, 2020), while in Africa CE solutions in food systems could help create a trillion-dollar industry and drive millions of green jobs by 2030 (World Economic Forum, 2021).

However, the implementation of the CE requires systemic innovation and adjustment amongst all the relevant stakeholders, for example companies, policymakers, and higher education institutions (HEIs) (Bertassini et al., 2021; Pieroni et al., 2021). In recent years, the role of the private sector has stood out because of dramatic changes in industrial structures, especially waste management and business operations (Lieder and Rashid, 2016; López-Ruiz et al., 2010). The CE has also become a political priority (Friant et al., 2021; Johansson and Henriksson, 2020). The governments of the European Union, China, Japan, the United States, and Canada, which are amongst the most active countries in terms of CE policies development (Kalmykova et al., 2018; Geissdoerfer et al., 2017), are developing agendas, macro socio-economic policies, and investment strategies that promote the enhancement of the CE. These strategies validate the CE importance as a new fundamental pillar of the international economy. Finally, from an academic point of view, HEIs are one of the key players in the implementation of all SDGs of Agenda 2030 (Paletta et al., 2019). In this vein, they can initiate the systemic level transformation needed for the CE to become a reality (Longoria et al., 2021; Peer and Stoeglehner, 2013)

by playing a vital role in the local and regional uptake of CE approaches (Nunes et al., 2018). HEIs are in a unique position to lead and influence local change (EMF, 2019) through applied research, the transformation of new knowledge into innovations, patents, new businesses, teaching, student-led initiatives, and campus management (Zaidi et al., 2019). They can foster the change not just in knowledge but also in values and behaviours required to increase awareness of environmental concerns and sustainable development. Through two main vehicles, i.e. their campuses operations management and the implementation of different institutional initiatives, HEIs can develop the necessary knowledge and tools that support the transition to a CE (Merli et al., 2018) by mobilising policymakers, stakeholders, and business leaders in the private sector to learn, think, and act differently. However, whilst HEIs are widely acknowledged as important change agents (Longoria et al., 2021) and major drivers of economic growth (Mendoza et al., 2019; Organisation for Economic Cooperation and Development [OECD], 2010), the issues and practices they have to address on their path towards CE are still unclear (Paletta et al., 2019; Nunes et al., 2018). Systematic literature reviews can provide further clarity on this issue. A comprehensive analysis of the phenomenon using rigorous and reproducible research criteria will help scholars trace a path for future research, thus enhancing progress within the field. However, only one paper (Salas et al., 2021) has attempted to synthesise the contribution of HEIs to the transition towards the CE, albeit in the Latin American context. Hence, a systematic and extensive literature review is needed to take stock of what is currently known about the role of HEIs in the CE. The present study aims to answer the following research questions (RQs):

> RQ1): What is the growth trajectory and what themes are addressed in the literature on the role of HEIs in the transition to the CE?
> RQ2): What research gaps in the role of HEIs in the transition to the CE have been identified in the literature?

The study contributes to CE literature in several ways. First, it enhances our understanding of how HEIs can help to implement circularity solutions in industry and new consumption patterns in society, thus contributing to deliver benefits across different SDGs, in particular SDG 12. Second, it advances scholarly research on the topic by identifying areas for improvement and further development of the field in general. Finally, it offers practical guidance for both internal and external HEI stakeholders in their transition towards the CE. The revisited material consists of 77 peer-reviewed articles collected from the Web of Science database. The 77 papers were read in depth, evaluated, and grouped into an integrative framework. The framework is composed of five analytical categories in accordance with the role of HEIs, as proposed by the Ellen MacArthur Foundation (EMF). From this framework, key findings regarding each category and a reflection on the current and future contributions of HEIs as supporting stakeholders of a CE transition are presented.

2. LITERATURE REVIEW

The CE is a newly emergent but already widely applied concept (Tseng et al., 2021). It refers to “an industrial economy that is restorative by intention and design” (EMF, 2013, p.14); “an economic system that keep[s] the added value in products for as long as possible and eliminate[s] waste” (European Commission [EC] 2014, p.2); or “an economy constructed from societal production–consumption systems that maximizes the

service produced from the linear nature–society–nature material and energy throughput flow" (Korhonen et al., 2018a, p. 39). This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishment, and recycling (Mhatre et al., 2021; Jia et al., 2020). Hence, "the primary objective of CE is to dismantle the relation between economic growth and environmental degradation and resource consumption through new production practices and technological developments, satisfying consumer needs in different, more sustainable ways" (Lopez-Ruiz et al., 2020, p. 3). In other words, the CE represents a "win-win" philosophy, hypothesising that a prosperous economy and healthy environment can co-exist (Fonseca, 2018). CE "relies on three principles: (i) preserve and enhance natural capital, (ii) optimize resource yields and (iii) foster systems effectiveness (The Ellen MacArthur Foundation, 2015)" (Acerbi and Taisch, 2020, p.2).

Different schools of thought gave rise to the idea of the CE (Korhonen et al., 2018). Its deepest roots can be traced back to the theoretical contributions of Boulding (1966), Meadows (1972), and Pearce and Turner (1989). These in turn were underpinned by ecological and environmental economics and industrial ecology (Ghisellini et al., 2016; Saavedra et al., 2018). More recently, the concept has been adopted in a variety of different settings (Alnajem et al., 2020), and other theoretical influences, such as regenerative design, performance economy, cradle to cradle, biomimicry, and the blue economy have contributed to its further refinement and development (Homrich et al., 2018).

Progress and a growing international interest in the development of the CE as a fundamental pillar of the global economy (Mahanty et al., 2021; Kristensen and Mosgaard, 2020) have been validated by several indicators. First, the CE has been adopted as a guiding principle in many countries' policies, and it has been implemented in different ways. The European Union (EU), with Germany and the Netherlands the main precursors, has been one of the most active regions in the transition to the CE as has China (Ghisellini and Ulgiati, 2020; Merli et al., 2018). Both of them are considered active in terms of CE policies development. More precisely, in the case of the EU, since the Directive 2008/98/EC on the implementation of best waste management practices, the EU has given continuity to its CE strategy through the development of different policies. They include the programme "Towards a Circular Economy: A Zero Waste Programme for Europe" (COM 398, 2014), which was followed by "Closing the Loop: An EU Action Plan for the Circular Economy" (COM 614, 2015), the Circular Economy Action Plan (EC, 2018) and, more recently, the "Circular Economy Action Plan for a Cleaner and More Competitive Europe" (EC, 2020). On its part, China included the CE as a central objective in its 11th Plan for National Economic and Social Development in 2008 with the Circular Economy Promotion Law. This was subsequently amended in the 12th and 13th plans (2012–2020). Similarly, Japan (with the Basic Law for Establishing the Recycling-based Society (BASICRECLAW), the United States, and Canada (with the Resource Recovery and Circular Economy Act 2016 (RRCEA; SO 2016 c. 12), amongst others, are recognised for having introduced legislation on the implementation of CE principles (Merli et al., 2018). Second, the more active role of the major consulting companies, such as McKinsey & Co., Accenture, Deloitte, Ernst and Young, and KPMG, have reflected the popularisation and acceptance of the concept in the business domain (Mahanty et al., 2021). Third, not only governments and industry, "but also academia and nongovernmental organizations, such as the Ellen MacArthur Foundation, are committed to spreading CE principles" (Merli et al., 2018, p. 704) across the globe. These principles are based on three main "actions", – the so-called 3R framework: reduce, reuse, and recycle (Ghisellini et al., 2021). This was at the core of the 2008 Circular Economy

Promotion Law of the People's Republic of China. Academics and practitioners have been proposing various "R" frameworks for decades (Blomsma and Brennan, 2017). These have included the 4R framework (the core of the EU Waste Framework Directive), the 6R (Sihvonen and Ritola, 2015), and even the 9R (Potting et al., 2017). All varieties of the 3R framework are hierarchical, with the first R – reduce – being the priority (Kirchherr et al., 2017).

Several systematic literature reviews about the CE have been published. Some cover the entire field (Homrich et al., 2018; Merli et al., 2018; Blomsma and Brennan, 2017) and others map CE research using bibliometric indicators (Alnajem et al., 2021) or identify drivers and barriers (Aloini et al., 2020; Lieder and Rashid, 2016). Korhonen et al. (2018), Reike et al. (2018), and Kirchherr et al. (2017), have summarised CE concepts and visions, assessed its historical evolution and explored the controversies surrounding its conceptualisation (Alnajem et al., 2020). Kircherr et al. (2017), after analysing 114 definitions, described CE as an economic system that is based on business models which replace the "end-of-life" concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes. Thus, CE operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation, and beyond), with the aim of accomplishing sustainable development, which implies creating environmental quality, economic prosperity, and social equity, to the benefit of current and future generations. (Kircherr et al., 2017, p. 224)

This definition has become a heuristic for developing strategies and policies on different levels, from global production and consumption systems to cities and municipalities. Other scholars have focused their attention on the creation and evaluation of indicators to monitor CE (Harries et al., 2021; Kuzma et al., 2021; Saidani et al., 2019), whether at macro (Smol et al., 2017), nano (De Oliveira et al., 2020; Cayzer et al., 2017), meso (De Pascale et al., 2021), or micro levels (Kristensen and Mosgaard, 2020). Other reviews have explored the relationship between sustainability and the CE (Schöggl et al., 2020; Suarez-Eiroa et al., 2019; Sauvé et al., 2016) and the development of more circular business models (Urbinatu et al., 2021; Centobelli et al., 2020). Some scholars have applied CE principles to sectors (Benachio et al., 2020; Jia et al., 2020; Rokicki et al., 2020) and geographical contexts, such as Latin America (Morales et al., 2020), Europe (Mhatre et al., 2021), and Asia (Cui and Zhang, 2018). Finally, academics have also reviewed specific literature streams, such as supply chains (Govindan and Hasanagic, 2018; Masi et al., 2017), innovation (Suchek et al., 2021) and big data and Industry 4.0 (Atif et al., 2021; Danstas et al., 2021; Rosa et al., 2021; Tseng et al., 2021; Nobre and Tavares, 2017).

Higher education is broadly defined as one of the key drivers of growth performance, prosperity, and competitiveness (OCDE, UNESCO, EC, 2020). The links between sustainability and HEIs are strong and since the 1990s they have received increasing attention, in parallel with the United Nation's strengthening to education as a key factor in promoting the culture of sustainable development (SD) (Paletta et al., 2019). Different conferences and initiatives (e.g. Río de Janeiro 1992, Chapter 21 of Agenda; Johannesburg Conference 2002; Río de Janeiro 2012, document "The Future We Want"; The Higher Education Sustainability Initiative (HESI) 2012; G7 Environment Ministerial Meeting 2017, among others), have highlighted the relevance of HEIs as a key factor for cultural, economic, and social and sustainable development within the current

increasingly knowledge-based society (Paletta and Bonoli, 2019). Within this context, HEIs have stepped up their efforts to support SD by making significant efforts to address sustainability in campus operations, introducing new programmes and courses related to education for SD, and extending the value and impact of their teaching and research to their respective communities (Paletta et al., 2019, UNESCO, 2017; UNESCO 2014). Moreover, the roles of HEIs in sustainable economic and social development increase year by year, and this will continue over the next decades. This means that HEIs have to increasingly rethink their role in the twenty-first century and look to be both more responsive to societal needs and to become agents of change towards solving global challenges (Global University Network for Innovation (GUNI), 2021). An example of this is the fact that the 2030 Agenda for SD and the COP 21 Paris Agreement (2015) have also positioned HEIs as one of the key players to contribute to an equitable and ecologically sound future by establishing sustainability as a central academic and organisational focus.
In fact, in the words of Marie Paule Roudil (2017), Director of UNESCO:

> *"Universities and higher education networks can conduct research and provide advice and guidance on strengthening national education systems as well as aspects of capacity building for sustainable development across different sectors; high education subjects can strengthen the interface between research findings and decision-making using evidence-based data, as well as problem-based scientific research*".

Consequently, HEIs have the core responsibility of promoting a systemic approach in relation to the multiple societal challenges within and beyond their organisations (Castillo et al., 2021). Thus, they can accelerate a societal transition toward sustainability, and, considering the strong link between CE and sustainability (Mendoza et al., 2019), with the former representing a condition and strategic pathway to achieving the latter (Geissdoerfer et al., 2017), also toward CE transition. That is because HEIs provide the link between the intellectual and educational role of universities, on the one hand, and the development of society, on the other (Pee and Vululleh, 2020). Thus, HEIs emerge as a key strategic actor to create the right conditions for the socio-technical transition towards a CE by developing societies and workforces that are more sensitive to sustainability goals. In adition, they can help create business leaders and policymakers with appropriate skills, competences, and consciousness with reference to the CE challenge (Pee and Vululleh, 2020; Martin and Jucker, 2005).
However, even though the key role of HEIs in supporting CE has emerged as a relevant new field of study (Giannoccaro et al., 2021), and despite the huge number of systematic reviews in the field of CE available to date, none have explored the extent to which HEIs contribute to the transition to the CE. As has been noted, we identified the systematic review by Salas et al. (2021), which explored the role of HEIs in the CE in Latin American countries in a search of the Scopus database for the period 2010–2020 and reported a final sample of four articles relating to HEIs. The present study extends and complements this research by analysing the broader contribution of HEIs to the transition to the CE. In particular, the review provides a deeper knowledge of current HEI practices and how these have to be developed if they are to be recognised by policymakers, industry, and society in general. Specifically, research identified was evaluated and grouped into one of the five analytical categories in accordance with the role of HEIs, as proposed by the EMF, defined as follows:

1) Teaching for CE: how HEIs are embedding CE principles into teaching across the curricula for supporting a mindset shift that will enable future leaders and young professionals to gain CE insights, skills, and capabilities, which they can take forward within their careers.

2) Lead innovation by students: initiatives which drive circular solutions through students' commitment, application, and exploration of the topic in real-world contexts.

3) Stimulate research on CE: academic or applied research on CE that can provide the critical insights and knowledge required to support industry and policy shifts to act differently and tackle CE.

4) Lead and influence local change: working in conjunction with their municipalities (or regional/national funders), this category summarises how universities can provide the driving force for a collective movement to a CE, addressing a number of challenges as leader and agent for change.

5) Campus management: how universities, as own organisations, can act as lighthouse demonstrators of CE practices across their estate operations and as local leaders by implementing ambitious plans for more circular campuses and have emissions reduction targets.

3. MATERIAL AND METHODS

In order to achieve our goal, articles were identified through a systematic literature review (Serrano-Bedia et al., 2013). Systematic reviews are "an essential feature of any research activity since they provide a summary of previous studies in the area and look for the gaps of knowledge in those published studies" (Benachio et al., 2020 p.2). According to Jia et al. (2020) or Briner and Denyer (2012), a systematic review should involve an explicit, transparent, and reproducible method, which can be replicable and updatable to identify, evaluate, and interpret the existing body of recorded documents.
The scientific literature has been scrutinized in a systematic way, following the Preferred Reporting Items for Systematic Re-views and meta-Analyses (PRISMA 2020) guidelines (Page et al., 2020; Moher et al., 2009) (Figure 1).

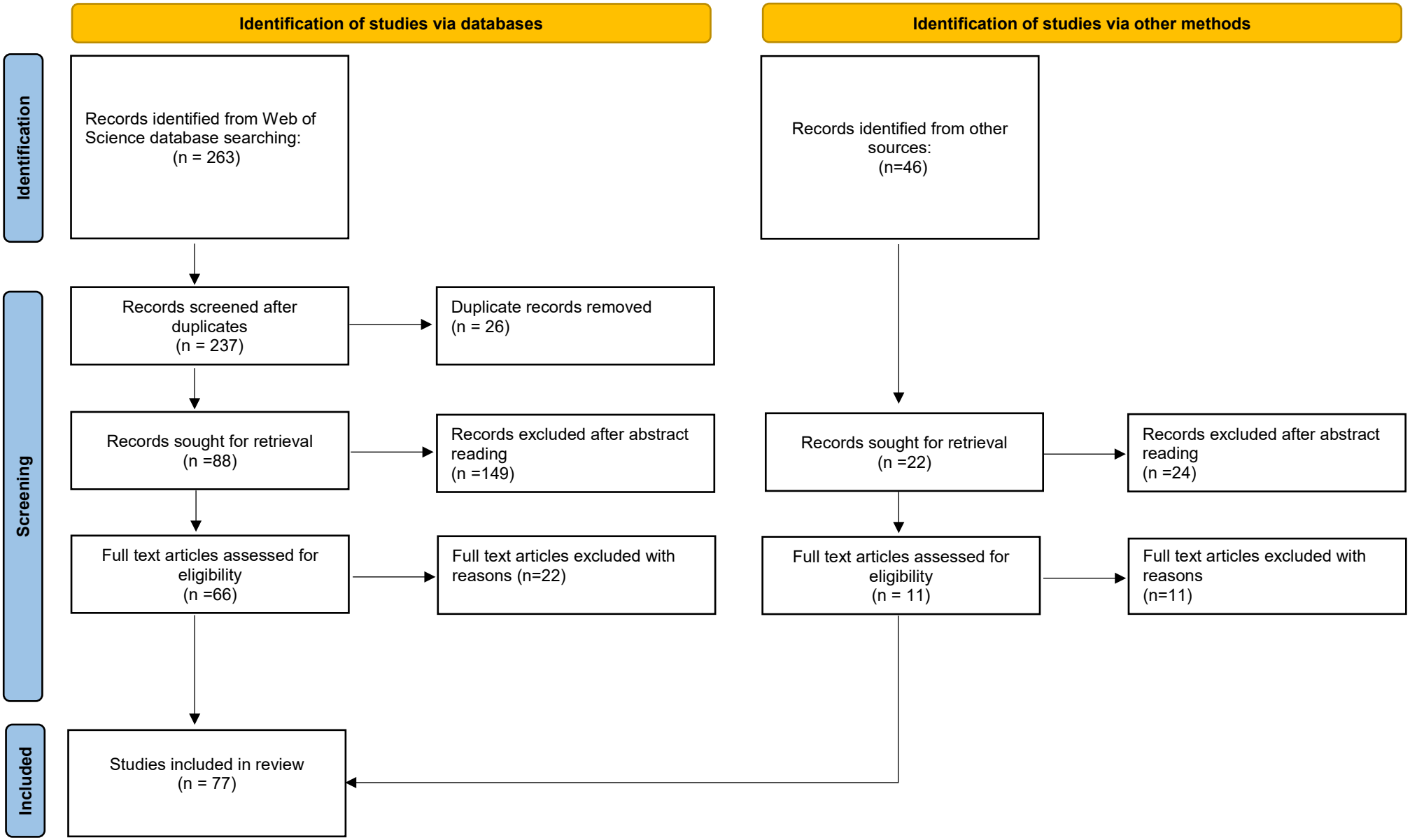

Figure 1. The review process, according to the PRISMA guidelines (Page et al., 2020; Moher et al., 2009).

3.1. Identification

Guided by the research questions presented in the Introduction section, a set of keywords encompassing both university and CE-related terms were selected. The search was conducted through the combination of such keywords using Boolean operators (AND/OR). The search string applied to the scientific databases was:

("circular econom*" OR "close loop econom*" OR "zero waste econom*") AND ("university*" OR "education*" OR "campus*").

The modifier asterisk "*" was used in the Boolean search as a root word for all derivative keywords. The keyword combination was applied to the "Title, Author Keywords, Abstract, and Keyword Plus" in the Web of Science (WoS) database, in September 2021. WoS is considered the world's leading scientific citation search and analytical information platform (Li et al., 2018) and offers access to upwards of 100 million references from 33,000 journals, which are indexed with an impact factor calculated in the *Journal Citation Reports* (JCR) (Munaro et al., 2020). Filters for document type were set to "articles", "review", and "article in press". Moreover, the search was not limited to a specific timespan, journal, or scientific area. The academic literature was limited to articles in English as it is by far the most frequently employed language and is generally considered the international academic language (Merli et al., 2018; Pérez-Pérez et al., 2018). These search criteria reported an initial sample of 263 documents. Cross-referencing was used to complement the initial search (Bressanelli et al., 2020). This led to a further 46 records.

3.2. Screening

A total of twenty-six documents were duplicated and removed from the sample, thus leading to 283 retained publications. To ensure the robustness of this review, only articles published in peer-reviewed journals were included for screening by reading the titles and abstracts as they are the source of most up-to date knowledge (López-Fernández et al., 2016). Articles not conforming to the objective of the research were excluded (149 studies from WoS and 24 from the cross-referencing search). After this process, 110 records were selected (88 records from WoS and 22 from the complementary search).

3.3. Eligibility and Inclusion

Two eligibility criteria were used to assess the remaining 110 articles: (i.) articles have to focus on the circular economy concept, in (ii.) the higher education context. Articles that consider only one of these two criteria (i.e. focus on circular economy but not in a higher education context and vice versa) were considered to fall outside of the scope of this study and were excluded from the sample. The selection of eligible publications was based on a full reading of the remaining articles (Sassanelli et al., 2019). Both authors independently performed the entire process of selecting the documents to avoid interpretation bias. Results obtained by each of them were compared and the papers were excluded after both researchers agreed that they did not satisfy the inclusion criteria. A total of 33 publications were ruled out upon full-text reading as they did not fit the purpose and goals of this study (22 studies from WoS and 11 from the cross-referencing search).

Thus, the final sample included 77 publications (66 from WoS and 11 from cross-referencing search).

4. RESULTS AND DISCUSSION

4.1. Growth trajectory and topic trends

To illustrate the growth trajectory of the field, articles were first categorised based on their publication year (Figure 2). As can be seen, all but three articles were published after 2017, with a rapid increase in the number of publications in 2019 and 2021. The lower number of publications in 2020 may be due to the COVID-19 pandemic, one of the most disruptive events in recent decades with profound consequences in all aspects of life, from the social to the economic sphere. This situation may have inspired a wave of academic research on this topic in various disciplines (Cruz Cardenas et al., 2021; Yang et al., 2021) that may have reduced the research on other emerging and/or relevant topics before the pandemic, such as is the case. Despite this, the last three years – from 2019 to 2021 – amount to approximately 80% of the total number of publications, thus confirming the growing popularity of the subject and the overall increase in the associated literature relating to higher education.

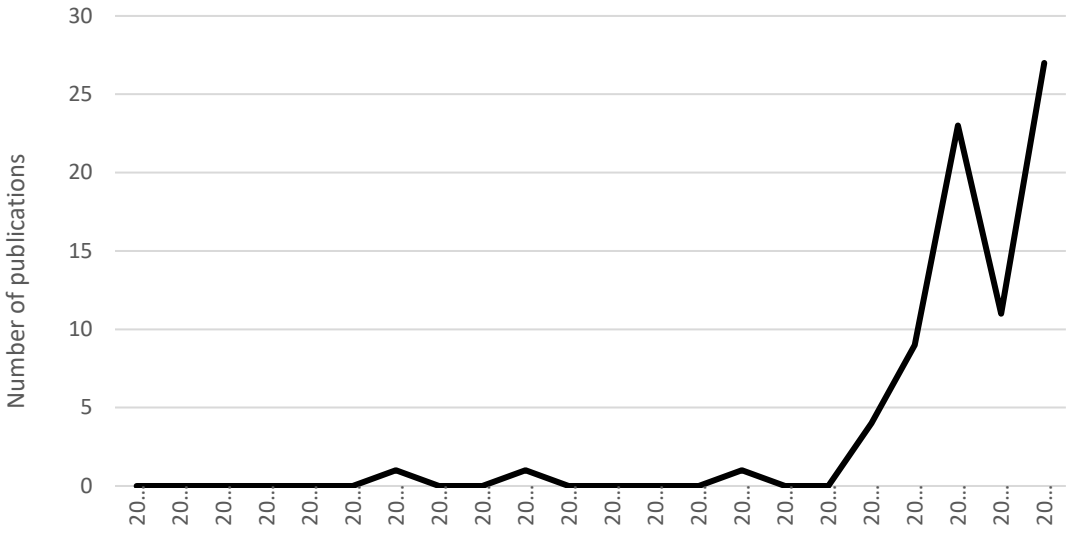

Figure 2. Growth trajectory of the reviewed literature, 2006–2021.

To ascertain the main themes and trends, each of the articles were mapped into one of the following categories (EMF, 2019): (1) Teaching for CE; (2) Leading innovation by students; (3) Stimulating research on the CE; (4) Leading and influencing local change; and (5) Campus management. A general and comprehensive portrayal of each category, its subthemes, and the supporting literature base is provided in Table 1 for traceability.

Table 1. Classification of the sample per category

Category name	***Teaching for CE***	***Lead innovations by students***	***Stimulate research on CE***	***Lead and influence local change***	***Campus Management***
References per category	*Bugallo-Rodríguez & Vega-Marcote (2020)*	*Bakırlıoglu, & McMahon (2021)*	*Bianchini and Rossi (2021)*	*Bas-Bellver et al. (2020)*	*Bakos & Schiano-Phan (2021)*
	De la Torre et al, (2021)	*Bakırlıoglu et al. (2021)*	*Block et al. (2019)*	*Bringsken et al. (2018)*	*Beu et al. (2018)*
	Fraccascia et al. (2021)	*Bonoli et al. (2018)*	*Bonoli et al. (2021)*	*Cerreta et al. (2021)*	*Ciugudeanu et al. (2019)*
	Geng et al. (2009)	*James & Kent (2019)*	*Börühan and Ozbiltekin-Pala (2021)*	*Christensen (2021)*	*Colares et al. (2019)*
	Hoffman et al. (2021)	*Kilkis & Kilkis (2017)*	*Brenes-Peralta et al. (2020)*	*De Medici et al. (2018)*	*Ferronato et al. (2020)*
	Jääskä et al. (2021)	*Mansour et al. (2020)*	*De Sousa et al. (2021)*	*Erälinna & Szymoniuk (2021)*	*Fleischmann (2019)*
	Janssens et al. (2021)	*Mateus et al. (2019)*	*Iuorio et al. (2019)*	*Gao et al. (2006)*	*Hopff et al. (2019)*
	Kirchherr & Piscicelli (2019)	*Neto (2019)*	*Kooduvalli et al. (2021)*	*Keng et al. (2020)*	*Maruyama et al. (2019)*
	Kopnina (2014)	*Onur (2020)*	*Korançe (2021)*	*Kumble (2019)*	*Mendoza et al. (2019)*
	Kopnina (2018)	*Piekarski et al. (2019)*	*Mahdi et al. (2021)*	*Lacerda-Fernándes et al. (2021)*	*Mendoza et al. (2019[a])*
	Kopnina (2019a)	*Rizzo et al. (2017)*	*Matrapazi & Zabaniotou (2020)*	*Newton & Frantzeskaki (2021)*	*Owojori et al. (2021)*
	Kopnina (2019b)	*Sanchez-Carracedo & López (2021)*	*Vaskalis et al. (2019)*	*Rigillo et al. (2018)*	*Pierron et al. (2017)*
	Landrum (2021)	*Wandl et al. (2019)*	*Yeo et al. (2019)*	*Sukiennik et al. (2021)*	*Shittu et al. (2021)*
	Reichmanis Sabahi (2017)	*Williams & Powell (2019)*			*Torrijos et al. (2021)*
	Rodríguez-Chueca et al. (2019)	*Williams et al. (2018)*			
	Summerton et al. (2019)				
	Sumter et al. (2018)				
	Sumter et al. (2020)				
	Sumter et al. (2021)				
	Vera-Puerto et al. (2020)				
	Whalen et al. (2018)				
Total	**21**	**15**	**13**	**13**	**15**

A critical discussion based upon an in-depth reading of articles that compose each category as well as its subsequent substreams is provided below.

4.1.1 Teaching for CE

This first category, which constitutes the most developed category in the topic, is comprised of 21 works sustaining the view that HEIs are primarily strategic agents that, through their teaching activities, must support the principles of CE (Burgallo-Rodríguez and Vera-Marcote, 2020; Mendoza et al., 2019; Colucci-Gray et al., 2006), thus contributing to catalyse and accelerate a societal transition toward CE. In particular, the newness of this field requires the addition of new competences, knowledge, tools and methods within HEIs' courses and curricula to successfully offer future leaders and professionals the new capabilities and skills needed to cover the needs of a circular industry (Sumter et al., 2020; Stephens, 2008). Moreover, the transdisciplinary competences required to address the complexities related to holistic CE issues need to be developed by identifying the most relevant didactic tools and aligning them across HEI´s course programmes (Rodriguez-Chueca et al., 2018). As a result, two main research lines were identified: the curriculum designed to incorporate CE competences in HEIs, and the educational approaches and methodologies in HEIs' courses to promote CE.

4.1.1.1. Curriculum designed to incorporate CE competences in HEIs: While the amount of literature on CE is growing in general, there is limited academic literature that explores how the competences need to be changed in HEIs' curricula to enrich college courses with transdisciplinary CE competences, thus confirming the premature development state they are in. In this research line, first we have identified four papers published in the last four years with the aim of providing a roadmap of CE competences needed in the HEIs' engineering curricula to promote a successful CE design, an issue highly emphasised in the EU action plan for the CE (European Parliament Research Service, 2017). Beginning with Sumter et al. (2018), they present an in-depth longitudinal analysis of a case study to develop a framework that highlights the need for two strategic circularity-related competences: (1) the ability to concurrently develop the circular business model and product design; and (2) the ability to anticipate how the circular offering will evolve over multiple lifecycles. Sumter et al. (2020) and Vera-Puerto et al. (2020), after highlighting the need to implement in-depth learning from real-case methodology in HEIs' curricula, conclude that engineers' educational programmes must include new competences to enable a push for the CE transition. These competences include Circular Impact Assessment, Design for Recovery, Design for Multiple Use Cycles, Circular Business Models, Circular User Engagement, CE Collaboration, and CE Communication. In a more recent paper, Sumter et al. (2021) assesses to what extent these competences are recognised by practitioners working on CE projects, and whether any competences are missing. Its findings stress the importance of two additional competences for design: Circular Systems Thinking and Circular Materials and Manufacturing. Finally, with a broader perspective a fifth paper by Janssens et al. (2021) shows that both transversal and valorisation competences are equally important as technical competences for a CE.

4.1.1.2. Educational approaches and methodologies in HEIs' courses to promote CE: The 16 papers that integrate this research line, published between 2009 and 2021, show that "extant literature on education for the CE is grounded on a variety of theories of learning and teaching, which find expression in a wide array of teaching activities" (Kirchherr and Piscicelli, 2019, p.2). Thus, papers such as Geng et al. (2009), outline a pioneer experience with the teaching of Industrial Ecology at an HEI in China, while

Landrum (2021) reports a CE experience involving education, research, and work with industry stakeholders in a Dutch University. Another group of papers discusses the application of more traditional methodologies, such as case studies (Kopnina, 2014; 2018; 2019a; 2019b) for different purposes. These educational interventions that use EMF case studies are focused on natural metaphors with the aim to achieve a critical awareness of environmental problems (Kopnina, 2014), as well as to illustrate how difficult it is to address circular frameworks in practice (Kopnina, 2018). In other cases, the aim is to deepen their understanding of production processes, materials used, and CE challenges (Kopnina, 2019a), or to discuss philosophical debates about the possible risks associated with the implementation of CE business practices (Kopnina, 2019b).

Along with these papers, many proponents of CE courses and curricula in HEIs have explored the role of active-learning methodologies. These methodologies present the students with challenging situations whose resolutions imply the development of collaborative and professional skills and competences rather than just receiving instruction directly from the teacher (Rodriguez-Chueca et al., 2020). Following the previous research line, the various experiences in active-learning methodologies reported in the literature are mostly implemented in engineering and science courses. Thus, Rodriguez-Chueca et al. (2020) explore the efficiency of flipped classroom (FC) and challenge-based learning (CBL) methodologies to facilitate the learning and enhancement of environmental competences of HE science, engineering, mathematics, and technology students in Spain. Reichmanis and Sabahi (2017) describe an example of the implementation of the CBL methodology in a course for science and engineering students focused on the Life Cycle Inventory (LCI) assessment on an existing product to offer recommendations to render the processes more sustainable. Summerton et al. (2019) illustrate the use of workshops delivered by experts from both academia and industry in a course for chemistry students with the aim of embedding a system-thinking approach to CE issues, as well as improving vital skills, such as working in teams, problem-solving or critical thinking. The only examples of the use of active-learning methodologies in other disciplines are those by Bugallo-Rodríguez and Vega-Marcote (2020), Hoffman et al. (2020), and Kirchherr and Piscicelli (2019). Kirchherr and Piscicelli (2019) report the use of problem-based learning (PBL) to introduce undergraduate students of human geography and planning, earth sciences, and science and innovation to the CE concept. Bugallo-Rodríguez and Vega-Marcote (2020) describe the use of a “teaching for action” framework in an HEI programme for primary education students to prepare them to be active agents for CE change. Hoffman et al. (2020) describe a CE master course at a faculty of geoscience employing a “mixed classroom” formula in which students and policymakers learn together about circular challenges.

Finally, some papers explore the role of simulation and serious games as a learning tool to incorporate CE concepts in HE courses. Thus, de la Torre et al. (2021) discuss research opportunities regarding the use of these computational tools, while Fraccascia et al. (2021) present an industrial symbiosis (IS) business game developed in a master’s programme of industrial engineering and management. Jääskä et al. (2021) explore the use of a game-based learning solution in a blended-learning context in which project planning, stakeholder management, cost management, decision-making, and risk management skills are enhanced by means of experiential and problem-based learning. Lastly, Whalen et al. (2018) report a technology-enhanced learning experience, namely the use of the serious game In the Loop, to provide an experiential learning situation that

encourages engineering students to think holistically and reflect on CE concepts to address resource challenges.

4.1.2. Lead innovation by students

Outside the lecture hall as places of concentrated teaching and learning, HEIs can actively promote the CE mentality by introducing CE-related content in HE activities, as well as implementing initiatives that drive circular solutions through students' commitment, application, and exploration of the topic. Additionally, the lead innovation by student category, composed of 15 works published between 2017 and 2021, evidences how universities can facilitate the CE transition by involving students in applied research projects and initiatives to meet CE challenges (e.g. Bonoli et al., 2018) and engaging them in real-world contexts for applied learning (e. g. Kilkis and Kilkis, 2017).

4.1.2.1. Applied research projects and initiatives to meet CE challenges: Within this research line, which is composed of seven papers, we can find several examples of interventions aimed at motivating and involving students in applied research projects that seek solutions to open-ended problems and challenges (Tilbury, 2011; Moesby, 2005). More precisely, firstly we can find several examples of the use of this methodology to support living laboratories (Evans and Karvonen, 2014). Some of these examples in the sample explore aspects related to the incorporation of the CE concept in a course of planning architecture and urban design (Wandl et al., 2019). Other experiences report the involvement of students, researchers, and teachers on testing the water and rooting capacity of innovative recycled materials as substrates for the cultivation of edible plants, including the realisation of a soilless growing infrastructure within the university premises (Rizzo et al., 2017). In this vein, Bonoli et al. (2018) also analyse the effect of the use of a CE lab working to valorise disused electrical and electronic equipment (EEE) waste thanks to restoration, preparing for the reuse and refurbishment of obsolete EEE informatics. Finally, Sanchez-Carracedo and Lopez (2021) describe the implementation of a computer reuse programme carried out at the Universitat Politecnica de Catalunya, by which students increase their awareness regarding CE and contribute to the reduction of e-waste.

Along with these examples, other papers within this research line analyse educational interventions involving students in applied research projects. These are related to textile printing and graphic design in Oman, with the aim of applying a few waste products containing pigments as recycling sources for natural dyes in textile colouration (Mansour et al., 2020) or treating and reusing water and solid waste in Portugal (Mateus et al., 2019). Lastly, the paper by Williams and Powel (2019) applies environmental, social, and economic Key Performance Indicators (KPIs) as a measure of success of an end-of-term reuse scheme in the UK, with a particular focus on clothing and footwear, bedding and linen, kitchen and homeware, and books, games, and disks. The design of these indicators facilitated the standardisation of the collection of data, thus helping decision-making in judging CE strategies and performing regular comparative analyses about the generation of waste.

4.1.2.2. Applied learning in real-world contexts: This second research line, composed of eight papers, summarises several examples of the use of didactic approaches that engage students in local and real-world contexts to meet CE challenges. Specifically, we identify experiences that involve students in the development of energy action plans in a

university-founded dairy facility (Kilkis and Kilkis, 2017), or the identification of opportunities to apply CE thinking to a company's operations at a water treatment plant (Williams et al., 2018). Along this line, the paper by Bakırlıoglu and MacMahon (2021) outlines an experience of a CE training programme where industry partners, students, and academics from Ireland work together to address circular design real-world challenges. This initiative is part of a larger EU collaboration aimed at creating a co-learning environment for the analysis of design briefs developed in circular design internships (Bakırlıoglu et al., 2021). Other papers illustrate how fashion design students address the challenges of upcycling in the developing world by exploring opportunities to add value to waste clothing through the conceptualisation and redesign of materials bought in a real clothing market (St. John James and Kent, 2019) and generating alternatives to learning and designing through upcycling, craft, and collaboration (Atalay, 2020). Finally, a last group of articles summarises experiences focused on students' eco-design proposals to improve the environmental profile of both solid and reticulated paintbrushes (Piekarski et al., 2019) or the eco-efficiency for selected real products of a variety of industrial entities of the Aveiro region in Portugal (Neto, 2019).

4.1.3. Stimulate research on CE

This category is composed of 13 articles published after 2019 that summarise the R&D efforts of HEIs for the development of technological solutions that allow progress in the commitment to a CE model. In other words, the main goal of the articles comprising this category is to analyse the viability and the environmental impact of different CE innovations as a prior step to its subsequent transference to/implementation in society. These eco-innovative solutions are classified into two research lines: secondary resources recovery technologies (e.g. Bonoli et al., 2021 or Matrapazi and Zabaniotou, 2020) and eco-friendly solutions for bringing a sustainable built environment (e.g. Korançe, 2021 or Iuorio et al., 2019).

4.1.3.1. The secondary resources recovery technologies research line is composed of nine articles. Most of them evaluate the potential of different alternative harvesting systems for food waste (Sousa et al., 2021; Brenes-Peralta et al., 2020; Matrapazi and Zabaniotou, 2020; Vaskalis et al., 2019; Yeo et al., 2019). A smaller number of studies focus on plastic waste (Bianchini and Rossi, 2021; Börühan and Ozbiltekin-Pala, 2021; Kooduvalli et al., 2021), or rare earth resources (REE) waste recovery placed in the electrical and electronic (EE) industry (Bonoli et al. 2021).
Specifically, the papers by Matrapazi and Zabaniotou (2020) and Vaskalis et al. (2019) analyse, through two projects developed at Aristotle University (Greece), a standalone pyrolysis plant prototype designed to collect coffee-drink residue and a prototype bioenergy system for the efficient utilisation of rice husks, respectively. De Sousa et al. (2021) evaluate the viability of a biorefinery structure for the treatment of used cooking oil, pruning biomass, and organic and food residues to produce organic compost, and energy resources at the campus of the Federal University of Pernambuco, Brazil. Following a similar purpose, Brenes-Peralta et al. (2020) and Yeo et al. (2019), based on life cycle assessment (LCA), evaluate the environmental, social, and economic impacts of establishing food waste composting technologies to facilitate their treatment into an energy resource in the universities' canteens in Costa Rica and Hong Kong, respectively. The results of these solutions, that go beyond recycling, indicate that the implementation of these technologies for the development of zero-waste operating canteens would

improve on the waste management within the university campus, reducing the amount of GHG emissions in addition to obtaining valuable products.

Circular solutions for plastic waste recovery, a priority area of the new Circular Economy Action Plan (2020), were explored by Börühan and Ozbiltekin-Pala (2021), Bianchini and Rossi (2021) and Kooduvalli et al. (2021). Börühan and Ozbiltekin-Pala (2021) evaluate plate waste in a Turkish university refectory and create a system to reduce it from a CE perspective. Bianchini and Rossi (2021) develop an innovative visualisation tool to assess circular initiatives and some key performance indicators for managing plastic waste at sport events in the University of Bologna, Italy. Kooduvalli et al. (2021) demonstrate the feasibility of using compostable coffee pods over conventional plastic ones, using the existing local composting facility at the University of Tennessee–Knoxville (USA). Finally, the study by Bonoli et al. (2021) assesses the feasibility of the recovery of rare earth metals from small fluorescent lights and phosphors used in white light-emitting-diodes (Bonoli et al., 2021) developed by the Italian university of Bologna, in collaboration with an industry-partner. With these solutions, HEIs indirectly increase awareness about the importance of "closing-the-loop" and promote more sustainable lifestyles, as well as the transition to a circular future, thus having the potentiality to help to manage the REEs of the EE industry and greatly reduce plastic's environmental impact.

4.1.3.2. The eco-friendly solutions for bringing about a sustainable built environment research line is composed of four articles where HEIs act as an engine to stimulate research on innovations to help design and construct sustainable buildings that, with the whole lifecycle in mind, must be future-proof. Accelerating the circular transition of the construction industry is important for the community and society due to the fact it is one of the most energy-consuming, destructive, and material-consuming industries (Korançe, 2021). In this vein, the studies that compose this research line deal with the design, production, and monitoring of the environmental impact of new types of constructions or materials that can increase built lifetimes. Specifically, Iuorio et al. (2019) assess an innovative modular lightweight system to increase the energy efficiency of buildings; this is co-developed by three universities, one research centre and seven industrial partners. The innovative modular system is based on lightweight steel skeleton coupled with gypsum and cement ebased boards and other materials to provide a safe, fast, energy-efficient and long-lasting, high-quality solution to housing, particularly in high seismic-risk areas. On the other hand, Blok et al. (2019) design, produce, and monitor a fully bio-based composite footbridge at a university campus in Eindhoven. The footbridge is codeveloped by two Dutch universities and a manufacturer from the Natural Fibre Reinforced Bio-Polymer industry with the purpose of measuring deformations and change in elasticity that occur over time. Mahdi et al. (2021) explore Khalasa date palm leaf fibre obtained from the Qatar University farm as a reinforcement for the sustainable production of polymeric composite materials. Finally, Korançe (2021) puts in value designers and builders' need to achieve an optimal comfort and functionality to fully accomplish sustainable architecture design –specifically in elements such as spatial reversibility, energy efficiency system, community integration design, light, noise, temperature, infrastructure-. Overall, these articles show that sustainable buildings are relatively low cost to run and provide valuable properties in the long term.

4.1.4. Lead and influence local change

The lead and influence local change category gathers 13 studies that focus on the role of HEIs as CE catalysts for business and local impact. This line is the natural evolution of the previous one in the sense that it goes one step further, transferring and implementing CE innovations and knowledge to society and the industrial environment. As part of this view, HEIs, working in conjunction with their municipalities, define, implement, and support CE solutions that prove to be beneficial for regional communities or industries, thus promoting a domino effect triggered by the circularisation of the economy in the territory. These social and business outreach activities contribute to increasing the dynamism and diversity of the local area by promoting virtuous circular dynamics based on knowledge transfer that are implemented through the development of university–industry–government collaboration projects that could serve as an incubator for CE enterprises. In this sense, a first group of articles exemplifies how HEIs can act as a catalyst of CE from a social perspective. For example, Bringsken et al. (2018) evaluate the policymaking process of a CE plan that aims to reduce the use of plastic in the bars and canteens of Portugal. De Medici et al. (2018) analize the fostering of the successful heritage-led urban regeneration of Syracuse port city (Sicily). Cerreta et al. (2021) evaluate the regeneration strategies of cultural heritage of Morticelli church, Salerno (Italy). Similarly, Christensen (2021) analyses how the role of multiple modes of governance can promote the recirculation of construction and demolition materials and waste textiles in the capital region of Denmark. Along the same line, Rigillo et al. (2018) aimed to prevent and manage waste flows in urban and peri-urban areas of Naples (Italy) and Amsterdam (the Netherlands). On their part, Keng et al. (2020) and Erälinna and Szymoniuk (2021) present experimental projects supporting the implementation of circular food waste treatment from landfill in Malaysia or the restaurants in Turku, Finland. Moreover, Newton and Frantzeskaki (2021) outline the multiple applications and expected benefits of a nationally networked digital urban collaboration platform (iHUB) engaging multiple stakeholders across government, industry, and community and co-developed by a consortium of five leading Australian universities with the aim of triggering and accelerating circular transformative change in cities.

A second group of studies focuses on the promotion of circular business models from a business perspective. The studies gathered in this block create start-ups or develop projects to aid companies and industries in assessing the potentials and pitfalls of CE, and to understand and map value in a broader context than that of the traditional economy. Similarly, Gao et al. (2006) explain the results of a university–industry–government project aimed at protecting natural resources and improving eco-efficiency practices for promoting CE in a Chinese development zone based on the underground brine chemical industry. Moreover, and in the context of promoting the establishment of CE within agricultural industries, Bas-Bellver et al. (2020) present the results of a Spanish collaboration project to successfully transform vegetable residues generated in the manufacturing lines of this cooperative by hot air-drying or freeze-drying. A last group of articles summarise the efforts of different universities to promote the development and establishment of circular enterprises. In this vein, Kumble (2019) reports how the University of Massachusetts tries to improve the living conditions in one of the most impoverished neighbourhoods in Guatemala City through job creation. Specifically, this initiative develops a start-up, built upon the pillars of CE, to make compost from the green waste generated by a large central wholesale market (CENMA). Sukiennik et al. (2021) explain the results of an international consortium of four universities aimed at strengthening the entrepreneurship within the Polish mining sector to meet the CE requirements. Finally, Lacerda-Fernándes et al. (2021) exemplify, using a long-term case

study, how to co-create a circular business model that facilitates access to clean water in the context of the Brazilian Amazon.

4.1.5. Campus management

This last category emphasises the relevance of campus management, which emerges by itself as an ideal testing ground for the development and implementation of circularity practices, as well as demonstrators of the successful implementation of these practices across their operations. More precisely, CE implementation enables HEIs to expand their potential for leading by example (Mendoza et al., 2019), thus significantly impacting the way in which upcoming generations will tackle CE issues in future (Ferronato et al., 2020; Hopff et al., 2019) through a bottom-up approach. An in depth reading of this category composed of 15 articles outlines two article subgroups that view circularity in campus development from different but interrelated angles. The first reports initiatives for the development, implementation, and coordination of a global and integral CE policy that serves as a guide to the implementation of campus practices, whereas the second primarily discusses the results of the development and implementation of particular circularity initiatives.

4.1.5.1. Integral CE policy development: this research line is composed of four articles published in 2019 and 2021, thus suggesting that the development of frameworks for implementing CE in the HE sector constitutes a research area that is in its infancy. Mendoza et al. (2019) is the pioneer on proposing a generic three-step methodological framework for the implementation of a CE strategy aimed at improving resource efficiency and environmental sustainability of campus operations that can be applied by any institution across the HE sector. Analogously, albeit adopting a narrower perspective, Hopff et al. (2019) develops an explorative research study to provide a framework for CE implementation based on four dimensions of campus development: organisation, use and function, spatial scale levels, and flows and materials. Finally, Mendoza et al. (2019a), in a case study examining the University of Manchester, reveals how HEIs can use an action-led step-by-step approach to implement CE thinking in practice. In this way, this paper tries to cover the lack of evidence of benefits and barriers to implementing CE frameworks in the field. More recently, Bakos and Schiano-Phan (2021) investigated how to develop an exemplary and innovative university campus in compliance with regenerative CE principles and bioclimatic design strategies. They defined a framework for a 'Circular University Campus' and established its main principles, that were subsequently tested at a student residence within an Indian university.

4.1.5.2. Clean energy and waste management campus initiatives: this research line is composed of 11 studies published in the last four years. Along this research line, we find, firstly, two articles (Ciugudeanu et al., 2019 and Beu et al., 2018) that present the results of an internal lighting efficiency project aiming to determine the energy consumption of a technical university in Romania. Another group of articles analyses the effect of implementing circularity practices for improving solid waste management on university campuses. The different areas of action involved in these studies vary from circularity practices to reducing water waste at the University of Santa Cruz do Sul (Brazil) (Colares et al., 2019) or organic waste at University of Venda (South Africa) (Owojori et al., 2021). Other studies are focused on recyclable selective waste management initiatives, with particular focus on plastic, paper, and cardboard waste (Ferronato et al.,

2020; Salguero-Puerta et al., 2019). Other papers explore the assessment of recycling small household appliances, stockpiling, and discarding habits among student households in the UK (Pierron et al., 2017), small-scale applications of waste management initiatives on two Australian university campuses (Fleischmann, 2019), or the reduction of food packaging in the food court establishments of a campus university in Colombia (Maruyama et al., 2019). Along these lines, the implementation of a reuse-based electrical and electronic equipment recovery system in studen halls of residence at the University of Southampton (Sitthu et al., 2021) or the circularity practices to recover food and gardening waste at the University of A Coruña (Spain) (Torrijos et al., 2021) have also been assessed.

4.2. Insights and research opportunities

To discuss the results further and identify which practices still need to be implemented or improved by HEIs for being recognised as a relevant actor by policymakers, industry, and society, we present the integrative Figure 3. This figure offers a comprehensive view of how each of the five active roles of HEIs (EMF, 2019), represented in the internal spheres of the figure, can contribute to supporting the three expected benefits of the transition to a CE, represented in the external spheres of Figure 3.

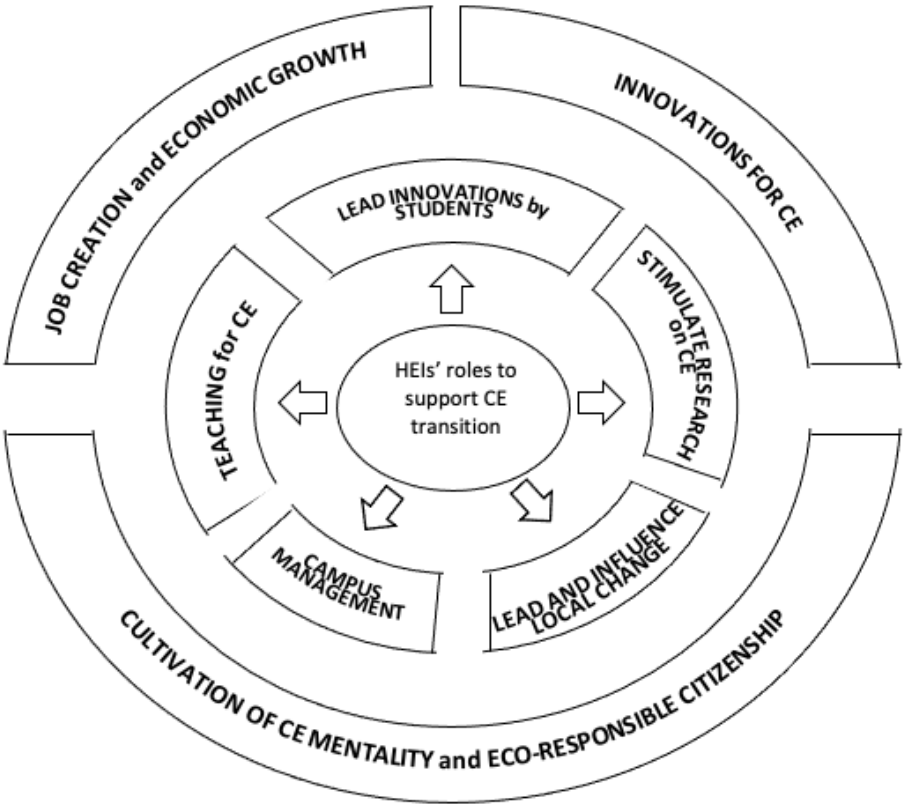

Figure 3. The role of HEIs on the transition towards CE

Therefore, the research gaps identified to map out future research agenda are grouped in terms of the three expected benefits derived from the transition to a CE. Below, a spectrum of useful recommendations unfolds:

4.2.1. Beyond engineering careers, new professional skills are required to support job creation and economic growth

HEIs, through teaching activities, play an active role in developing new competences, tools, and methods to offer the qualified professionals demanded by the green transition. However, the results of this review have ascertained that more research is required concerning which specific transdisciplinary CE competences and resulting learning outcomes need to be included to enrich HEIs' curricula. The scarce examples in the literature are almost exclusively related to the identification of competences in engineering curricula to promote CE design (Sumter et al., 2018; Sumter et al., 2020; Vera-Puerto et al., 2020), usually encouraging the use of LCA tools. Although CE design play a vital role in transforming current and unsustainable production and consumption patterns as it affects product manufacturing, distribution, use, and disposal (Friedman et al., 2015), this knowledge has to be completed with research aiming to provide a more complete picture in HEI curricula within other key disciplines for incorporating CE into society. This is because of the specificities of their products or value-chains or their environmental footprint, such as business management, sciences, architecture, tourism, fashion design, or geography, among others. All of them need to be addressed in a targeted way to ensure that the interactions between the various phases of the cycle are fully taken into account throughout the entire value chain.

4.2.2. Curricula reforms to support job creation and economic growth need to be accompanied by the implementation of new methodologies

HEIs need to be aware that any effective reform of curricula regarding CE needs a comprehensive reform of the methodological approaches used to learn to meet the challenges of disruptive times (Cother, 2020). In this vein, this review has identified successful and highly valued examples of the application of active-learning methodologies, such as applied learning or action research, that engage students in real-world CE challenges. These challenges are usually related to clean energy (Kilkis and Kilkis, 2017), water waste (Williams et al., 2018), upcycling, and redesign projects (Piekarski et al., 2019; St. John James and Kent, 2019;). Generally, these experiential, learning-by-doing initiatives, are positively valued by both companies and students. That is because they can contribute to the development of a CE mindset and a system-hinking approach to CE issues that may positively influence their attitude towards environmental issues and, in turn, their purchase behaviour (Morone et al., 2021), converting their purchase intention into a green premium purchase (Shao et al., 2021). However, further research is still needed regarding the development and testing of innovative methodologies to best approach education for CE in HE to equip students with the necessary tools to address real-world CE challenges, as well as to alter their prior assumptions about production and consumption processes. In particular, more studies reporting how CE must be diffused and widely supported in curricula with locally tailored cases and course materials that favour the integration of teaching and learning with the surrounding industry are required. Also, the existing knowledge about the application of

active-learning methodologies in CE courses, mostly focused on engineering and science courses of European universities, must be complemented and extended to other different disciplines and geographical contexts.

4.2.3. Involving students in real contexts provides industry with fruitful CE innovations

Empowering students to meet future challenges must be at the centre of pedagogical innovations for CE education. Different experiences reported in the literature include the use of living labs (Evans and Karvonen, 2014), as well as educational interventions involving students in applied research projects. These initiatives explore aspects related to urban design (Wandl et al., 2019), water (Mateus et al., 2019), the rooting capacity of innovative recycled materials (Rizzo et al., 2017), EEE waste management (Bonoli et al., 2018), textile printing and graphic design (Mansour et al., 2020), and end-of-term reuse schemes (Sanchez-Carracedo and Lopez, 2021; Williams and Powel, 2019). However, research about this topic is still very scarce and disperse, hence more research is needed to explore how to engage students in real-world contexts where collaboration with enterprises and local communities may help them to promote future circular innovative solutions and resource conservation. These additional contributions could help to extend the knowledge base for the treatment of such a complex problem, so that it could match the entirety of the aspects of the issues at hand.

4.2.4. R&D activities stimulate innovations for CE

HEIs can promote R&D efforts for the development of technological solutions that support the industrial sector's transition in its commitment to a CE model. However, this review still reveals a limited number of examples about this topic. The scarce existing literature is largely focused on the development of different technologies for food (Matrapazi and Zabaniotou, 2020; Vaskalis et al., 2019), plastic (Börühan and Ozbiltekin-Pala, 2021; Bianchini and Rossi, 2021; Kooduvalli, et al., 2021; Yeo et al., 2019) or rare earth resources waste recovery (De Sousa et al., 2021), and the design and construction of sustainable buildings (Korançe, 2021; Iuorio et al., 2019;). These projects are mostly the result of public funding that may come from several sources in Europe and elsewhere and would take its roots in North America as soon as government agency funding becomes inevitably available for research (Sikdar, 2019). In the EU region these sources include programmes such as Horizon 2020, the European Fund for Strategic Investments, Innovfin, and LIFE, among others. In the Latin American region, the Multilateral Investment Fund and other sources are provided by governments and financial institutions, such as the Inter-American Development Bank (IADB) (Silva et al., 2021) or the Corporación Andina de Fomento (CAF) Development Bank. In Asia the Asian Development Bank (ADB) supports different initiatives aimed at stimulating sustainable economic growth (ADB, 2017). In Australia the Lead-Educate-Assist-Promote (LEAP) programme, part of GISA's Business Sustainability Program of the government of South Australia, or the funding opportunities launched by NSW Circular, support businesses, universities, and research organisations ready to "take the leap" into the CE. In other contexts, such as Africa, the African Circular Economy Alliance (ACEA) has given rise to programmes such as the Africa Circular Economy Support Programme (ACESP) that funds CE entrepreneurs and activities in the countries that have joined the alliance. As a result, it can be expected that, as public funding and financial institution programmes are encouraged by different policymakers worldwide, HEIs' circularity innovations can be extended to all the industrial sectors, and particularly those identified as priority sectors

in the EC Circular Economy Action Plan (EC, 2020) or aimed at building a new sustainable "blue economy" (ADB, 2021). These include electronics and information and communications technology (ICT), batteries and vehicles, packaging, plastics, textiles or food, and water and nutrients. Within this line, research developed on HEIs may also contribute to advancing aspects such as the sustainability of renewable bio-based materials and energy (Angulo-Mosquera et al., 2021), circularity in a toxic-free environment (Van Dijk et al., 2021) or the analysis of environmental impacts and circularity potential of further product groups (Thonemann and Schumann, 2018), among others. This is a particularly interesting topic that requires more research.

4.2.5. Lecturers need to be trained to cultivate a CE mentality and eco-responsible citizenship

HEIs need to be aware that any effective reform of curricula regarding CE needs to be accompanied by the respective investment in teacher training, given the key role teachers play in building a circular society, as well as comprehensively reforming the methodological approaches used to learn. However, research on the development of contemporary and systemic pedagogical approaches aiming to prepare teachers to envision the CE systems and cultivate a CE mentality and eco-responsible citizenship is still scarce (Bugallo-Rodríguez and Vega-Marcote, 2020). In this context, more research is needed about how HEIs should advance the creation of training grounds through the design and evaluation of different teacher training initiatives. These can include peer-to-peer educational programmes or out-of-classroom learning, among others, to equip these professionals with the necessary skills to perform effectively, thus multiplying the positive effect of the CE-oriented curricula they deliver to their students. Thus, emerging initiatives such as EURECA-PRO, promoted by the EC to create a global educational core hub on SDG 12, or CIRCLE, can serve as examples to support trainers, teachers, mentors, and other professionals in promoting CE in other contexts.

4.2.6. University campuses can be ideal prospection grounds for the cultivation of a CE mentality and eco-responsible citizenship

The findings of this study identify several examples of implementation of partial CE initiatives in university campuses worldwide (e.g. Owojori et al., 2021; Ferronato et al., 2020; Colares et al, 2019; Salguero-Puerta et al., 2019). However, the development of an integral CE policy aimed at nurturing HEIs' internal stakeholders with more eco-responsible mindsets and circular habits constitutes a research area that is in its infancy (Bakos and Schiano-Phan, 2021; Mendoza et al., 2019, 2019a; Hopff et al., 2019). Circularity is an organisational issue that requires integral policy and specialised management to reduce complexity. Another challenge for HEIs is to prevent partial formulations that are not gradually and consistently developed with the circularity purpose set by the institution. Hence, more research is needed concerning the benefits and barriers of CE strategic plan implementation in university campuses, as well as the development of indicators that allow researchers to monitor this process, in line with a data-intensive approach to quantifying the material flows of university campuses (Stephan et al., 2020). Among the barriers identified are those related to the perceived increased upfront costs to build green versus conventional buildings (Hopkins, 2015), among other aspects. As a result, more research is needed to propose possible solutions to turn interest into adoption of green buildings in HEIs, such as the implementation of

grants and incentives that can decrease the upfront green premium and full building lifecycle cost (Hopkins, 2017).

4.2.7. HEIs can be a catalyst partner to businesses and government for the cultivation of CE mentality and eco-responsible citizenship

This review highlights that HEIs have worked in conjunction with their municipalities and local industry to promote virtuous dynamics based on knowledge transfer, effective public participation in strategic decision-making, and the incubation of CE enterprises. The solutions reported in the previous literature, albeit still in their infancy, have mainly focused on making our economies less wasteful and more resourceful. Thus, they include aspects such as the development of circular city models for port cities (De Medici et al., 2018) or urban and peri-urban areas (Newton and Frantzeskaki, 2021; Cerreta et al., 2021; Rigillo et al., 2018). Other aspects analysed include recovering and reusing materials and/or composting systems for organic waste (Erälinna and Szymoniuk, 2021; Keng et al., 2020; Bringsken et al., 2018), as well as initiatives implemented in industrial sectors such as chemical (Gao et al., 2006), mining (Sukiennik et al., 2021) or agricultural industries (Bas-Bellver et al., 2020). However, the results evidence that European universities are the most active. Therefore, further research is needed to highlight that HEIs can proceed to partnerships with local businesses gaining mutual benefits and introducing CE frameworks directly at the local and regional level in key priority sectors and other geographical contexts. As a result, they can contribute to the progress towards cleaner industry and improved environmental quality, as well as to the improvement of the living conditions of their territories. Moreover, a deeper understanding of motivations, activities, and results existing in this path, something vital to influence future strategic choices on the part of its partners and serving as a benchmark for other social impact businesses, deserves more academic attention to promote these co-creation processes.

5. CONCLUSIONS

The CE presents new production and consumption patterns and, along with them, challenges at all systemic levels. However, there is a lack of literature reviews discussing the critical role of HEIs in this new paradigm. Unlike previous studies, focused in the Latin American (Salas et al., 2021), or Italian (Giannocaro et al., 2021) contexts, or the "hidden curriculum" for supporting CE practices (Nunes et al., 2018), this work relies on the EMF to propose an integrative framework for illustrating the current insights and future potential of HEIs as a catalyst of the CE transition worldwide. The analysis points out to the fact that, although HEIs have stepped up efforts to support CE, they are not giving equal emphasis to all the roles proposed in the integrative framework. Thus, most of the CE initiatives developed by HEIs have focused on curricula reforms. However, research activities, government, and industry collaborations to extend the value and impact of their teaching and research to their respective communities, and campus initiatives to cultivate a CE mentality and eco-responsible citizenship appear to be underdeveloped.

The discussion of these findings put forward in Section 4 makes it possible to identify specific targets that can be addressed in the future. Moreover, it also provides a means for different key stakeholders to use this knowledge to inform their decisions. University managers and teachers can identify best practices (and less successful ones) for implementing CE, from which lessons can be drawn, whatever the geographical context. Industrial practitioners, consumers, and governments can also realise that HEIs are well

placed to collaborate with them to address any CE challenges with satisfactory results. Finally, policymakers and industry leaders can reflect on how they might engage with HEIs when developing agendas and macroeconomic policies to stimulate innovation and thereby to increase and accelerate the number of beneficiaries of the CE.

Despite these contributions, this paper contains certain limitations. This review may have ignored some relevant knowledge, as it focused only on peer-reviewed, English published articles available at the time of searching through one database (WoS). Although the search was followed by a complementary search process, different types of publications on the topic have not been included in our analysis, e.g. book chapters, conference papers, along with professional magazines and reports, that could be considered in future studies.

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