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University Contributions to the Circular Economy: Professing the Hidden Curriculum

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Abstract: In a world dominated by linear economic systems, the road to improving resource use is multi-faceted. Whilst public and private organisations are making progress in introducing sustainable practices, we ask ourselves the extent to which education providers are contributing to the circular economy. As engines for skills and knowledge, universities play a primary role in propelling circular economy approaches into reality and, as such, hold the potential for raising the bar on sustainable performance. A rapid evidence assessment (REA) was therefore undertaken to examine the interactions between university estate management and the circular economy. This assessment identified six pertinent themes: campus sustainability, the hidden curriculum, environmental governance, local impact, university material flows, and the role of universities as catalysts for business and examined 70 publications. A second part of the study reviewed the environmental activities of 50 universities ranked highly in terms of their environmental credentials or their environmental science courses. The results are presented and then discussed in terms of how universities can affect material flows, promote sustainability outside of the formal curriculum, and act as catalysts with business. The economic significance of universities provides an appreciable demand for circular products and services. Universities should develop "hidden curriculum" plans to promote improved environmental behaviours of staff and students. Universities can also catalyse a circular economy by working with business to improve eco-effectiveness as well as eco-efficiency. For example, projects should extend the focus from decreasing carbon footprint to achieving carbon positivity, from improving water efficiency to treating wastewater, and from recycling to reverse logistics for repurposing. Pilot projects arising from such work could provide valuable research bases and consultancy opportunities.

Keywords: circular economy; hidden curriculum; university estate; material flow; environmental management

1. Introduction

The dominant economic system for many industries is an unsustainable linear process of take, make, use, and dispose [1]. In addition, the process of extraction, transformation, and disposal of materials is challenged by volatile prices for raw materials due to real or perceived scarcity [2]. Many current business models also result in products that have no end of use value or incur a financial or environmental cost.

Improved eco-efficiency is one way to address the negative environmental effects of the linear economy, through approaches such as the use of the waste hierarchy or the 3Rs of reduce, reuse and recycle. These approaches can reduce the extent of environmental damage and provide additional income streams for businesses. However, the overall process can still cause, albeit at a lower level, resource degradation and environmental damage through, for example, the use of toxic chemicals [3].

A focus on initiating positive activities, in addition to creating less harm, is captured in the term eco-effectiveness. An eco-effectiveness approach includes the identification of a desired positive outcome and then focuses on the development of products and industrial systems to achieve that target [4]. Braungart et al. [5] explain that the goal of eco-effectiveness is not merely to minimise the cradle to grave flow of materials, but to generate new sustainable cyclical cradle to cradle processes that can enhance the quality of resources. They [5] use the analogy of "metabolism" to describe these processes drawing inspiration from the way, for example, organisms in an ecosystem can continually cycle nutrients. The cradle to cradle design framework has also identified that it is useful to separate natural resources (such as wood and food which can be readily and safely re-incorporated in natural ecosystems) from technical resources (such as plastic or metals which can be toxic and damaging in the wrong place).

The focus of this paper is on the promotion of the circular economy paradigm which draws on the ideas of eco-efficiency and eco-effectiveness to provide an alternative to a linear economy approach. In fact, Murray et al. [6] argue that the term circular economy has gained substantial traction primarily because it is a clear antonym to a linear economy. Although there is no single definitive definition of the circular economy, it builds on many of the concepts of eco-efficiency and eco-effectiveness (Table 1). The Chinese government has used the term to describe their approach to address unsustainable production and consumption by drawing on industrial ecology and life cycle assessment [7]. WRAP in the UK [8] uses the term to describe an economy in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life. One of the key organisations promoting a circular economy is the Ellen McArthur Foundation [9]. They define a circular economy as an industrial system that is restorative and regenerative by intention and design. They also outline that the circular economy creates four opportunities for value creation through minimising material use (e.g., efficient cycles), maximising material use (e.g., long cycles), having diversified options (e.g., multiple cycles), and the benefits of ensuring uncontaminated material for reuse (e.g., pure cycles). The last point builds on the cradle to cradle approach in that products should be based on homogeneous materials or built for disassembly so that man-made or technical materials can be reused and biological or natural materials can be cascaded.

The circular economy approach also provides opportunities for new business models (such as product leasing, targeted reverse logistics, and remarketing) which recognise the value of the resources embedded within products whilst at the same time offering a better service to the user [10,11]. The circular economy approach is also convergent with the broader requirements of sustainable development listed by Hopwood et al. [12], as it promotes better use of finite resources, increases the resilience of the economic system, increases job opportunities [13], and encourages developments in technology and business studies [14]. Companies implementing the circular economy concept can increase profitability by reducing the costs and the cost variability of raw materials. For example, the Ellen MacArthur Foundation [15] forecasts global material savings valued between $595 and $706 billion per year for fast-moving consumer goods and profits of $172 per tonne of food waste from the transition towards a circular economy.

Table 1. The circular economy approach builds on the concepts of eco-efficiency and eco-effectiveness.

Approach	Definition
Eco-efficiency	The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the Earth's estimated carrying capacity [16].
Eco-effectiveness	Rather than just focusing on minimising harm, eco-effectiveness seeks to identify the desirable ecological aspects of products and systems (e.g., enhance the quality of materials) and then defines and implements a strategy to achieve that target [3,4].
Cradle to Cradle	Cradle to cradle production is an approach of intelligent material pooling to achieve eco-effectiveness by viewing all material inputs and outputs either as technical or biological nutrients. Technical nutrients need to be cycled in different streams to biological nutrients which can be readily reintegrated in natural ecosystems [5].
Circular Economy	The antonym of a traditional linear economy (e.g., take, make, use, dispose), which aims to be restorative and regenerative by designing for material reuse, minimising material flows, keeping resources in use for as long as possible, and regenerating products and materials within each cycle [5,8,9].

Universities play a primary role in propelling new frameworks for managing resources and turning them into a reality. However whilst public organisations and private businesses are making progress in introducing circular economy practices, the extent to which education providers are contributing is unclear. Kopnina and Meijers [17] proposed a framework for using circular economy concepts to embed sustainable development in education environments, but the focus of this research was restricted to early formative years only.

A university's direct impacts can include making the local area more dynamic and diverse by increasing employment and creating income and expenditure flows. It also indirectly impacts local areas by generally upgrading human resources and attracting business in education-related activities [18–20]. One economic assessment found that the university sector accounts for 2.7% of all UK employment and generates 2.8% of its GDP based on both on and off campus expenditure [21]. This gives universities the potential to play a key role in the local and regional uptake of circular economy approaches.

Various studies have examined how universities can support sustainable development through formal learning outcomes. Khalili et al. [22] conducted a study to determine how education could develop capabilities for sustainable development and cleaner production. It explored the requirements for the creation of academic programmes in various areas of knowledge that would support national sustainable development goals. In a separate study, Barth [23] highlighted how student-led change from formal and informal learning, sustainability in campus operations, and branding the 'green university' were key factors for embedding sustainability in education. However few studies have focused on the "hidden curriculum" and the role that universities, as part of the local economy, can assume in implementing the sustainability practices they teach. The hidden curriculum is defined as the difference between the actual learning and the curriculum-based learning in the personal student experience within an educational facility [24–26].

There is also relatively little literature on the role of specific circular economy approaches in university estate management; most of the literature focuses on the role of university estates in reducing environmental impacts. The aim of this paper is therefore to detail, analyse, and critique the contribution that universities can bring to the circular economy by addressing three gaps in the literature. The approach used was to undertake a rapid evidence appraisal, a review of material from selected universities, and the results are then examined in relation to three research questions:

1. What are the material flow transformations that a university estate can develop within the context of the local circular economy?
2. How can a university effectively use and train human resources outside of the formal curriculum?
3. How can a university catalyse circular economy activities in industry?

2. Materials and Methods

2.1. Rapid Evidence Assessment

In order to bridge research gaps and address the aim of this paper, a question-led, rapid evidence assessment (REA) was conducted. The approach allows the efficient synthesis of evidence and critical assessment of available research in a subject area by focusing on a relatively narrow topic area [27,28]. Unlike some systematic reviews, a REA can pre-specify criteria (e.g., only peer-reviewed) for what evidence may be included. The approach is considered more efficient than traditional systematic reviews by limiting the breadth or depth of the process whilst maintaining the same level of quality criteria in assessing evidence [29,30]. In this study, the initial scope of the study focused on the interactions between university estate management practice and circular economy theory (Figure 1).

The primary literature chosen to create a broad framework for performing a REA was Thomashow's *The Nine Principles for a Sustainable Campus* [31] and the factors highlighted by Barth [23], since it focuses on practical experience and academic research. The framework included the content prepared by the Ellen MacArthur Foundation in the form of their "Towards the Circular Economy" reports [9,15,32] and "A New Dynamic: Effective Business in a Circular Economy" [33] to discover the aspects of university management overlapping with the circular economy topics. This initial analysis identified six themes including "campus sustainability", "the hidden curriculum", and "environmental governance". The themes of "the local impact of universities" and "university material flows" focused on the role of universities both as education institutions and economic entities. Finally the operation of "the business in a circular economy" was assessed in terms of its importance towards the university sector and wider society (Figure 1).

Using a series of keywords related to the six themes (Figure 1), the academic search engine Scopus was used to identify 150 pieces of relevant literature. These were then reduced to 70 studies by only including (i) papers appearing in journals with an impact factor cited by the Web of Science, (ii) books receiving a high level of citation on Google Scholar, and (iii) publications relevant to the topic of study. The initial lessons derived from these publications are reported in the initial section of the results.

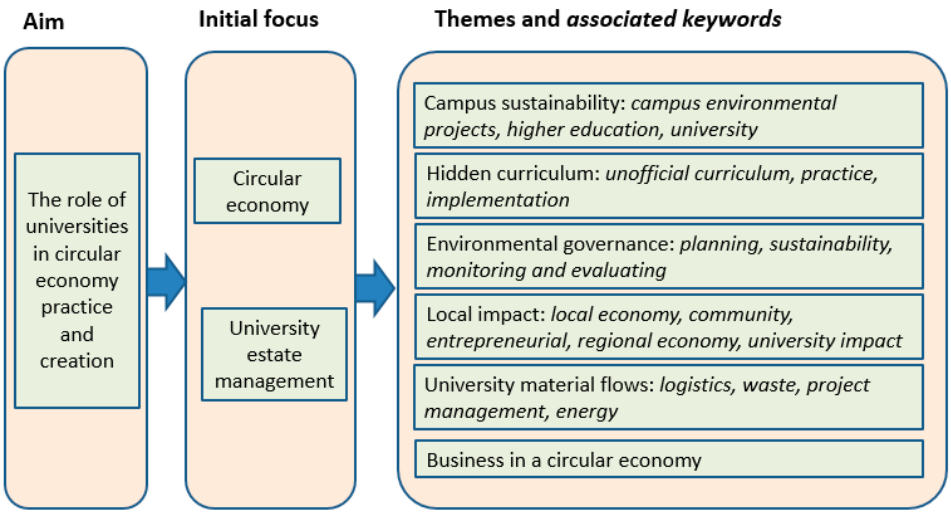


Figure 1. The aim of the rapid evidence assessment, the initial focus, the six identified themes, and choice of identified keywords for the literature review.

2.2. Engagement of Universities with the Circular Economy

Following the implementation of REA, the research set out to gauge how universities practically engage in the circular economy at an operational level. The databases of two global ranking systems were used to understand university environmental practice in sector-leading educational institutions. The UI GreenMetric® [34] was the first global ranking of the sustainable behaviour of universities [35] and was chosen for being the most complete and up to date list that was publicly available. QS© Top Universities© [36] details the global top universities for a range of subjects. Although there are other global rankings (e.g., Shanghai Rankings and Times Higher Education); the QS© list was chosen as it allowed a specific focus on "environmental science".

We started by identifying the top global universities in environmental performance according to the UI GreenMetric® from 2013 [34], and the top global universities teaching environmental science according to QS© Top Universities in 2013 [36]. In order to identify the relationships between a high ranking for environmental performance and a high ranking for teaching, we reviewed the reported environmental activity of the six universities that appeared in the top 50 of both lists. We then explored the reported activity of another 10 universities placed in the top 50 of one list who appeared in the second list, and lastly the remaining universities in the top 25 of either list. This yielded a total of 50 universities, following the elimination of three universities (Chulalongkorn, Kyoto, and Stockholm) due to lack of available information in English. The list of universities and the reported activities reviewed are provided in the Appendix A.

3. Results

3.1. Rapid Evidence Assessment

The results from the REA of the interaction between universities and support for a circular economy results can be explained in terms of social benefits, the need to monitor assets and flows of energy and materials, the importance of management, the delivery of knowledge, and financial support for innovation. These results are discussed in turn.

The evidence gathered in the REA highlighted that tackling university sustainability must include social, economic, and environmental considerations [37]. On the social side, the literature suggests that high standards for staff and students' physical and mental well-being should be reflected in university strategy and action [31,38]. It is further suggested that empowering a heightened understanding of individual and university impacts on the environment by implementing a 'good-living campus' could cause a more optimistic outlook and foster holistic approaches to environmental problem-solving [31,37,39,40].

It is argued that a circular economy approach requires universities to recognise and start monitoring all assets—natural, financial, social, and intellectual—their use, appreciation or depreciation, and their impacts [15,27,31,41–43]. One method of enabling this is the 'input-output' method proposed by Li [44] and Fry et al. [45] which can capture processes and impacts across entire supply-chain networks underlying, in this case, the operations of a university. Input-output techniques can reveal influences and impacts that lie hidden in distant upstream supply-chain segments, and are thus usually not clear and/or accessible to decision makers, as demonstrated in an institutional footprint study at the University of Sydney, Australia [46]. The impact of particular products can be assessed through life cycle assessments. However, strategists should be mindful of potential rebound effects and a whole system approach should be adopted to mitigate against undesirable consequences of implementing circular economy actions [47].

Energy is one of the most important flows affected by universities. The Carbon Trust [48] reports that two-thirds of all energy consumed by the higher education sector is produced from fossil fuels, largely required for heating and lighting; this compares with UK fossil fuel dependency of about 87% as of 2012 [49]. Funding sources such as the Revolving Green Fund [50] can help in the transition away from fossil fuels. For example, it has funded the biomass boiler used to power heaters at Cranfield

University and the refurbishment of a small-scale hydropower facility at the University of Chester. While being individually small, these financially-viable solutions help progress the sector. Another similar programme in the UK is the HEFCE small-scale energy efficiency programme which supports projects with a mean payback period of less than 6.5 years; the mean for successful projects has been 4.5 years [51]. Lighting and heating comprise 80% of energy use in higher education institutions, so monitoring, infrastructure improvements, renewable heat improvements, and feed-in-tariffs could all play a role, and the government can provide subsidies for selected projects associated with businesses in the UK [52–55].

University management can also affect the flow of materials on campus, in particular in the areas of estate management and service provision [56]. In terms of procurement, incentives for good environmental performance by suppliers needs to be translated from vision to investment throughout the value chain [57]. Supplier dependent firms that invest in procurement partners can especially increase bargaining power, improve relationships and drive down costs [58–60]. Two focus areas in terms of sustainable food sourcing are working with multiple stakeholders to offer choice and benefits, and overcoming the lack of distribution networks [61]. Incentivising local and sustainable food chains, on campus and within the community, can promote healthy lifestyles and diets amongst students [31]. Involving student organisations can promote uptake and coherent behaviour beyond the university's grounds [31,43,62]. In short, the development of a circular economy approach to food systems is reported to require communication, engagement, and implementation at all levels [15].

The management of innovations can also be important. Environmental management systems, like ISO 14001, that focus on resource conservation and waste reduction have helped to ensure that 88% of UK universities had recycling schemes in place by 2007. However, there were substantially lower proportions of universities who had reuse and composting schemes in place (57% and 33% respectively) [63–65]. It is a requirement of environmental management systems that managers commit to continual improvement of environmental standards including recycling, reuse and refurbishment [66]. However, as discussed in Section 1, there is a risk that the emphasis is placed on doing things that are simply 'less bad', rather than delivering positive benefits. Ghosh et al. [67] report that when undertaking sustainability projects it is helpful to clearly distinguish between the creation of the vision and implementation. One common approach is that a project management team first plans and details all specific projects, and the planned projects are then progressed by implementation teams. Monitoring and feedback loops between them will improve the effectiveness of integration and quality of delivery, abating future project risks, and increasing economic viability [68,69]. For breakthrough projects, such as circular economy buildings and products, decision-making also needs to include lateral stakeholders, especially users, to decrease adoption risks [70–73].

As a university's main role is in accreditation and transformation of knowledge into innovation, it is desirable that universities engage individual students in the process [56,73,74]. Even old buildings that are not up to sustainability standards can provide a useful learning experience [75], and they can provide platforms to demonstrate the feasibility of curriculum content, and student engagement in the process can further enhance learning [40]. An important responsibility for the hidden curriculum lies with the teaching staff, as they create the context and meaning of the field of study, shaping the information to transmit its importance and maturity [76]. Even so, the students' perception of the staff, the learning environment, and the social environment play a considerable role in how the hidden curriculum is received [77]. While the social environment is particularly hard to control, incentivising and communicating extracurricular activities could enhance soft skills and enhance employability [26,31,78]. In this aspect, partnerships with companies to either complement or overlap knowledge bases can be beneficial [79].

Lastly, the review highlighted financial mechanisms that appear to support the uptake of circular economy approaches. For example modular budgets [31], which are a part of some university endowments, can provide baseline sums in multiple instalments without needing a detailed budget. The mean value of such budgets across UK universities was about £1.7 million in 2012–2013 [53]. A

second approach is a bank loan, which is paid back as the investments results in increased revenue or savings [31,54]. A third approach is a revolving loan based on a fund, where all returns on investment are returned to the fund to be reinvested in relevant projects [54]. These mechanisms are supplemented by government funding [50], as well as public-private financing [55]. With correct planning and environmental goals, circular economy projects could be candidates to receive all three types of funding.

3.2. Global Implementation of Sustainability Strategies in Universities

Most of the 50 universities included within the study, and derived from the two selected ranking lists from 2014, had plans focused on energy efficiency (48) and the reduction of carbon dioxide (43) (Figure 2). By contrast, only 23 universities had a climate action plan, with 11 universities seeking to reach carbon neutrality. The great majority of universities (42) detailed waste management plans, including the diversion of waste from landfill through recycling. There were 32 universities seeking to reduce water use, with 12 focused on the positive impacts of recycling wastewater. Approximately half of the universities (27) were generating at least some of their own energy, often with the primary goal of limiting environmental damage and cost savings. Student-led sustainability projects were an underdeveloped area, as only nine universities were providing incentives for such projects.

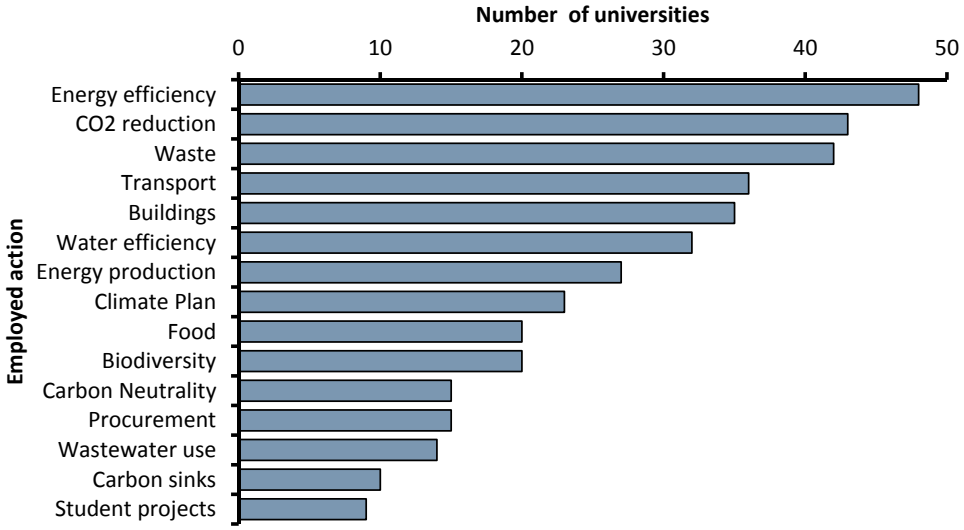


Figure 2. Results from the data analysis of the focal points of environment practice for 50 universities.

The three universities excelling in both environmental education and education had CO_2 reduction goals (see Table A2 in Appendix A). Many of those ranking high on the GreenMetric® (see Table A3 in Appendix A) were also aiming towards carbon neutrality. Within the 50 selected universities, 27 universities were producing, or had the intention to produce, energy on campus; 36 had produced transport CO_2 reduction methods; while only 15 were focused on carbon sequestration. In total, 30 of the universities studied reported on energy reduction in buildings, 20 had considered sustainable food policies, and 15 had taken a holistic approach for sustainable procurement.

As indicated by the REA, a sustainability mindset can bring positive action and can help people understand how environmental and business practice can improve resource optimisation. The sample provided examples of where a focus on costs and/or resources has led to solutions that are compatible with a circular economy. The grey water harvesting solutions of the Universities of Ottawa [80] and Nottingham [81] are examples that take the full lifecycle of water into consideration. The re:centre building at the University of Bradford [82] is an exemplary demonstration of where a sustainable

lifecycle has been planned at a university. The building includes a material bank that can allow a circular flow of resources.

The ranking of universities in terms of the reputation of their environmental courses (according to QS©, as of 2013) was not necessarily consistent with their environmental performance. This could be because older universities (which often have more highly-rated courses) may be responsible for older and more inefficient infrastructures, high costs of refurbishment, and a stronger division between education and estate management. By contrast, universities highlighted in the GreenMetric® list seem to understand the advantages inherent in cost and resource savings. They also appeared to make good use of new funding mechanisms, and made productive use of students and the estate to co-create environmental benefits.

4. Discussion

Having completed the REA and an assessment of the activities of universities with highly ranked environmental credentials and/or courses, it becomes pertinent to identify potential ways forward. This is done in relation to how a university can address the following three objectives: (i) to develop material flow transformations, (ii) to effectively use and train people outside the formal curriculum, and (iii) to catalyse circular economy activities in industry (Figure 3).

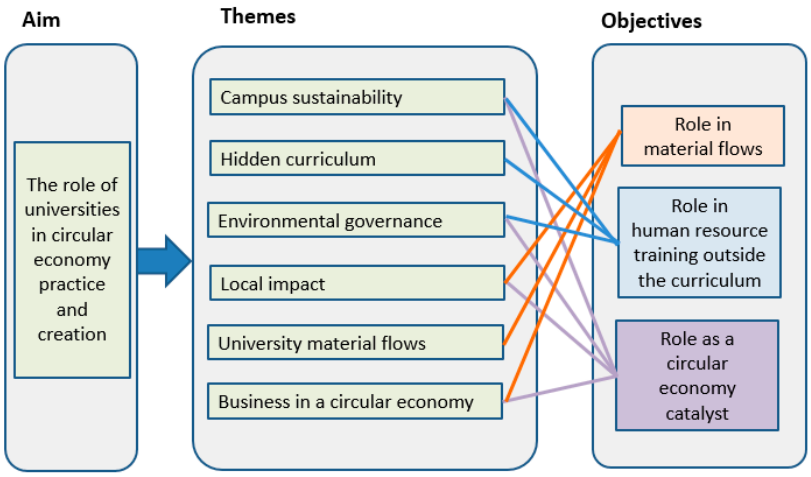


Figure 3. The results from the six themes of the rapid evidence assessment feed into three research objectives.

4.1. The Role of a University in Material Cycles

Universities seeking circular material flows need to address procurement and waste management across the entire value chain. This can be policy and target-driven or driven through in-depth conversations with suppliers, partners, and contractors. The former top-down approach can create more clarity and direction with the university being the end user in the system, however the latter allows more inclusive solutions and the co-designing of the standards. Discussions with stakeholders could help ensure that purchased products were designed for disassembly and with non-toxic materials. This could be supported by policies for major reductions in the amount of material sent to landfill, as well as ensuring cleaner streams for upcycling. Service and repair contracts can be used to create reverse logistic flows which provide incentives for the re-use of products or services. Such a holistic approach would allow various material cycles without loss of quality.

Important areas for focus include food, energy, and water use. Biological and food waste can be used within composting and anaerobic digestion projects to promote the reintegration of waste streams. Involving all relevant stakeholders on campus is recommended to match behaviour with ways of maximising the value of the food waste. Such comprehensive reverse logistics would also

help set expectations for any new partners or tenants. Circular economy approaches to lighting and heating include the use of renewable energy. Circular economy approaches to water use include wastewater treatment, grey water harvesting, and water efficiency solutions such as 'smart' facilities (i.e., automated taps and smart flushing in toilets). Using these would ensure some autonomy, while reducing bills and decreasing losses.

4.2. Human Resource Development outside of the Formal Curriculum'

Universities can enhance their capital by investing in the right assets [55], and providing training grounds in sustainable development where future leaders can become environmentally conscious. This should include both a focus on eco-efficiency and eco-effective transformational actions that are 'good' for the environment. Education is needed about the benefits of recycling, the greater returns associated with re-use, and the importance of biological flows. In order to achieve this, universities need to embed local development in their strategies and to combine on-campus projects with a robust curriculum and community action. There is also a need to educate managers, staff and students on the different approaches to sustainable development and their outcomes [74,80,83,84].

To understand the impact of universities in preparing their students for a circular economy, the role students will play in a university circular economy must also be understood. Bartolomeo et al., [85] argue that a lack of understanding about life cycle costs is a barrier to sustainable development, which stops businesses and consumers from seeing the benefits of circular products. Changes in staff and student behaviour around products and their disposal are also needed in order to complement the efforts of the university estate. Feedback should be provided on sustainability initiatives; as such awareness can increase the willingness to participate in projects. This communication of environmental practices can also be extended to visitors.

The literature underlined the importance of involving students in campus environmental plans, but only 9 out of 50 universities assessed currently do this. This figure needs improving to obtain advantages for student development, employment and well-being. An effective way for universities to promote initiatives that can shape student experience and learning for professional life is to implement a hidden curriculum plan. Such a plan, based on alumni feedback, could frame desired skills and behaviours for future careers, and improve the external image of the university. This plan could incorporate goals for mainstreaming leasing models, where the user of the product need not be the owner [86].

Buildings can provide good tools to increase knowledge about the circular economy. Building standards such as the Building Research Establishment Environmental Assessment Method [87], can be presented as good examples. Explaining circular building operations and lifecycles would help enhance students' expectation of the environmental performance of the built environment. Similarly, recycled, refurbished or repurposed products can be promoted in a positive way to encourage acceptance. However if done incorrectly, surrounding students with remade goods could be seen as an imposition rather than a positive choice.

A revolving fund for students and researchers to start their own projects based on a circular economy rationale, could serve as an incubator for sustainable enterprises. Repairing facilities for goods such as electronic items could motivate students. This could provide an area for small repairs to be performed by students for students, supported by tools such as iFixit® [88], or for student hall procurement. Student participation would be encouraged by the prospect of a new source of revenue. This would enable students to have a positive impact on campus services, as well as enhance skill-sets by preparing them for management, visioning, prototyping, and leadership with a circular outlook.

Finally, the hidden curriculum plan should also tackle campus life in a healthy environment that fosters good behaviours to enhance biological cycles. As it was found that quality of life and physical and mental health are important parts of a sustainable campus, increasing healthy food offerings and easy daily exercise options would be beneficial.

4.3. The Role of a University in Catalysing the Circular Economy

The third objective of the work was to examine how a university can catalyse circular economy activities in industry. Collaborations between businesses and universities to promote circular economy activities can be encouraged by third organisations and funding schemes. For example the CE100 Annual Summit organized by the Ellen MacArthur Foundation brings together commercial companies, students, and universities [89]. The UK Government [90] and the European Union [91] also have funding schemes to enable universities and business to work together to create innovations for the circular economy.

At a local level, universities can also start partnerships with local businesses that would enable benefits to be shared and two-way support with implementation and financing. Local circular partnerships can be mutually-beneficial cutting material costs or providing a new income flow. A holistic approach could be needed to start such intra-partner investment in order to identify the long-term benefits that can enable investments to be recouped through improved service provision, returns on investment, and savings. Again, funding mechanisms can support such initiatives, such as the revolving green fund of the Higher Education Funding Council for England (HEFCE) which support circular projects, such as combined heat and power systems [50] that mobilise local economies. The need for holistic thinking is also needed in the construction or refurbishment of buildings. Cost-benefit analyses of buildings' lifecycles become crucial for circular economy infrastructure. However, building upgrades are often only sought if they show a positive net margin. With the context of a circular economy, buildings should be constructed with the aim of reducing energy consumption as well as planning for the disassembly of materials in the long term.

A university can be a key local, regional, or national partner for research and development of practical solutions that enhance a circular economy. It can leverage funding for the creation of new products, develop business models to fit in reverse operations, and influence user behaviour. It can contribute to increased use and retention of biological nutrients to support farming and forestry sectors, and it can advance technology to support transition. Such changes in the management of the waste streams in campuses and university buildings requires planning, and users must be thoroughly informed of waste disposal procedures.

The analysis of ranked universities showed that whilst there was significant evidence of universities undertaking activities to reduce their overall environmental impact, the majority of initiatives focused on energy and resource efficiency and/or reduction. Further initiatives are needed to encourage universities to develop an eco-effective mindset and to invest in those circular initiatives that could result in positive socio- and environmental outcomes.

If universities are used as pilot testing grounds for sustainable innovations, then research to enable data gathering, analysis, and reporting is needed to enable the effective up-scaling of the results. There could also be useful research in user behaviour and the identification of pathways to foster the relationship between service provider and user should build on best practices from the disciplines of psychology and business management. Studies into how such pilots affect university educational performance and student experience could further support the justification of such research.

4.4. Limitations

This analysis of the activities of the 50 universities reviewed in this study was completed in 2014, and largely based on reports produced in 2013. Although, universities have continued to advance their environmental sustainability, this study still provides a useful baseline for further analyses. It should also be noted that there are limitations on the rankings used to identify the 50 selected universities. The GreenMetric and QS lists are not definitive and additionally environmental science is not taught at all universities therefore the research presented reflects sustainable practise at a pre-defined group of universities. Further research is required to assess whether the findings of the research can be generalised across the higher education sector.

5. Conclusions

The vision of a circular economy is that key non-renewable resources should be used sustainably, and this involves different parts of the university working together and with others in a symbiotic way. There are multiple areas in which universities can target operations and research, complemented by suppliers from multiple sectors and government institutions. This paper presents a novel investigation of how universities are embedding circular economy approaches. It has focused on universities' material cycles, human resources development outside of the curriculum, and the university's role as a catalyst for circular economy approaches in industry. The three key conclusions and associated recommendations are:

(i) Universities need to progress their sustainability plans if they are to fully contribute to a circular economy. This is particularly the case for the strategic and environmental plans that shape the operation of universities. The use of life cycle assessments can help universities quantify the environmental impacts of different circular economy strategies. Working groups should be created that can identify, enable, and organise finance for potential improvements in material flows. Projects must shift their focus to address eco-effectiveness as well as eco-efficiency, for example from decreasing a carbon footprint to achieving carbon negativity on campus, from increasing water efficiency to treating wastewater, and from increasing recycling to implementing symbiosis and reverse logistics.

(ii) Many universities are using a circular economy as a focus for both teaching and research. However the development of a hidden curriculum plan would further enhance sustainability strategies and learning in practice by encouraging sustainable consumption and behaviour. Promoting new circular economy enterprises on campus could enhance student skills through involvement and portray sustainable commerce as a realistic business opportunity.

(iii) There are real synergies to be gained from universities engaging with industry partners already pursuing sustainability strategies. The potential rewards include reduced long-term costs for the university, enhanced reputations, and funding opportunities.

In summary, the changes in design, manufacturing and services associated with a circular economy create resource, research and business opportunities. Agile universities can play a key role in helping to promote circular economy approaches by engaging their students and being a key partner with both public and private organisations. This paper highlights how universities have the power to alter procurement policies and thereby material and product flows, the demand power to scale products and services, and the influence to disseminate it through their graduates, local communities and wider society.

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Appendix A

Table A1. Universities that rank in the top 50 of both GreenMetric® (2013) and QS© list for environmental science (2013).

University	Green Metric® (2013)	QS© (2013)	Activities
University of California Davis	9	12	Improving buildings (energy efficiency, water, waste), imbedding in new build, reduce energy use, replacing fossil fuels for renewables, travel emission reductions, carbon sequestration.
University of California, Los Angeles	11	33	Energy efficiency in existing buildings and new, expansion of renewable energy portfolio, cap-and-trade, fleet transformation off fossil fuels, sustainable food procurement, water efficiency.
University of California, Berkeley	14	1	New build minimising energy and water consumption, and involving sustainable design principles including material fully life costs. Water use minimisation driven by residence halls, procurement of environmentally friendly products, sustainable food purchases at 28%, fuel used by commuters and campus fleet reduced by 50%.
University of Melbourne	18	18	New buildings all qualify for 5-star green design ratings. 24% reduction in energy; 49% reduction in net energy related carbon emissions; 38% reduction in water usage; 41% recycling of waste; and Development of a Green IT program.
University of Washington	28	48	Student lead projects through Campus Sustainability Fund with awards between \$250 and \$100,124. 8%. CO_2 reduction achieved, commuters driving alone to 19%. 59% of sustainable foods, waste diverted from landfill at 58%. \$13.1m in utility savings, cooking oil to biodiesel conversion.
National University of Singapore	44	19	Reduced plastic bag use by 80% by charging for them, increased recycling streams, 13 buildings awarded for environmental performance. 70% of staff and 75% of students on board with environmental practices, including inter-hall competitions for waste reduction.

Table A2. Universities that feature in the top 50 of the QS© list (2013) and also feature anywhere on the GreenMetric® list (2013).

University	Green Metric®	QS©	Activities
Georgia Institute of Technology	64	44	9 LEED certified buildings; retrofitting 64 campus buildings with energy and water efficiency; 46 more buildings to reduce energy use by 15%; 500kW of solar PV on campus in 2012; a geothermal heat pump.
Kyoto University	206	45	Energy reduction and yearly environmental reports and a long term plan.
Stockholm University	190	47	Information available through further contact, no translated information available.

Table A3. Universities that featured in the top 50 of the GreenMetric® list (2013) and on the QS© (2013) list.

University	Green Metric®	QS©	Activities
University of Nottingham	1	101–150	Improvements in recycling rates from 4% to 29% in (clean recycling streams) and 85% by 2012 (including separation by waste contractor). Water savings by urinal controls, leakage detection work, and grey water harvesting.
University College Cork National University of Ireland	2	151–200	Achieved an increase in the campus recycling rate from 21% to 75% in 2013, a 9% decrease in total energy consumption. Staff choosing to cycle to work to 12% in 2012; a saving of €1,000,000 on waste costs over the last 6 years; a saving of over 750,000 cubic metres of water saved since 2007.
University of North Carolina, Chapel Hill	8	51–100	Green roofs, also used as water filters and buffers; 12% reduction in building related GHG emissions; 33% reduction in energy since 2003; all new buildings have LEED Gold certification; 23% less petroleum use since 2005; 42% of waste diverted from landfill; 25% of local or sustainable food in dining services, and 13% also organic.
Universiti Putra Malaysia	16	101–150	Environmental conservation through use of local species; promotes the use of bicycles and biodegradable materials on campus; certified ISO 14001: 2004 and must continuously improve environmental practice because of it; amongst many other solutions.
University of Ottawa	25	151–200	Community gardens establishment; Fair Trade campus; furniture and goods reuse programmes; campus wide bicycle lanes with repair stations on campus; improving lighting on campus with sensors; implementing waterless urinals; eliminating bottled water; increasing grey-water capacity; 51% waste diverted from landfill (2011); responsible irrigation; use of drought resistant native plants; carpooling, discounted transit passes, bicycle incentives, and shuttles.
University of Massachusetts, Amherst	37	101–150	Campus permaculture initiatives; Sustainability Innovation & Engagement Fund; 27% CO_2 reductions since 2004; central heating plant (mostly burning natural gas) reduces 30% of GHG emissions; incentives for electrical car buying and charging stations; bicycle and car sharing incentives; composting widespread; reclaimed water; low flow water fixtures widespread; single stream waste recycling.
Chulalongkorn University	50	101–150	Activity exists, but non-discernible, not easy to find.

Table A4. Top 25 QS© ranked universities (2013) in environmental science programmes, which did not rank on the GreenMetric® (2013).

University	QS©
Stanford University	2
Massachusetts Institute of Technology	3
Harvard University	4
ETH Zurich	5
University of Oxford	6
University of Cambridge	7
Imperial College London	8
The University of Queensland	9
Wageningen University	10

Table A4. *Cont.*

University	QS©
University of Michigan	11
Yale University	13
University of Wisconsin–Madison	14
Cornell University	15
University of British Columbia	16
Delft University of Technology	17
Tsinghua University	19
University of Toronto	21
University of Sheffield	22
Australian National University	23
University of Colorado Boulder	24
The University of Tokyo	25

Table A5. Top 25 GeenMetric® ranked universities (2013), which do not rank on the QS© ranking (2013) of top environmental science programmes.

University	Green Metric®
Northeastern University	3
University of Bradford	4
University of Connecticut	5
Université de Sherbrooke	6
University of Plymouth	7
North Carolina Agricultural & Technology State University	10
University of Alcalá	12
York University	13
University of Bath	15
University of California, Merced	17
Bangor University	19
Linkoping University	20
University of Sussex	21
Virginia Commonwealth University	22
National Taipei University of Technology	23
Universidad Autónoma de Madrid	24

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