Supporting the Transition from Linear to Circular Economy Through the Sustainability Protocols

Isabella M. Lami, Francesca Abastante, and Marika Gaballo(✉)

Interuniversity Department of Regional and Urban Studies and Planning (DIST), Politecnico di Torino, Viale Mattioli 39, 20125 Turin, Italy
{isabella.lami,francesca.abastante,marika.gaballo}@polito.it

Abstract. The significant paradigm shift that contemporary cities are experiencing in terms of economic, social and environmental issues frames the particular urgency of a transition towards more sustainable urban systems.

In this context, the Ellen MacArthur Foundation (EMF) has begun to explore the possible applications of the circular economy (CE) principles and objectives within cities, promoting their relevance among city policy makers in order to address sustainable urban planning and design issues. In particular, the EMF emphasizing the importance of a sustainable design of the urban environment on people's quality of life, promoting the sustainability protocols such as useful tools to spread the design of a sustainable built environment through effective strategies.

In this perspective, this paper aims to investigate if and to what extent the sustainability protocols at the neighborhood scale are evolving towards the transition to the CE paradigm within cities. First, the two most internationally used sustainability protocols at the neighborhood scale, respectively the LEED-ND and the BREEAM Communities, are analyzed in terms of assessment structure and contents. Second, a comparative analysis is provided, stating how many criteria of these two tools can be traced back to the principles and key elements of CE in cities, and providing their relative importance. Furthermore, on the basis of this analysis, the paper highlights within the conclusions if and in what terms the sustainability protocols at the neighborhood scale analyzed support the paradigm shift toward circularity that is taking place within cities.

Keywords: Circular Economy · Sustainability protocols · Decision criteria · Sustainable cities

1 Introduction

The economic, social and environmental paradigm within cities is changing, underscoring the urgency of a transition to more sustainable systems able to address the challenges faced within cities [1, 2].

Accordingly, the concept of Circular Economy (CE) is gaining more and more importance among city policy makers and is becoming increasingly relevant in order to address

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sustainability issues [3] as emphasized by the European Commission. In the field of academic research, the CE has also gained strong attention especially during the last decade, with an increase in the number of articles and journals dealing with this topic [1].

Specifically, the concept of CE appears in the 1970s [4], emphasizing that the economy and the environment should coexist in balance, as natural resources influence the economy while providing inputs for production and consumption and serving as a container for outputs in the form of waste.

During the last decade, in order to incorporate concepts and elements that relate to the idea of closed loops, the concept of CE and its applications have evolved to include issues related to regenerative planning and design [5]. More recently, the Ellen MacArthur Foundation (EMF) has begun to explore possible applications of the CE concept within cities, considering them as the main places where the transformation processes take place and therefore where it is possible to drive the change towards the circular transition in terms of resource use [6, 7].

Hence, the land can be considered as a key resource not to be wasted within cities, thinking also about the relationship between the people's need to use the space and its limitation [7]. In view of this, the EMF highlights the importance of a sustainable design of the urban environment [8, 9], in particular identifying within its 10 urban policy levers, as useful orientation for city governments to enable the transition to an CE, the sustainability protocols as useful tools in order to implement effective strategies for spreading the culture and the design of a sustainable built environment [8]. Actually, the sustainability protocols as evaluative tools aim to ensure a low environmental impact in relation to the construction sector, incentivizing sustainable construction through the application of a rating system [7].

In this perspective, this paper aims to investigate how the neighbourhood-scale sustainability protocols can be useful tools in supporting the transition towards a CE within cities, thus highlighting whether they are evolving considering the paradigm shift that is taking place.

In particular, the paper is structured as follows: Sect. 2 analyses the links between the sustainability protocols at neighborhood scale and the CE principles and goals regarding cities. Moreover, Sect. 3 provides a comparative analysis between the two most widely used sustainability protocols at the international level, respectively the neighborhood scale protocols Leadership in Energy and Environment Design - Neighborhood Development (LEED-ND) [10] and the Building Research Establishment Environmental Assessment Methodology (BREEAM) Communities [11]. Specifically, trying to understand how the principles and the key elements of the CE in cities relate to the criteria of the sustainability protocols examined. Finally, Sect. 4 relates to the conclusions, in which an attempt is made to understand if and how the sustainability protocols are evolving within the paradigm shift towards a CE within cities.

2 Sustainability Protocols and Circular Economy: Interlinkages

2.1 The Evolution of the Sustainability Protocols at the Neighborhood Scale

Since the end of the twentieth century, a progressive attention has been emphasized towards sustainable issues, developing at the same time a growing need to measure the

sustainability of the built environment, considering both the single building and the urban scale [12]. This need has found answers within the development of the sustainability protocols, developed as multi-criteria tools [13] aimed at assessing the sustainability of buildings, focusing mainly on the energy and environmental efficiency issues [14].

The first sustainability protocols were developed at the single building scale on a voluntary basis between the end of the twentieth century and the early 2000s [7]. In particular, in 1990, the BREEAM was the first sustainability protocol developed in the United Kingdom [14, 15], which provided the basis for the development of the other sustainability protocols that have progressively been developed within the international context. The purpose of the BREEAM protocol was to support the design and certification of the degree of environmental sustainability of the building's project, allowing comparability between different buildings and projects thanks to a rating system based on criteria and indicators. In particular, the criteria consist of thematic characteristics considered relevant in order to evaluate the sustainability of the project, while the indicators are both quantitative and qualitative descriptive measures, useful for expressing a measurable evaluation considering each criterion [15, 16].

On the wave of the success of the BREEAM protocol, between the late 90s and early 2000s, there has been a proliferation of sustainability protocols at the building scale, and to date each developed Country has one nationwide [17].

It is important to note that the sustainability protocols have evolved since their development [18] shifting the attention from the exploitation of resources in purely energy-environmental terms towards a broader perspective, increasingly considering the impact of the built environment on people's quality of life [7]. This paradigm shift has thus brought about the need to progressively bring the social and the economic issues on the same level as the environmental ones into the assessment framework [19, 20].

Moreover, this needs to consider in a comprehensive manner the different issues of the multidimensionality of the sustainability within the urban environment [14], has progressively led to the desire to include a wider portion of the territory within the assessment [7]. Therefore, since the early 2000s in the international contexts the single building scale progressively began to be considered too limited to fully guarantee the sustainability of the built environment, which instead refers to broader concepts that can only be implemented on a larger scale [14].

Consequently, the sustainability protocols have progressively shifted from the single building scale to the neighborhood and the city scale to fully assess the sustainability of the built environment also considering the processes of strain and resource use that characterize cities [15, 16].

This need for a broadening of scale is also confirmed within the EMF early explorations of the application of CE principles within cities [21]. In particular, the neighborhood scale provides ideal conditions for the proximity of resources, materials and products, within which this scale is in fact shared and reused several times by different users. Therefore, with a view to transformation processes and use of resources, special attention should be paid to planning and designing cities from this scale, assessing physical, social and environmental factors and determining the development and use of urban structures [21].

2.2 The Circular Economy Within Cities

The fundamental role that cities have in the transition toward more sustainable societies it is clearly highlighted by the European Union (EU) [6]. Cities represent the greatest challenges of the linear economy, since they host most of the world's population increasing the pressures on urban infrastructure and resource consumption [22]. In addition, a holistic approach to urban management still does not exist, inevitably leading to economic losses due to wasted resources and negative environmental impacts [21]. So, the potential of cities in becoming both centers of changes is recognized, considering that within the global economy cities play a key role being the main site of transformation processes [7].

The CE has been often described as "a concept that mimics living systems" made up of many dynamic, active and interdependent subsystems. In cities the process is analogous: the different urban systems must work together to make thriving, livable and resilient cities [23].

The CE could therefore constitute a tangible path to a prosperous recovery by giving urban systems a key role in achieving a paradigm shift to look beyond the current economic model of "take-make-waste" by focusing on the benefits for society [4].

Accordingly, the EMF defined the following 5 universal CE policy goals [24] applicable to local contexts: Goal 1 "Stimulate the design of circular economy", Goal 2 "Manage resources to preserve value", Goal 3 "Make the economics work", Goal 4 "Invest in innovation, infrastructure, and skills" and Goal 5 "Collaborate for system change". These goals consider several application areas, including the urban context, providing a useful reference for aligning the common goals of governments to facilitate the transition from a linear economy to a CE [24].

In fact, the goals and the principles expressed within the concept of the CE can offer concrete solutions for city governments, which in this sense play a key role by establishing and encouraging a framework for incorporating those elements into urban policy levers [24].

In order to facilitate city governments in putting into practice the transition towards a CE, the EMF in coherence with the 5 universal Goals [24] has identified 10 political levers based on 5 interconnected categories [8]. Among those levers, the sustainability protocols are identified as a potential economic incentive lever to design and evaluate the sustainability of the built environment [7]. In fact, the implementation of fiscal measures to encourage the diffusion of these tools can be particularly effective also to encourage positive behaviors regarding resource use processes within urban planning policies [22].

The adoption of the sustainability protocols entails many advantages, including the control in the application of sustainable approaches during the design process, the reduction of the environmental impacts by increasing the construction quality and the access to common economic, social and environmental benefits, considering both the construction and the management of the building stock [17].

Therefore, the sustainability protocols could play a potential role in creating new values towards livable and circular cities [22], contributing to the achievement of the CE policy Goals identified by the EMF with reference to local contexts. However, despite having their potential [7] in many Countries the sustainability protocols are voluntary tools and incentives to encourage their use is still missing.

3 Research Methodology

In order to understand how the neighbourhood-scale sustainability protocols can be effective tools in supporting the transition from a linear economy to a CE within cities, this paper first investigates the principles and the key elements highlighted by the EMF. Then, starting from the two widely used international sustainability protocols [25] at the neighborhood scale (LEED-ND [10] and BREEAM Communities [11]), the paper provides a comparative analysis to highlight whether the principles and the key elements of the CE within cities are effectively considered in the assessment frameworks of the sustainability protocols.

In particular, the comparative analysis is based on two consecutive steps:

- Framing the LEED-ND and the BREEAM Communities protocols in terms of both structure and content, highlighting which categories are considered and the weight given to each of them within the whole protocol;
- Analyzing the criteria contained within each category of the LEED-ND and the BREEAM Communities protocols, both in terms of descriptions and credits assigned, stating how many criteria can be traced back to the principles and key elements of CE in cities, and providing their relative importance.

3.1 The Principles and the Key Elements of Circular Cities

In 2017 the EMF began exploring possible applications of the general concepts and principles of the CE within cities, outlining them as the main driver towards the transition to circular economy and cities [6]. Particularly, the EMF outlines 3 principles to be pursued on which 5 key elements are based (Fig. 1).

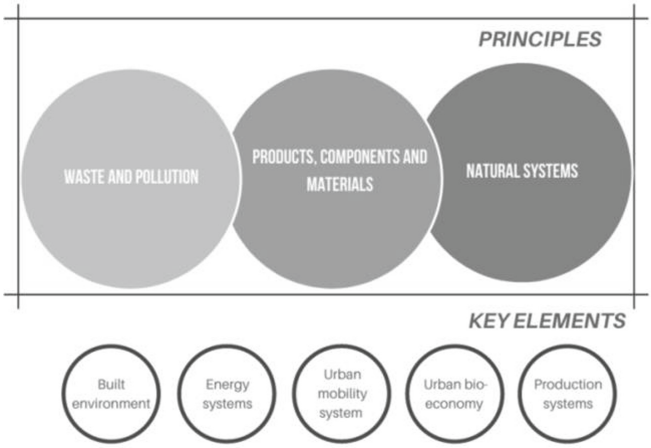

Fig. 1. Circular cities: principles and key elements.

The 3 principles to be considered (Fig. 1) are mainly related to:

1. Waste and pollution: considering the negative externalities within the urban context, such as the release of toxic substances, greenhouse gas emissions, air, soil and water pollution and traffic congestion;
2. Products, components and materials: maintaining them at maximum value and in use, especially in reference to design for reuse and remanufacturing to keep components and materials circulating and contributing to the economy;
3. Natural systems: considering the enhancement of natural capital, creating the conditions for its regeneration.

In a circular city the 3 principles are applied in all its functions considering 5 key elements [21] to create a regenerative, livable urban system, that keeps resources at their highest value (Fig. 1). The 5 key elements include:

1. A built environment which is widely used, thanks to flexible and modular spaces and includes materials which should be renewed and not harmful to the quality of life of the residents;
2. Efficient and renewable energy systems to reduce costs and having a positive impact on the urban environment;
3. A multimodal urban mobility system, aiming at reducing air pollution and congestion, also considering a conversion of excess road infrastructure;
4. An urban bioeconomy to generate value and minimize food waste, using the organic component of municipal solid waste and wastewater flows in local circuits, in order to produce food and provide a more resilient and diversified energy system;
5. Production systems that encourage local economic circuits, also through digital applications.

Therefore, considering the principles and the key elements outlined (Fig. 1) within the urban policies, city administrations could encourage and set up a regulatory framework to establish favorable conditions for cities to become more circular. In particular, paying attention to spreading the importance of creating responsible production and consumption and to adopt a responsible approach towards materials, stimulating new values.

3.2 Comparative Analysis: The Assessment Framework of LEED-ND and BREEAM Communities Protocols

Once the principles and the key elements to be considered in order to develop circular cities have been considered, the following phase consists of deepening the LEED-ND and the BREEAM Communities protocols [10, 11].

Accordingly, the aim of this analysis is both trying to highlight the assessment framework of the LEED-ND and BREEAM Communities protocols and frame the categories mainly considered within them in terms of the concepts analyzed, providing the first step of the comparative analysis.

In particular, the LEED-ND protocol develops its application at neighborhood scale first compared to the BREEAM Communities protocol and will therefore be presented first.

Leadership in Energy and Environmental Design - Neighborhood Development (LEED-ND)

The LEED protocol was developed as a voluntary tool at single building scale by the US Green Building Council (USGBC) in 1998, but over time has seen widespread implementation also in Europe.

In 2009, the LEED protocol was implemented by expanding its scale of application with reference to the neighborhood context, introducing the LEED Neighborhood Development (LEED-ND) [10]. The aim of this tool is mainly to promote the cycle of sustainable resources and materials, to improve the global climate, environmental justice and the quality of life, with particular attention to individual well-being and to build a green economy protecting the natural ecosystems.

The LEED-ND protocol within its assessment framework highlights 5 categories with a different percentage weight within the overall system (Fig. 2). Each of the 5 categories within the LEED-ND protocol is divided into mandatory prerequisites, which are not given a score but are mandatory elements to have in order to proceed with the evaluation, and credits, aiming at better structure the contents for evaluation purposes.

In particular the LEED-ND protocol stresses 12 total prerequisites, relating to 3 categories out of 5, respectively "Neighborhood pattern and design (NPD)", "Green infrastructures and buildings (GIB)" and "Site location and linkages (SLL)". Furthermore, the total criteria considered are 44, to which credits are assigned in order to differentiate their importance within the final assessment. Accordingly, the evaluation model of the LEED-ND protocol assigns a predetermined number of credits to each criterion, that can reach a maximum value of 10 [26].

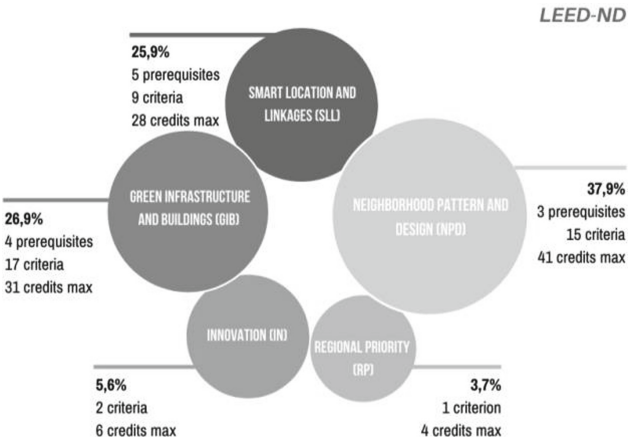

Fig. 2. Composition of the categories considered within the LEED-ND protocol evaluation framework: weight and related prerequisites, criteria and credits.

Figure 2 underlines that the "Neighborhood pattern and design (NPD)" category provide the highest weight (37.9%), immediately followed by the categories "Green infrastructures and buildings (GIB)" (26.9%) and "Site location and linkages (SLL)" (25.9%). In fact, the choice of the intervention site and the design choices adopted are both considered fundamental from a sustainable point of view. Finally, the categories "Innovation (IN)" and "Regional priority (RP)" show the lower percentage weights (respectively 5,6% and 3,7%), as they are considered specific categories of contexts [27].

Within the final evaluation of the LEED-ND protocol it is possible to reach a maximum of 110 credits obtained based on the sum of the credits within each category.

Consequently, a different level of certification can be obtained, respectively: not certified, certified, silver, gold and platinum.

Building Research Establishment Environmental Assessment Methodology Communities (BREEAM Communities)

The BREEAM has been the first voluntary protocol. It has been developed in 1990 in the UK and applied for new construction projects at the building scale.

The BREEAM protocol has a flexible structure, with the aim of being implemented in multiple international contexts, presenting criteria that can be modified according to how to achieve the necessary performance for a sustainable project in reference to the context of application [11].

The BREEAM protocol, as well as the LEED protocol, has developed over the years, extending its scale of application to the neighborhood context with the aim of also considering economic and social aspects, as well as environmental ones.

BREEAM Communities was thus developed in 2012 as a voluntary and independent assessment and certification tool for new development projects on the urban scale of the neighborhood [11]. This protocol aims to ensure quality through a holistic and balanced quantified measurement of impacts on sustainability, to also integrate construction professionals into operational processes and, where possible, to adopt existing industry tools to support developments and minimize costs.

The BREEAM Communities protocol considers a set of 40 criteria (over 44 of the LEED-ND), useful for measuring the actual degree of sustainability of each project under consideration [11].

Similar to the LEED-ND protocol, the criteria of the BREEAM Communities protocol are divided into 5 categories with a different percentage weight (Fig. 3).

Figure 3 shows that the category "Social and economic well-being (SEW)" has the highest weight (42,7%), also underlining a significant difference with the other 4 categories considered. This highlights the predominance of social and economic elements within the BREEAM protocol.

Furthermore the "Resources and energy (RE)" category is the second in terms of weight (21,6%), while the "Transport and movement (TM)", "Soil use and ecology (SE)" and "Governance (G)" categories have similar weights (respectively 13,8%, 12,6% and 9,3% respectively). In this sense, the BREEAM community protocol recognizes that site selection and subsequent management are almost as important as sustainable mobility policies and strategies [11]. Furthermore, aspects related to governance are less significant in defining the degree of sustainability of a neighborhood (Fig. 3).

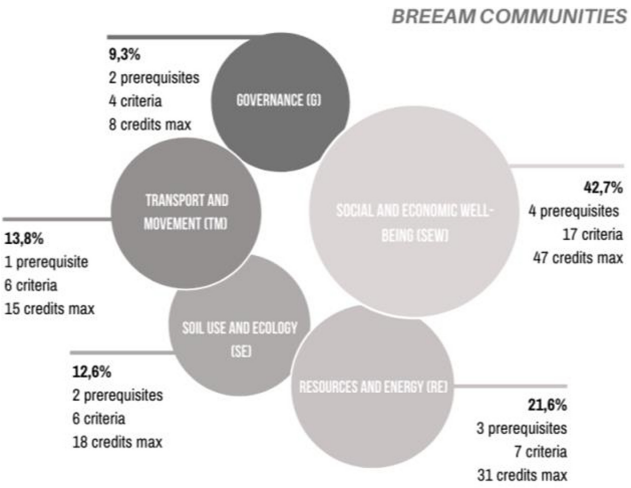

Fig. 3. Composition of the categories considered within the BREEAM Communities protocol evaluation framework: weight and related prerequisites, criteria and credits.

It is significant to underline that similar to the LEED-ND protocol, a further category, called "Innovation (IN)" recognizes the importance of developing innovative sustainable practices, capable of adapting to changes related to the climate issues. However, unlike the LEED-ND protocol (Fig. 2), within the BREEAM protocol no weight is assigned to this category, considered optional and specific for those projects capable of obtaining innovative results to which further credits can be assigned as part of the final evaluation [14, 16].

Similarly, to the LEED-ND protocol, each of the categories are divided into prerequisites, criteria and credits. However, the BREEAM Communities protocol assigns credits to the prerequisites in addition to the criteria, thus assessing not only their compliance but the degree of response quantifying their value. In particular, the highest number of credits can be reach though one prerequisite within the "Resources and energy (RE)" category, which ranges from 1 to a maximum of 11 credits. Accordingly, it is emphasized that in the BREEAM Communities protocol the maximum value of credits that can be obtained is equal to 11, unlike the LEED-ND in which it is possible to reach up to 10 [11, 26].

Moreover, the number of criteria differs between the categories considered and the subdivision of credits reflects the weight of each category within the protocol. In fact (Fig. 3), the "Social and economic well-being (SEW)" category having the highest weight, also shows the highest number of criteria and credits (respectively 17 criteria and 47 credits), while the "Governance (G)" category having the lowest weight, also shows the lowest number of both criteria and credits (4 and 8 respectively).

Moreover, in the BREEAM Communities protocol the sum of the credits of all the categories does not correspond to the final assessment of the degree of sustainability [11, 14, 26]. In fact, all credits are normalized and translated into percentage weight, subordinated to the total weight of the reference category.

In particular, the final score is obtained through a few consecutive steps. The first step is the attribution of credits for each criterion on the basis of the scale of reference values. Subsequently, a percentage ratio is created for each criterion, between the credits obtained and the total available credits, which is consequently multiplied by the corresponding percentage weight of each criterion. After this, any credits are added, up to a maximum of 4, if the project responds to innovative applications in the field of sustainability. Finally, the sum of the final percentages is provided, determining the placement of the project in one of the final certifications of the protocol, which are one more than the LEED-ND protocol, including: not certified, certified, good, very good, excellent and exceptional.

4 Results and Discussion

In order to understand if the principles and key elements emphasized by the EMF are captured within the LEED-ND and BREEAM Communities protocols, the criteria of both protocols were analyzed in depth.

Specifically, starting with each category contained within the sustainability protocols, an analysis of the description of each criterion was conducted to optimally capture its content [27]. Consequently, it was possible to list how many criteria for each category considered within the LEED-ND and the BREEAM Communities protocols meet the principles and key elements of the CE in cities (Fig. 4).

In particular, the acronyms of the categories (Fig. 2 and Fig. 3) included within the examined protocols were used in Fig. 4.

Figure 4 shows that the LEED-ND protocol categories contain a total of 36 criteria out of 44 that meet the principles and key elements of the CE in cities.

Specifically, the majority of criteria are contained within the "Green infrastructures and buildings GIB" category (17 out of 36), which is the second highest weighted category within the LEED-ND protocol (Fig. 2). Moreover, the "Neighborhood pattern and design NPD" category, which is the first most weighted category within the protocol, contains 9 out of 36 criteria, equally to the " Site location and linkages SLL" category. While it is interesting to note that the categories with less weight within the protocol, respectively "Innovation (IN)" and "Regional priority (RP)", do not contain any criteria meeting the CE principles.

From this first analysis, Fig. 4 underlines that despite the efforts made to include aspects related to social issues and mobility in terms of transition towards circular cities, the LEED-ND protocol still provides a focus on energy-environmental aspects.

Figure 4 also points out that the categories of the BREEAM Communities protocol contain a total of 32 criteria out of 40 that meet the principles and key elements of the CE in cities. This first element leads to the preliminary consideration that in comparison with the LEED-ND (which reports 36 out of 44) the two sustainability protocols are therefore balanced.

In the BREEAM Communities protocol, the "Social and economic well-being SEW" category has the highest weight (Fig. 3) also containing the highest number of criteria (14 out of 32). While the other categories contain 6 out of 32 criteria, with the exception of the " Governance G" category which contains none. Accordingly, within this protocol,

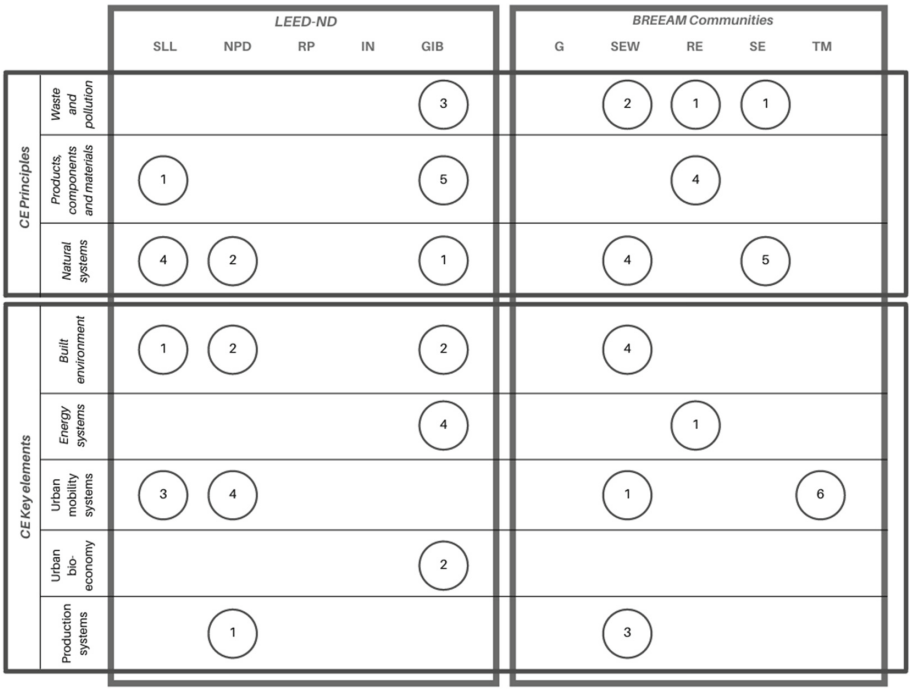

Fig. 4. Number of criteria from the LEED-ND and BREEAM Communities protocols that meet the principles and key elements of the CE in cities

as opposed to the LEED-ND protocol, there is a clear willingness to move beyond the energy-environmental aspects including also the social ones. This is emphasized both by the number of criteria of the "SEW" category and by the protocol's ability to include evaluation criteria useful for supporting a CE. In fact, although the CE principle "Natural systems" is the one related to the highest number of criteria (9 out of 32) highlighting a similar environmental focus as within the LEED-ND protocol (Fig. 4), however within the BREEAM Communities protocol there is an attempt to include also other aspects in terms of CE, related to the social and economic well-being.

Since to each criterion within the assessment framework of both the LEED-ND and the BREEAM Communities protocols is given a different weight in term of credits assigned (Fig. 2 and Fig. 3), after analyzing the criteria of the two protocols in terms of content, a comparative analysis was also conducted in order to highlight the importance of the criteria identified.

Therefore, both in terms of principles and key elements of the CE (Fig. 1), each criterion identified in Fig. 4 was analyzed by highlighting how many credits were assigned to each. Subsequently, in order to understand its importance within the protocol, the credits assigned to each criterion were compared to the overall credits considered in the protocol. Finally, the values obtained were normalized to bring them into percentage terms (Fig. 5 and Fig. 6).

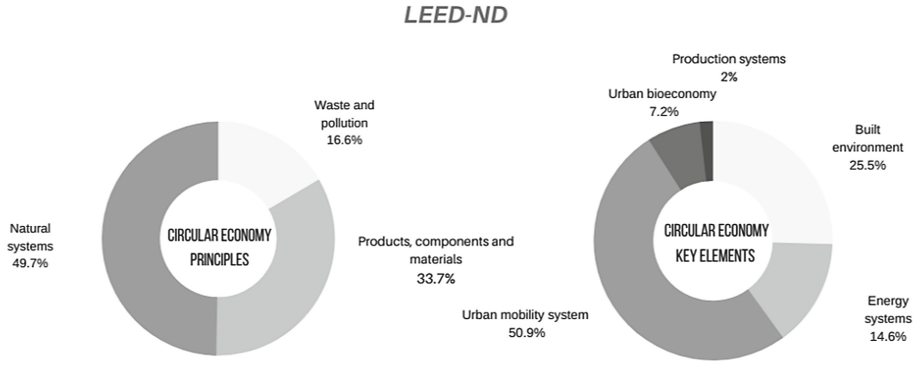

Fig. 5. The LEED-ND protocol: importance of the principles and key elements of the CE in cities

Figure 5 shows how within the LEED-ND protocol the principle of the CE considered having more weight is the "Natural systems" principle (49,7%), which is also the principle containing the highest number of criteria (Fig. 4). The "Product, components and materials" principle has the second highest weight (33,7%), followed by the "Waste and pollution " principle (16.6%). This analysis confirms the energy-environmental footprint of the LEED-ND protocol outlined in the previous analysis of the criteria (Fig. 4).

Furthermore, Fig. 5 underlines that the key element "Urban mobility system", which is also the one containing the highest number of criteria (Fig. 4), significantly differs from the others, reporting the highest weight of 50,9%. This may be due to the fact that the LEED-ND protocol has endeavored to evolve to include aspects of mobility in terms of CE, paying attention to promoting a multimodal system and therefore incorporating public transport with other forms of sustainable mobility [10]. This is particularly in line with the CE key element on mobility, which considers the private car only as a last-mile solution [21], favoring more sustainable alternatives and encouraging a mobility system that is accessible and efficient, but also cost-effective and environmentally friendly [21].

Moreover, the key elements "Built environment" and "Energy system" stress respectively a weight of 25,5% and 14,6%, while the "Urban bio-economy" key element shows a weight of 7.2%. Finally, the "Production system" weights only for 2%, which is also the one containing only 1 criterion (Fig. 4).

Figure 6 shows how the principle of the CE with more weight within the BREEAM Communities protocol is "Natural systems" (48.1%), which is also the principle containing the majority of criteria (Fig. 4). In fact, although the BREEAM Communities protocol highlights an effort to also include social and economic aspects in terms of CE within its assessment framework, the CE principle "Natural systems" is the one related to more criteria (Fig. 4).

Moreover, the following principles with more weight are respectively the "Product, components and materials" (33.3%) and the "Waste and pollution" (18.5%). Looking at the CE principles, the two protocols analyzed are similar showing a propensity for assessing the regeneration of natural systems. This could be due to the fact that "natural systems", "product, components and materials" and "waste and pollution" can be seen as consequential principles. It seems that a rational control of waste and pollution and a

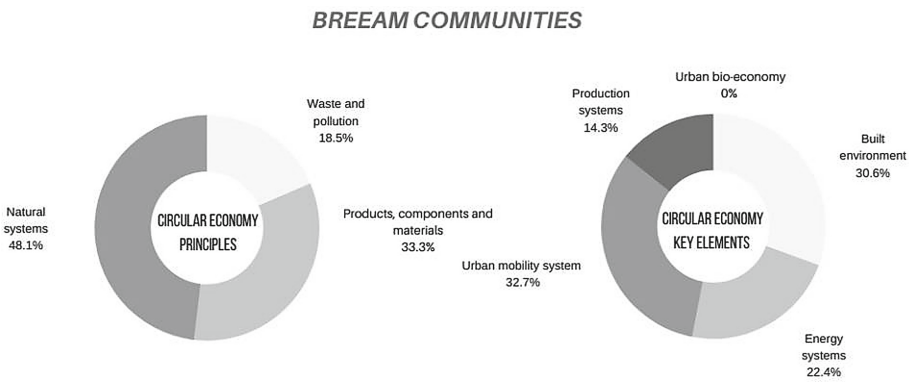

Fig. 6. The BREEAM Communities protocol: importance of the principles and key elements of the CE in cities.

"green" management of the products components and materials contribute equally to the regeneration of natural systems. In this sense, those two principles are not seen as less important, but rather as instrumental in achieving the goal of protection and regeneration of natural systems.

Looking at the BREEAM protocol, the key elements "Urban mobility system" and "Built environment" are the ones with the greatest weight, presenting a low percentage difference (respectively 32.7% and 30.6%). The key elements "Energy system" and "Production system" instead show a weight of respectively 22.4% and 14.3%, while the key element "Urban bio-economy" reports a weight of 0%, in line with the fact that this key element does not refer to any criteria inside the protocol (Fig. 4).

It is interesting to note how the key element "Energy systems" within the BREEAM Communities protocol weighs more (22,4%) than the LEED-ND protocol (14,6%) even though it has only one criterion, compared to the 4 criteria considered in the LEED-ND (Fig. 4). Accordingly, this difference is due to the fact that the only criterion considered within the BREEAM Communities protocol has a significantly greater weight than the 4 criteria considered within the LEED-ND protocol.

In the perspective of translating the CE principles into the key elements, the "urban mobility" and the "built environment" seem to be fundamental for both LEED and BREEAM protocols, although with very different importance among the two.

This is may be attributable to the fact that those are largely investigated phenomena and therefore their measurement is more reliable. One can therefore assume that the greater reliability may result in a greater capacity of intervention on these two elements in a view of the sustainability.

5 Conclusion and Future Developments

The comparative analysis developed in this paper allowed to understand how the neighbourhood-scale sustainability protocols can be useful tools considering the transition to a CE which are characterizing cities. Through the methodology carried out it was possible not only to identify how many criteria of the two analysed sustainability

protocols can be traced back to the principles and the key elements of the CE, but also to understand their relative importance within the protocols' assessment framework. In this sense, the analysis made it possible to highlight whether the sustainability protocols are evolving considering the paradigm shift that is taking place.

In particular, it can be noted that the neighbourhood-scale sustainability protocol LEED-ND and BREEAM Communities already give a significant contribution towards the CE transition. In fact, from the analysis emerges that the three CE principles are strongly represented in the descriptive modalities since they can be considered as interrelated and consequential. Moreover, it should be considered that some progress has been made in consideration of an assessment framework within the protocols that also considers issues that pursue long-term sustainability in a "closed loop system" view [1], for example giving more importance to aspects such as the reduction of externalities caused by mobility or the value of materials and components used (Fig. 5 and Fig. 6).

In spite progress, some principles and key elements of a transition to CE within cities are still not considered within the sustainability protocols analysed. In fact, the comparative analysis shows that issues related to the production systems that improve the local economy and to the urban bioeconomy are hardly considered. In particular, the key element of the urban bioeconomy is only considered within the LEED-ND protocol, meeting no criteria within the BREEAM Communities protocol (Fig. 4).

The sustainability protocols aim to improve the quality of urban design, so despite their scale considering the broader vision of the neighbourhood, the focus is still on considering design-related issues [14, 16].

Finally, regarding the limits of the research, it should be emphasized that only neighborhood-scale protocols were considered in this comparative analysis and if this methodology were applied to sustainability protocols at different scales (e.g. single building scale) the results might change.

Furthermore, the analysis developed in this paper does not capture how and in what terms the neighborhood-scale sustainability protocols analyzed can help towards the transition of more circular cities. This research lays the foundations for further developments of the work, which will include a more in-depth analysis that will seek to understand in what terms the sustainability protocols can really help in achieving the CE paradigm and towards transition within cities. In particular, the purpose will be to analyse in depth the criteria and indicators used within the assessment framework of the LEED-ND and BREEAM Communities neighbourhood-scale sustainability protocols to understand their contents and functions, and eventually implement them within a new neighbourhood-scale sustainability protocol that intercepts the principles and the key elements of the CE.

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