Implementation and Consideration of Circularity Within International Sustainability Assessment Methods

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Chapter 19
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Abstract The construction sector is a major contributor to environmental degradation, prompting the need for integrating sustainability into its practices. This need has driven the development of sustainability assessment methods across various scales of the built environment. Simultaneously, the recent emphasis on Circular

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Economy (CE) principles has introduced challenges in translating these principles into measurable outcomes within the construction sector. This study aims to investigate the extent to which circularity principles are embedded within existing sustainability assessment methods for new buildings. The study begins by addressing the interrelationships and distinctions between circularity and sustainability concepts, establishing a foundation for the subsequent analysis. Five internationally recognised sustainability assessment methods for new buildings—BREEAM, DGNB, LEED, Level(s), SBTool—were examined to assess their incorporation of circularity aspects. Each component of these methods was scrutinised for alignment with the 10 circularity strategies outlined in the well-established 10-R framework of waste hierarchy. Expert groups, consisting of CircularB COST Action members, independently evaluated the methods and provided opinions on the direct and indirect associations between the assessed components and the 10-R principles. Disagreements were resolved through group discussions. The analysis revealed varying degrees of integration and explicit reference to circularity principles across the assessed methods. The study also highlighted the subjectivity inherent in identifying correlations and the challenges connected to linking certain circularity-related concepts in the built environment—such as resilience and adaptability—with the 10-R strategies. The findings underscore the need for a more in-depth analysis before making direct comparisons of the integration of circularity principles among different sustainability assessment methods, given their methodological differences. The study also identifies directions for future research.

Keywords Circular economy · Sustainability · Buildings' Sustainability assessment · 10-R Framework

19.1 Introduction

The main aim of this chapter is to investigate the extent to which circular economy-related aspects and strategies are integrated in the evaluation process supported and performed by well-known sustainability assessment methods of buildings.

The need for this investigation arises from the intersection of COST Action CircularB's objectives and the evolving role and nature of sustainability assessment methods in the built environment. Among the core targets of CircularB Action is the proposal of appropriate circularity indicators for evaluating the built environment. These indicators may be existing ones, modified versions, or entirely new proposals, and their effective development and application should be supported by robust data and frameworks, including regulatory standards. In parallel, Level(s) framework represents one of this Action's main interests, with the effective integration of circularity indicators into its structure being one of the foreseen research areas. Although Level(s) has distinct characteristics, it shares important similarities with other sustainability assessment methods used in the built environment.

Over the past decades, sustainability assessment methods for the built environment have evolved significantly and gained widespread adoption and recognition globally. These methods are crucial for embedding sustainability principles into the built environment. They essentially comprise sets of criteria and or indicators well-structured, relevant to the built environment and accompanied by grids of standards, data and regulations.

The combination of these factors, along with the recognition that sustainability, while closely related, is not synonymous with circularity, underscores the importance of the work presented in this chapter. The concepts and scopes of circularity and sustainability are discussed in Sect. 19.2, primarily through a comparative lens that highlights their interrelationships and distinctions.

This study involved the selection of five widely recognised sustainability assessment methods for buildings and their examination within the context of a circular economy framework. The methods considered are: BREEAM, DGNB, LEED, Level(s), and SBTool.

In both academic and practical settings, various R-frameworks have been employed to define strategies encompassed by the circular economy concept. At the European Union level, the 4-R framework (Reduce, Reuse, Recycle, Recover), which forms the core of the EU Waste Framework Directive [18], was expanded with the introduction of the EU's Circular Economy Action Plan (CEAP) in 2015 and the updated CEAP in 2020 (European Commission, 2020). These developments are integral to the EU Industrial Strategy, a key component of the European Green Deal. A more comprehensive framework, as presented by [28], includes 10 common circular economy (CE) strategies as illustrated in Fig. 19.1: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover. This framework was adopted in this study to scrutinise all the aspects covered by the selected assessment protocols in terms of circularity, given its clear and nearly exhaustive representation of existing CE strategies. It is worth noting that other similar frameworks exist in the literature, such as those proposed by [34] and [38].

The investigation focused on analysing whether, to what extent, and how circularity principles and strategies are implemented in the examined sustainability assessment methods. This analysis was conducted at the most granular, self-contained, distinct, and scored level within each method's assessment structure, as explained in the respective sections. The methodology involved conducting expert focus group exercises with five sub-groups (corresponding to the five examined methods), composed of researchers contributing to this study. Participation in each sub-group was voluntary, with the number of members varying; some researchers participated in multiple sub-groups, while others were involved in only one. Detailed information regarding the number of contributors in each sub-group is provided in the respective sections of this chapter.

Each sub-group analysed a specific protocol/assessment method by studying the technical manuals, guides, or descriptive materials accompanying each method, which contain comprehensive descriptions of the content, benchmarks, and intended goals of the assessment levels under consideration. For SBTool, the analysis was based on the study of the method's computational tools (Excel-type files). The

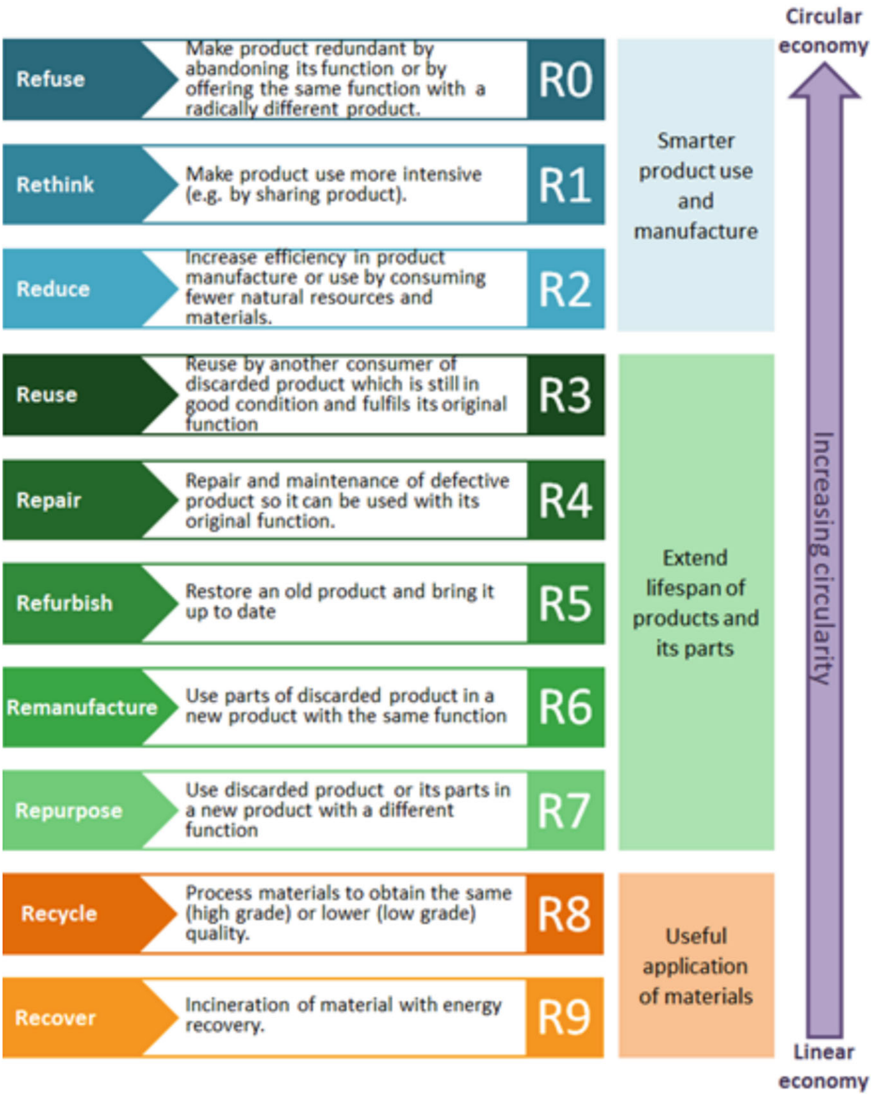

Fig. 19.1 The employed 10-R framework (adapted from [28])

members of each subgroup independently provided their opinions on whether and which of the strategies outlined in the 10-R framework are reflected in the examined components of the analysed method. It is important to note that, for this correlation to be meaningful and effective in the context of individual buildings, the investigation centred on assessing building products and buildings as products through the lens of the 10-R framework. Differences in estimations and assessments within each sub-group were resolved through discussions. Through this process, two types of associations were established: direct and indirect. Direct associations are based on direct, explicit references to one or more of the employed framework's strategies/ principles within the content, aim, indicators, and overall structure of the examined component. Indirect associations reflect relationships where no explicit references were found, but correlations could be inferred on a consequential basis. More detailed classifications, and information on each method's unique features influencing the treatment of this issue, are provided in the sections presenting the results for the examined methods.

The results are presented in tables listing the components of each method directly and indirectly associated with the 10-R strategies. The discussion of the findings follows. This approach outlines the consideration of various circular strategies in the context of the examined methods, highlighting the differences and similarities among the adopted approaches. An important outcome of this analysis pertains to the challenge of distinguishing between sustainability and circularity and the resulting variations in the related interpretations.

The structure of the chapter is as follows: Sect. 19.2 discusses the interrelationships and distinctions between circularity and sustainability. Section 19.3 provides an overview of sustainability assessment methods for the built environment and analyses the integration of circularity in five international methods: BREEAM, DGNB, LEED, Level(s), and SBTool. Finally, Sect. 4 concludes the chapter.

19.2 Sustainability Versus Circularity

The relationship between the concepts of circular economy (CE) and sustainability has sparked an ongoing debate [33]. However, the lack of clear boundaries defining each concept has fueled this conflict, despite their widespread use among scholars and practitioners. Unfortunately, this lack of clarity hinders the effective application of these concepts in both theory and practice [22]. Sustainability can be defined as the balanced integration of economic performance, social value, and environmental resilience, benefiting both present and future generations [22]. On the other hand, the circular economy is defined as an industrial system intentionally designed for restoration and regeneration. It aims to replace the concept of disposal "end-of-life" with regenerative growth, prioritise renewable energy, eliminate toxic chemicals that hinder reuse, and strive for waste elimination through superior material, product, system, and business model design [17]. While various scholars have proposed multiple definitions of circular economy, the definition put forth by the Ellen MacArthur Foundation is the most accepted [23, 28].

While both sustainability and circular economy share concerns about technological advancements, industrial practices, and consumption patterns, they also highlight the importance of integrating environmental and social dimensions with economic progress [22]. Despite these similarities, the two approaches differ significantly in their origins, objectives, scopes, motivations, institutionalisations, timespans, and beneficiaries [22]. Sustainability embodies a more open-ended essence in the context of sustainable development compared to a circular economy [22, 46]. It encompasses a wide range of goals that can be reframed over time to align with the interests of involved parties. Conversely, the circular economy is more specific in defining its goals and aspirations for closed-loop systems that eliminate waste and minimise emissions. These goals are to be achieved within defined theoretical and practical thresholds [17].

Scholars diverge into two directions regarding the relationship between CE and sustainability. The first direction argues that CE surpasses the linear thinking models of sustainability and offers prospective solutions to its shortcomings [28, 40]. Geissdoerfer et al. [22] provide a more comprehensive perspective, acknowledging both positions. They identify three major types of relationships between sustainability and circular economy: (1) circular economy as a condition for sustainability, (2) a mutually beneficial relation, or (3) a trade-off. These relationship patterns foster diversity and encourage the deployment of a wide range of complementary strategies. According to Brundtland Report (1987), sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This definition highlights that sustainable development is an ever-evolving goal for our planet and society. A circular economy, in this regard, establishes new sustainability benchmarks to meet modern-day goals for sustainable development. However, employing the circular economy without considering sustainability would lead to undesirable results. For example, multiple cycles of reusing or recycling a product may eventually either produce more emissions or consume more energy than producing a new one. Therefore, it is crucial to strike the right balance between resource circularity and their environmental, economic, and social impacts, taking into account case-specific requirements.

The relationship between circular economy and sustainability also extends to the built environment, particularly the building sector [27]. However, while sustainability has often been associated with "doing less bad" instead of good, the CE has been all about "doing good". Sustainability comes from the gradual optimisation of things, whilst the circular economy is about new business models that sell services rather than products [27]. Many literature studies on circular economy prioritise environmental improvements, neglecting a systemic integration of all three pillars of sustainability. The strong relationship between circular economy and environmental sustainability lies in the efficient solutions that circular economy concepts provide to alleviate the pressure of human activities on natural ecosystems [33]. However, most cases tend to link the environmental focus with economic aspects, paying marginal attention to social and institutional levels. The social value brought by the circular economy is often overlooked, with discussions mainly centred around job creation. This limited coverage of social aspects reflects a blurred perception of the circular economy's ability to contribute to subjective well-being [22]. The marginal attention given to social issues in circular economy studies may be attributed to their focus on an industrial context [12]. Consequently, the circular economy should broaden its scope to include societal concerns, which require a radical shift in consumer and stakeholders' attitudes. However, recent studies show a growing awareness of the need for a more inclusive approach that embraces the triple bottom line of sustainability [33].

Table 19.1 Differences between sustainability and circular economy on various levels

Aspects	Sustainability	Circular economy
Objective	More open-ended essence regarding sustainable development	More specific in defining its goals and aspirations for closed-loop systems that eliminate waste and minimise emissions
Impact	"doing less bad"	"doing good"
Focus	Focuses on the triple bottom line: People, the Planet and the Economy	Focuses on Resource Cycles
Practice ground	The practice of sustainability is grounded in and focused on the Biosphere	The practice of circularity is grounded in and focused on the Techno and Bio spheres
Responsibility	Responsibility is shared but not clearly defined	More defined responsibility primarily focusing on private businesses, regulators and policymakers
Beneficiaries	Main beneficiaries: the environment, the economy, and society	Main beneficiaries: the economic actors that implement the system
Interests	Interests are aligned between stakeholders and can be reframed over time	Interests prioritise financial advantages for companies
Prioritised aspects	Comes around the gradual optimisation of things	Prioritises improvements on the environmental aspect while the social aspect is marginally addressed

Table 19.1 summarises the differences between sustainability and circular economy in terms of objective, impact, focus, practice ground, responsibility, beneficiaries, interest and prioritised aspects.

19.3 Analysis of Circularity Implementation in Five Well-Known International Methods (BREEAM, DGNB, LEED, Level(S), SBTool)

19.3.1 General Information

Over the past few decades, sustainability assessment methods for buildings have evolved into a critical asset for implementing sustainability principles in the building sector. These methods have gained significant acceptance and recognition internationally across various stakeholders. The 1990s marked the inception of environmental performance assessment methods for buildings, with the first versions of BREEAM and LEED being published in 1990 and 1998, respectively [1, 41]. Additionally, GBTool, later known as SBTool, was initially launched in 1998 following an international development effort that began in 1996 [11]. In subsequent years, numerous sustainability assessment methods have been developed by organisations, institutions, and researchers across various countries and continents [4, 45, 16].

These methods exhibit varying degrees of similarity and differentiation in terms of their philosophy, scope of application (whether international or national, building uses addressed, etc.), range of criteria, and methodological structure. Notably, some differences can also be observed among the successive versions of these methods themselves, as they continuously evolve, expand in scope, and adapt to new challenges and conditions, which is key to their effectiveness and relevance.

When considering trends in the sustainability assessment of the built environment, it is important to note the growing interest in scales larger than individual buildings. Methods addressing neighbourhood or even city scales have emerged as early as the 2000s, with their development receiving continuous and intensive enhancement. While many issues at the building scale are being adequately addressed (with room for improvement), the broader scope offers greater opportunities and challenges, leading to a focus on larger entities within the built environment. Moreover, the principles of the Circular Economy can be effectively applied not only at the building scale but also at the neighbourhood and urban scales, considering key factors of circularity in the built environment. Prominent sustainability assessment methods for buildings, such as BREEAM, LEED, DGNB, and CASBEE, have expanded to develop tools for the urban scale (e.g., BREEAM Communities, LEED for Neighborhood Development, DGNB for Urban Districts, and CASBEE for Urban Development, respectively).

Another example of a multi-scale approach is CESBA (Common European Sustainable Built Environment Assessments), which extends the reliability of SBTool to both the building and neighbourhood scales. CESBA represents a bottom-up initiative aimed at promoting the harmonisation of sustainability assessments across Europe, from buildings to neighbourhoods and regions. It particularly emphasises a neighbourhood-level approach to developing synergies in energy efficiency[1]. However, the analysis in this work focuses on the building scale.

A significant number of comparative reviews of building sustainability assessment methods can be found in the literature, addressing their basic characteristics or their approaches to specific performance aspects (for example, see [2–6, 10, 15, 21, 24, 35–37, 39, 41, 45]. Detailed information about comparative review studies of such tools can also be found in various works, e.g., in [30]. Some of the most widely known and applied sustainability assessment methods appear more frequently in these review studies, highlighting their importance and influence. It is evident that the simultaneous, critical, and comparative consideration of multiple methods has been a focal point in scientific efforts aimed at improving these tools since their early development.

In this review, the analysis focuses on four sustainability assessment methods for buildings: BREEAM, DGNB, LEED, and SBTool. The versions studied are the most

[1] The CESBA SNTool led to the MED Passport enabling the comparison of the performances of buildings and neighbourhoods, in line with the EC COM 2014 445. A CESBA MED network of cities was setup in order to maximise the transferability of results [9].

recent, applicable to new buildings and suitable for international use. Where different schemes exist for tertiary and residential buildings, the tertiary sector version is examined. These methods were selected based on their widespread use in Europe and their international scope. Additionally, Level(s) is included in this review. Although Level(s) differs in some aspects of its philosophy compared to the other "typical" methods examined, it is a constantly evolving common European framework that may serve as a common axis for implementing sustainability assessment principles and procedures in the building sector and construction practices in the future. Moreover, given that Level(s) is a focal point of CircularB Action's interests, its inclusion alongside the other methods is essential.

19.3.2 BREEAM

Introductory remarks. BREEAM (Building Research Establishment Environmental Assessment Method) is a widely recognised environmental assessment method and rating system used to evaluate and measure the sustainability performance of various building types. Developed by the Building Research Establishment (BRE) in the United Kingdom in 1990, BREEAM has continuously evolved, adapting to advancements in sustainability practices and expanding its scope [7]. The system employs established performance indicators that adhere to defined standards and benchmarks, assessing the technical performance, design, construction, and ongoing use of buildings. These indicators encompass a broad range of factors, from energy consumption to ecological impact, covering multiple dimensions of environmental performance.

BREEAM's holistic approach and continuous development have enabled it to be successfully adapted to almost any building type and to various scales within the built environment. The method includes applications for different scenarios, such as evaluating new sustainable building projects through BREEAM New Construction or its international counterpart, assessing existing non-domestic, commercial, industrial, retail, and institutional buildings using the BREEAM In-Use scheme, applying a sustainable assessment method for refurbishment projects with BREEAM Refurbishment, and even planning for the creation of neighbourhoods and urban areas for new communities through BREEAM Communities [7].

This analysis focuses on the BREEAM International New Construction 2021 scheme (BRE [8]). BREEAM currently categorises its assessment into nine *environmental sections*: (i) Management, (ii) Health and Wellbeing, (iii) Energy, (iv) Transport, (v) Water, (vi) Materials, (vii) Waste, (viii) Land Use and Ecology, (ix) Pollution and an additional one – (x) Innovation. Each environmental *section* contains a varying number of specific issues. For example, the Management *section* includes five *issues*; Health and Wellbeing comprises nine *issues*; Energy covers 11 *issues*; Transport includes seven *issues*; both Water and Materials comprise four *issues* each; Land Use and Ecology and Waste cover four and seven *issues* respectively; Pollution

BREEAM Rating	*Outstanding*	*Excellent*	*Very Good*	*Good*	*Pass*	*Unclassified*
	★★★★★	☆★★★★	☆☆★★★	☆☆☆★★	☆☆☆☆★	☆☆☆☆☆
Score [%]	≥ 85	≥ 70	≥ 55	≥ 45	≥ 30	<30

Fig. 19.2 BREEAM rating benchmarks for new construction [7]

includes five *issues*; and the Innovation category, while not containing specific *issues*, contributes to the overall assessment.[2]

The assessment process in BREEAM is based on evaluating each *issue* against specific *criteria*. Each of the ten major BREEAM categories is assigned a certain number of credits based on its compliance with the relevant sustainability *criteria*, with each *issue* accompanied by a number of available credits. The total number of points awarded for each *environmental section* is divided by the total number of points available for it, and this ratio is multiplied by the *section's* relative weighting. The sum of these weighted scores, along with the potential contribution from the Innovation *section*, determines the overall BREEAM score, expressed as a percentage. This percentage score corresponds to a range of ratings, from "Pass" for basic levels of sustainability to "Outstanding" for exceptional and comprehensive sustainability performance (Fig. 19.2).

To achieve a "Pass" rating, a building must meet minimum standards in critical areas such as energy and water, with the requirements varying by building typology. As the rating level increases, the mandatory criteria and percentage scores required for each ranking become progressively broader.

Circularity implementation. In this study, the investigation of circularity implementation is conducted at the most granular rated level of BREEAM's structure, which is the level of individual *issues*. Each *issue* is examined based on specific assessment *criteria*, and, as outlined in the introductory remarks, credits are awarded or withheld depending on compliance with these *criteria*.

To identify the *issues* associated with circular economy-related strategies and principles, as defined in the employed framework, a comprehensive review of the entire BREEAM assessment structure was conducted. The identified *issues* are presented in Tables 19.2 and 19.3, which show *criteria* directly associated with circular economy principles and those that are indirectly related, respectively. The content of each *issue*, including assessment *criteria* and compliance conditions, was thoroughly analysed to determine the nature and type of association (direct or indirect).

Additionally, the tables provide information on the specific circular principles and strategies that are reflected within each *issue*, along with estimations regarding

[2] The numbers of the *issues* mentioned as being part of BREEAM's *environmental sections* exclude the ones that are not addressed as stand-alone *issues* in the context of the examined version of the method. Furthermore, it is noted that if an *issue* is differentiated for two types of building uses (e.g., Ene2a and Ene2b), it is counted as being two individual items (in the previous example, Ene 2a and Ene 2b are counted as two *issues* – and are treated as such in Tables 19.2 and 19.3).

Table 19.2 *Issues* which are directly[3] associated with circularity (circular principles as reflected in the employed framework)

Environmental section	Issue		Association with circularity (employed framework)	Level (site, material, design, construction, management)
Management (Man)	Man 02	Life cycle cost and service life planning	REDUCE primary materials and resources consumption (weaker direct association, since this principle is addressed through the LCC planning and the service life considerations)	Material & design & management
Health and wellbeing (Hea)	Hea 02	Indoor air quality	REDUCE: doing more with the same system (flexibility and adaptability of ventilation system is considered) is promoted RETHINK existing building ventilation strategy is designed to be flexible and adaptable to potential building occupant needs and climatic scenarios	Site & design
	Hea 04	Thermal comfort	REDUCE: doing more with the same system (adaptability to a projected climate change scenario is considered) is promoted REFURBISH: in case that the response to the projected climate change scenario is not satisfactory, then adaptation potential using passive strategies must be demonstrated for the related credit to be awarded RETHINK existing design solutions in order to be easily adapted in the future	Design
Energy (Ene)	Ene 01	Reduction of energy use and carbon emissions	REDUCE consumption of energy for operation (resources)	Design (site, material and management issues are involved)
	Ene 03	External lighting	REFUSE external lighting RETHINK existing design and management approach of external lighting in order to prevent operation during daylight hours	Design & management

(continued)

[3] Direct association: direct reference/description in the intent, indicator, benchmarks, and generally, in the structure and content of the criterion.

Table 19.2 (continued)

Environmental section	Issue		Association with circularity (employed framework)	Level (site, material, design, construction, management)
	Ene 04	Low carbon design	REDUCE non-renewable energy consumption (passive design and low or zero carbon technologies)	Design
	Ene 05	Energy efficient cold storage	REDUCE consumption of energy (resources)	Materials & design & management
	Ene 06	Energy efficient transportation systems	REDUCE consumption of energy (resources)	Design & management (in terms of how the transportation systems are fitted and work)
	Ene 07	Energy efficient laboratory systems	REDUCE consumption of energy (resources)	Design & management
	Ene 08	Energy efficient equipment	REDUCE consumption of energy (resources)	Materials (in the sense of appliances/ systems) & design
Trasport (Tra)	Tra 01	Public transport accessibility	REFUSE private transport use (objective as a whole) REDUCE: refusing, in consequence reduce transport-related pollution and emissions	Site & design
	Tra 03a	Alternative modes of transport	RETHINK: car sharing is considered in the context of one option REDUCE: more indirectly associated in comparison to the other elements of the 10-Rs; the use of high carbon transport modes and individual journeys is considered in the objective as a whole REFUSE using previous approach of using inefficient modes of transport	Site & design

(continued)

Table 19.2 (continued)

Environmental section	Issue		Association with circularity (employed framework)	Level (site, material, design, construction, management)
	Tra 03b	Alternative modes of transport	RETHINK: car sharing is considered in the context of one option REDUCE: more indirectly associated in comparison to the other elements of the 10-Rs; the use of high carbon transport modes and individual journeys is considered in the objective as a whole REFUSE using previous approach of using inefficient modes of transport	Site & design
Water (Wat)	Wat 01	Water consumption	REDUCE: water consumption (use of efficient systems is also considered), consuming fewer water resources RECYCLE & REUSE: greywater/ rainwater (the existence of such systems is taken into consideration)-REUSE water as a "product" RETHINK: multifunctional systems for efficient water consumption	Design & management (some site-related aspects are also taken into consideration)
	Wat 03	Water leak detection and prevention	REPAIR: as a result of detecting problems REDUCE: water consumption by preventing leaks	Design & management
	Wat 04	Water efficient equipment	REDUCE: water consumption (use of efficient systems is also considered)	Design

(continued)

Table 19.2 (continued)

Environmental section	Issue		Association with circularity (employed framework)	Level (site, material, design, construction, management)
Materials (Mat)	Mat 01	Life cycle impacts	This issue is concerned with the use of LCA on the project, and the robustness of the method or tools used. At present the performance is not benchmarked As such: RETHINK & REDUCE, since the reliable consideration of the life cycle impact is promoted. Furthermore, performance of LCA studies may lead to the examination of more alternatives and the adoption of environmentally friendly solutions REDUCE: by calculating life cycle impact, using data from the EPDs and conducting this analysis, environmental emissions-related impacts could be reduced	Material & design
	Mat 05	Designing for durability and resilience	REDUCE raw materials consumption (resilient and durable structures requiring fewer repairs): resilience and (raw materials consumption) - durability; frequent repairs	Material & design
	Mat 06	Material efficiency	RETHINK: increase of materials' and their use's efficiency is promoted REDUCE: increase of materials efficiency, reduce impacts and waste and, use of primary materials REUSE: of existing materials is considered RECYCLE: the procurement of materials with higher levels of recycled content is included among the potential practices for increased efficiency in use of recycled content	Material & design (some management-related issues are taken into consideration)

(continued)

Table 19.2 (continued)

Environmental section	Issue		Association with circularity (employed framework)	Level (site, material, design, construction, management)
Waste (Wst)	Wst 01	Construction waste management	REDUCE: construction waste reduction and consuming fewer materials REUSE & RECYCLE: construction waste and key refurbishment and demolition materials RECOVER of waste materials is considered	Material, construction & management
	Wst 02	Recycled aggregates	RECYCLE: aggregates REPURPOSE of secondary aggregates REDUCE: raw materials consumption and primary sources (as a consequence of the above)	Material
	Wst 03a	Operational waste	RECYCLE: the enabling and facilitation of operational waste recycling is considered RETHINK: old approaches to the space for the provision of recycling-related facilities and spaces	Design & management (some material-related issues are also taken into consideration)
	Wst 03b	Operational waste (residential only)	RECYCLE: the enabling and facilitation of operational waste recycling is considered RETHINK old approaches to the space for the provision of recycling-related facilities and spaces	Design & management (some material-related and urban site-related issues are also taken into consideration)
	Wst 04	Speculative finishes	REDUCE the unnecessary waste of materials and refurbish in future	Material

(continued)

Table 19.2 (continued)

Environmental section	Issue		Association with circularity (employed framework)	Level (site, material, design, construction, management)
	Wst 05	Adaptation to climate change	REDUCE resources consumption (reduced need for repair and reconfiguration as structural and fabric resilience is under consideration, with adaptation to climate change being also included as an exemplary credit) RETHINK: the previous design approach by conducting a climate change adaptation strategy, as one of the principles of circular construction, appraisal for structural and fabric resilience by the end of Concept Design	Design
	Wst 06	Functional adaptability	REDUCE resources consumption for future adaptations and change of use (adaptability is under consideration) REFURBISH as the facilitation of an "update" of the building uses in the context of its adaptability RETHINK: the previous design approach by introducing functional adaptation measures, as one of the principles of circular construction, through the finalisation of the technical design	Material, design & management (in the sense of preparing a functional adaptation strategy study)
Land use and ecology (LE)	LE 01	Site selection	REUSE land—as a consequence: REDUCE the consumption ("occupation") of previously unoccupied land REUSE/REPURPOSE in terms of brownfields REFURBISH (in the sense of restoring) contaminated land	Site

the level at which these associations occur (e.g., site, material, design, construction, management). It is important to note that general circularity principles, such as adaptability and resilience, have also been considered in this analysis, even though they are not explicitly mentioned in the 10-R framework used. Where applicable, these general principles were correlated with one or more of the 10 strategies in the framework, and the related information is included in the tables.

Table 19.3 *Issues* which are indirectly[4] associated with circularity (circular principles as reflected in the employed framework)

Environmental section	Issue		Association with circularity (employed framework)	Level (site, material, design, construction, management)
Management (Man)	Man 03	Responsible construction practices	REDUCE: Environmental impacts as result of monitoring site impacts like waste or water	Site, material, design, construction & management
	Man 05	Aftercare	REDUCE: water and energy consumption (setting targets for those items in the context of the exemplary level criteria) RETHINK: by increasing multifunctionality, existing approach and start providing aftercare to ensure the building operates and adapts for future needs	Design & management
Health and wellbeing (Hea)	Hea 09	Water quality	REDUCE water contamination by increasing efficiency in product or system manufacture—e.g., greywater treatment at the building scale	Design & management
Energy (Ene)	Ene 02a	Energy monitoring	REDUCE: energy consumption by monitoring energy input and output (energy cycling process)	Management
	Ene 02b	Energy monitoring	REDUCE: energy consumption by monitoring energy input and output (energy cycling process)	Management
	Ene 10	Flexible demand side response	REDUCE: energy consumption reduction due to flexible demand side response capability for electricity, which is promoted. (adaptability/flexibility aspect issue)	Design & management
Trasport (Tra)	Tra 02	Proximity to amenities	REDUCE transport use and as result its impacts (objective as a whole), the need to access amenities elsewhere RETHINK the space in the neighbourhood	Site & design

(continued)

[4] Indirect association: no reference/description in the intent, indicator, benchmarks, and generally, in the structure and content of the criterion. However, a clear connection of the following type can be seen: if this criterion is met, then, as a consequence, a circularity principle will be served.

Table 19.3 (continued)

Environmental section	Issue		Association with circularity (employed framework)	Level (site, material, design, construction, management)
	Tra 05	Travel plan	REDUCE reliance on and, therefore, use of forms of travel and transportation that have the highest environmental impact (objective as a whole) RETHINK existing travel plan issues	Site & design
	Tra 06	Home office	REDUCE/REFUSE transportation use to and from work as result its negative impacts (objective as a whole)	Site & design
Water (Wat)	Wat 02	Water monitoring	REDUCE water consumption by monitoring water input and output	Management
Pollution (Pol)	Pol 03	Surface water run-off	RETHINK: multifunctionality of green roofs REDUCE resources consumption in the sense of promoting flood resilience	Site & design

As with all the methods examined in this study, the results presented reflect the estimations and opinions of the sub-groups that worked on them. The determination of whether an association was direct or indirect was the outcome of discussions among sub-group members. These discussions led to a consensus on each *issue*; in cases where disagreements persisted, the majority opinion was recorded. The associations listed in the relevant columns of the tables indicate the principles that at least one sub-group member identified as being reflected in the respective BREEAM *criteria.*

The BREEAM study was conducted by a sub-group consisting of three researchers working on this chapter. As with the other methods examined, the researchers' opinions exhibited varying degrees of agreement and divergence. This variability is expected, given the inherent subjectivity in interpreting and estimating whether certain *issues* are more closely related to sustainability or circularity.

Based on the results shown in Tables 19.2 and 19.3, a key conclusion is that all the major *environmental sections* of the BREEAM method are represented to some extent, although with varying degrees of emphasis. It is important to note that the Innovation is neither included in Table 19.4 nor in the preceding analysis. This exclusion is due to the fact that credits in the Innovation section are awarded either for exemplary performance in certain *issues* (as defined in the BREEAM manual [8]) or when a "particular building technology or feature, design, construction method, or process" [8], p. 35, is recognised as innovative. In the first case, these associations are considered within the context of the respective *issues*, while the second case cannot be easily categorised or included in this type of analysis.

Regarding the nine *environmental sections* examined, it is evident that some are more strongly represented in Tables 19.2 and 19.3 than others. Specifically, direct associations were identified for all *issues* (seven out of seven) in the Waste *environmental section.* Another strongly represented *environmental section* is Water, where three out of four *issues* have direct associations, with the remaining *issue* being indirectly related to the employed circular economy framework. The Energy *section* presents a similar image, with seven directly and three indirectly associated *issues* among the ten ones that are included in it. The Transport *section* also shows a significant connection to circularity, with three direct and three indirect associations out of a total of seven *issues*. The Materials *section* is similarly well-represented, with three of its four *issues* included in Table 19.2.

In contrast, Health and Well-being *section* and the Management *section* are less represented in Table 19.2, with only two out of nine and one out of five *issues*, respectively, showing direct associations. The same pattern is observed in Table 19.3, where only one of the nine Health and Well-being *issues* and two of the five Management *issues* are indirectly related to circularity. The Land Use and Ecology *section* is represented by one *issue* in Table 19.2, while the Pollution *section* shows even weaker representation, with only one indirect association identified.

Overall, direct associations outnumber indirect ones. However, it is important to remember that BREEAM uses weighted scores, meaning that some *issues* contribute more to the final score than others. For instance, the fact that three out of nine Health and Well-being *issues* are associated with circularity does not imply that one-third of the available credits in this *section* are linked to circular principles or strategies. Moreover, within any given *issue*, only a portion of the available credits may be related to circularity. Additionally, each *environmental section* has its own relative weighting, which affects its contribution to the final score.

The results in Tables 19.2 and 19.3 also indicate that certain strategies and principles are more strongly represented than others in the identified associations. For example, the "Reduce" principle appears frequently across different *sections*. "Rethink" is also commonly found in both tables, while "Recycle" and "Reuse" are strongly represented among the direct associations.

All levels examined (site, material, design, construction, management) appear in Tables 19.2 and 19.3, with some levels being more frequently encountered than others. It is expected that the design level is the most frequently referenced, given that the examined BREEAM method primarily addresses new constructions.

19.3.3 DGNB

Introductory remarks. Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) System is a buildings' environmental performance assessment system developed by the German Sustainable Building Council (DGNB in German). The rating system was

Table 19.4 *Criteria* which are directly[5] associated with circularity (circular principles as reflected in the employed framework)

Topic	Criteria group	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
Environmental quality (ENV)	ENV1-Effects on the global and local environment	ENV1.1	Building life cycle assessment	REUSE: reusing components or structural elements is taken into consideration (indicator 3) REDUCE: resources consumption (energy, materials) is considered (indicator 3) RECYCLE & RECOVER: taken into consideration within LCA (indicator 3) REPAIR: more indirect association in comparison to the other 3, detected in the fact that service-life considerations are included in LCA	Material & design & construction
		ENV1.3	Sustainable resource extraction	REDUCE the primary raw materials extraction (indicator 2) RECYCLE: for secondary raw materials use (indicator 2)	Material
	ENV2-Resource consumption and waste generation	ENV2.2	Potable water demand and wastewater volume	REDUCE waste water production and potable water consumption (indicator 1) RECYCLE greywater & rainwater (indicator 1)	Site & design
		ENV2.3	Land use	REPURPOSE/REUSE land and REDUCE "consumption" of free land (indicator 1) REPAIR land in case of contamination (CE bonus)	Site & design

(continued)

[5] Direct association: direct reference/description in the intent, indicator, benchmarks, and generally, in the structure and content of the criterion. Also, CE association declared in the manual or CE bonus available.

Table 19.4 (continued)

Topic	Criteria group	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
Economic quality (ECO)	ECO1-Life cycle costs	ECO1.1	Life cycle cost	REUSE of building components is taken into consideration (CE bonus) RECYCLE & RECOVER taken into consideration (CE bonus) REPAIR & REDUCE: more indirect association in comparison to the other 3 detected in the fact that service-life considerations are taken into consideration in LCC analysis	Material & design & management
	ECO2-Economic development	ECO2.1	Flexibility and adaptability	REDUCE: doing more with the same building (all indicators) RETHINK: high intensity of use (CE bonus), REUSE & REPURPOSE via the flexibility and adaptability promotion (all indicators)	Design
		ECO2.2	Commercial viability	RETHINK: contribution to circular economy by at least one party (CE bonus) *note:* the association of this criterion with circular economy is not considered to be as clear as in the other cases; its inclusion in this table is established by the fact that within its framework, a CE bonus is offered	Design & management

(continued)

Table 19.4 (continued)

Topic	Criteria group	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
Technical quality (TEC)	TEC1-Technical quality	TEC1.4	Use and integration of building technology	REDUCE: promoting the reduction of non-renewable energy consumption by the integration of passive systems (indicators 1,2,4 and CE bonusses) REPAIR: All components of the technical facilities are easily accessible for repair. The technical facilities have a sufficient number of sufficiently large mounting openings, doors and corridors to minimise unnecessary interaction with materials during repair or maintenance REFURBISH: promoting the accessibility of the building technologies (indicator 3)	Design & management
		TEC1.6	Ease of recovery and recycling	REDUCE the primary resources required (CE Bonus 1.2-and general aim of the criterion) REUSE of building components taken into consideration (CE bonus 1.3), RECYCLE: easy to recycle materials (indicator 1), REFUSE: avoiding use of building components (CE bonus 1.3), RECOVER: the CE bonus promotes reuse and recovery of materials. The criteria assess the ability of building structures to be easily recoverable - ease of disassembly and ease of separation of building components in terms of max. possible material content (indicator 2)	Materials & design

(continued)

Table 19.4 (continued)

Topic	Criteria group	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
		TEC3.1	Mobility infrastructure	REFUSE: refuse to use inefficient mobility infrastructure and old approaches - instead use bicycles, electric vehicles (indicator 1,3); refuse to use personal vehicles - instead use the concept of sharing. (CE bonus 2.1) RETHINK: mobility sharing is promoted (CE bonus 2.1) REDUCE: more indirect association in comparison to the previous ones, as resources consumption may be achieved, e.g. with the provision of bicycle parking facilities (indicators 1–4, taking into account the references in Innovation area)	Site & design & management
Process quality (PRO)	PRO1-Technical quality	PRO1.4	Sustainability aspects in tender phase	REUSE & REPURPOSE & RECYCLE: not excluding and or enhancing at the tender phase the use and or reuse of recycled and or secondary materials for specific applications is promoted (CE bonus 1.2)	Material & management
	PRO2-Construction quality assurance	PRO2.1	Construction site / construction process	REDUCE the amount of generated waste (indicator 4, CE bonus 4.4.)	Site & management
Site quality (SITE)	SITE1-Site quality	SITE1.4	Access to amenities	RETHINK the space and its possible uses (CE bonus) *note:* the association of this criterion with circular economy is not considered to be as clear as in the other cases; its inclusion in this table is established by the fact that within its framework, a CE bonus is offered	Site & design

initially launched in 2008 [4, 15], with its first version addressing the sustainability assessment of new administrative and office buildings in Germany. The certification scheme was used for the first time in the market in 2009 [15]. In the following years, the constantly evolving method expanded to involve additional building uses and lifecycle stages. Currently, schemes / differentiated versions of the method are available for buildings of a plethora of uses, with regard to different stages of their lifecycle, and to areas of application of more specific interest (e.g. "Interiors") are available. A DGNB system for the evaluation of built environment entities at larger scales (districts) has also been developed, encompassing schemes for business districts, event areas, commercial areas, industrial sites, urban districts and other cases (resorts and vertical cities) [15]. DGNB method can be applied also outside Germany (adaptation to local conditions, employment of international standards). The application of the method across Europe, but also in other continents keeps increasing.

In this review, DGNB System for new buildings version 2020 (international) [14] is examined. The method addresses various building uses (office, education, residential, hotel, consumer market, shopping centre, department store, logistics, production, assembly buildings) and has an international scope of application. The aspects of the building that are evaluated (and, consequently, the assessment *criteria*) are classified into six major *topics*: (i) Environmental Quality (including six *criteria*), (ii) Economic Quality (incl. three *criteria*), (iii) Sociocultural and functional Quality (incl. eight *criteria*), (iv) Technical Quality (incl. eight *criteria*), (v) Process Quality (incl. nine *criteria*) and (vi) Site Quality (incl. four *criteria*). Within each one of those *topics*, the *criteria* are organised into *criteria groups*. Each *criterion* includes a set of indicators, which form the basis for its assessment. Each indicator is associated with a maximum number of available points, which are awarded fully, partially or not at all to the assessed building, depending on whether and to which degree this building complies with the requirements and or conditions implemented in the examined indicator's structure and content. The maximum number of available points accompanying each indicator may differ for the various building uses. The score of each *criterion* is derived based on the points awarded to the building in the context of the indicators integrated in this criterion. Regarding the maximum number of points available to be awarded within each *criterion*, 100 is a key value; for some *criteria* 100 points can be achieved, for others more than 100 can be achieved but only 100 can be awarded, while in the context of several *criteria* additional (in regard to 100) bonus points can be "obtained" by the building. Based on the points achieved in the context of each *criterion* and its weighting factor,[6] the scores of the higher levels of the method's structure are calculated. Taking into consideration the derived performance indices and the relative weightings of the six major *topics* (Environmental Quality: 22,5%; Economic Quality: 22,5%; Sociocultural and Functional Quality: 22,5%; Technical Quality: 15%; Process Quality: 12,5% and Site Quality: 5%), an overall performance score is calculated (total performance index). This overall performance

[6] Each criterion is accompanied by a weighting factor, which is associated with its share in the total score. The value of this weighting factor remains the same across all building uses for some criteria, while for others some differentiations appear for specific uses.

Levels of certification	Total Performance Index	Min. Performance Index
Platinum	≥ 80%	65%
Gold	≥ 65%	50%
Silver	≥ 50%	35%
*Bronze**	≥ 35%	-

*only valid for the passed certificate or for the certificate "Buildings in operation"

Fig. 19.3 Levels of certification (ranking classes) of buildings assessed with the application of DGNB System (adapted from [13, 14])

score in combination with the individual performance indices calculated for the six major *topics*, all expressed as percentages, result in the classification of the buildings into a ranking level (platinum, gold or silver) as depicted in Fig. 19.3.

It is noted that there are a few performance requirements within certain *criteria* that must be met by the building in order for the assessment as a whole to be carried out.

Circularity implementation. The investigation of the circularity implementation is taking place at the level of criteria, i.e. the lowest rated level of the method's structure—where the evaluation takes place via the examined indicators for each criterion).

The *criteria* integrated in DGNB's assessment structure, which are additionally associated with the circular economy-related strategies/principles that are outlined in the employed framework, are listed in Tables 19.4 and 19.5. Specifically, Table 19.4 includes the directly associated *criteria*, while in Table 19.5. the indirectly related ones are shown. The additional information appearing in those tables is of the same types as the ones analytically explained for the respective tables (Tables 19.2 and 19.3) appearing in BREEAM's analysis. Following a uniform methodological approach for all the examined methods, the nature of the association is established based on the whole content of each *criterion* (indicators, benchmarks, aim, etc.) and the consideration of general circularity principles (adaptability, resilience, etc.) has also been attempted. In total, the information appearing in the following tables (Tables 19.4 and 19.5) reflects the analysis conducted by the sub-group of researchers involved in it, via the process described for BREEAM.

The sub-group working on DGNB consisted of four members. The fact that the opinions expressed by those researchers were characterised by differences and similarities of a smaller or larger degree, since subjectivity was inherent in the interpretations and the attempted estimations, with several issues lying in the limit between being considered as "sustainability-related" rather than "circularity-related" or vice versa. Specifically, for DGNB, the detection of the *criteria* association was facilitated by the fact that certain of them are accompanied by circular economy bonuses in the structure of the method itself. In those cases, a direct association with circular economy and, consequently, with one or more of the principles outlined in the employed framework is de facto established. However, it has to be pointed out that

Table 19.5 *Criteria* which are indirectly[7] associated with circularity (circular principles as reflected in the employed framework)

Topic	Criteria group	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
Process quality (PRO)	PRO1-Technical quality	PRO1.5	Documentation for sustainable management	REPAIR/REFURBISH: prolonging the lifespan of the building or of specific elements (indicator 1.1)	Management
	PRO2-Construction quality assurance	PRO2.2	Quality assurance of the construction	REDUCE/RECYCLE: with regard to the requirement lists on the construction site fulfilling ENV1.3 criteria (indicator 3.1)	Site& design & construction & management
		PRO2.5	FM-compliant planning	REDUCE energy consumption for buildings' future operation	Management
Site quality (SITE)	SITE1-Site quality	SITE 1.1	Local environment	*Resilience is under consideration; as such,* REDUCE (resources consumption for retrofitting), REUSE (facilities / buildings that have already been impacted by extreme events), REFURBISH (instead of demolishing constructions beyond repair) and RETHINK (the old design approaches and considering adaptability strategies, as one of the main circular principles, regarding the natural effects), *can be referred to*	Site & design & management

the associations detected in this study are not limited to the *criteria*, in the context of which circular economy bonuses are offered.

One of the basic observations resulting from Tables 19.4 and 19.5 is that the vast majority of the *criteria* in DGNB are estimated to be directly related to the examined principles. This is partly due to the fact that circular economy strategies and

[7] Indirect association: no reference/description in the intent, indicator, benchmarks, and generally, in the structure and content of the criterion. However, a clear connection of the following type can be seen: if this criterion is met, then, as a consequence, a circularity principle will be served.

requirements are explicitly dealt with and considered in this assessment method. Furthermore, it is noted that several of the *criteria* (four out of six) belonging to the Environmental Quality topic and all of the *criteria* constituting Economic Quality are found to be directly associated with circularity. This is not the case for Sociocultural and Functional Quality (no associations were identified), while three out of the eight *criteria* included in Technical Quality are determined to be characterised by direct relationship with the employed circular economy framework. Process Quality is also represented in Tables 19.4 and 19.5 (two of the nine *criteria* of this *topic* are estimated to present direct associations, with additional three ones being characterised by indirect relationships), with Site Quality also participating with two out of its four *criteria*. At this point, it has to be mentioned that the presented numbers do not account for an exact outline of the contribution of the estimated to be associated *criteria* to the building's total score; indeed, each criterion in DGNB is accompanied by a relevance factor (i.e. a type of weighting) varying for the different building uses and, furthermore, a relative weight is set by the method for each *topic* (see "Introductory remarks" for DGNB).

Additionally, the results shown in the tables above indicate that certain principles seem to be more frequently encountered than others in the identified associations. For example, "Reduce" appears in almost all associations, with "Reuse" and "Recycle" having a considerable impact as well. Of course, other principles/strategies are also reflected in the provided estimations.

Finally, more than one level (site, material, design, construction, management) seem to be aimed at by the vast majority of the criteria presenting a kind of association with circular economy.

19.3.4 LEED

Introductory remarks. In 1998, Leadership in Energy and Environmental Design (LEED) was introduced by the US Green Building Council, as a pilot programme and became an official rating system in 2000. LEED certification serves as a framework for promoting healthy, highly efficient, and cost-saving green buildings, which deliver various environmental, social, and governance benefits. Recognised globally as a symbol of sustainability achievement, LEED certification is supported by a dedicated network of organisations and individuals driving market transformation [44].

LEED-certified buildings can play a key role in addressing climate change, achieving environmental, social and governance (ESG) goals, promoting resilience, and fostering equitable communities. Unlike a narrow focus on specific building elements like energy, water, or health, LEED takes a holistic approach, considering all essential aspects that contribute to creating better buildings [42].

The objective of LEED is to construct superior buildings that:

- Mitigate the impact on global climate change
- Enhance the well-being of individuals

- Safeguard and restore water resources
- Preserve and enrich biodiversity and ecosystem services
- Promote sustainable and regenerative material cycles
- Improve the quality of life for communities

Within the LEED framework, 35% of credits are dedicated to climate change, 20% directly impact human health, 15% focus on water resources, 10% address biodiversity, 10% contribute to the green economy, and 5% impact community and natural resources. In LEED v4.1 Building Design and Construction (the version examined in this report [43]) the majority of credits revolve around operational and embodied carbon considerations. Additionally, LEED categories can contribute to the achievement of the Sustainable Development Goals of the United Nations [42].

The examined performance aspects by the rating systems are divided into categories, which vary depending on the rating system. Each *category* has *prerequisites*, that are mandatory, and *credits*. *Credits* and *prerequisites* constitute the lowest autonomous scored level of the method's structure. To obtain LEED certification, a project accumulates points by meeting *prerequisites* and *credits* related to carbon, energy, water, waste, transportation, materials, health, and indoor environmental quality. These projects undergo a thorough verification and review process conducted by the Green Building Certification Institute (GBCI), which assigns points based on their performance. The number of points attained determines the level of LEED certification awarded: Certified (40–49 points), Silver (50–59 points), Gold (60–79 points), and Platinum (80 + points) [42]. Figure 19.4 illustrates the levels of LEED certification.

Circularity implementation. As mentioned previously, to evaluate the relationship of circularity and the LEED certification, the Building Design and Construction (BD + C) rating system was chosen as the baseline for evaluation. All *categories*, *credits*, and *prerequisites* from BD + C were considered in the analysis.

The circular economy-related strategies and principles, along with their associated *credits* and *prerequisites*, are detailed in Tables 19.6 and 19.7. Table 19.6 outlines the directly related *credits* and *prerequisites*, while Table 19.7 covers the indirectly related ones. The comprehensive content of each *credit* and *prerequisite*, including intent, assessment criteria, and compliance conditions, serves as the basis for identifying the nature and type of association (direct or indirect). Tables 19.6 and 19.7 also provide information on the specific principles/strategies associated with each *credit/prerequisite*, along with estimations of the corresponding *category* (Integrative Process, Location and Transportation, Sustainable Sites, Water Efficiency,

LEED level of certification	*Platinum*	*Gold*	*Silver*	*Certified*
Score [number of points earned]	≥ 80	60-79	50-59	40-49

Fig. 19.4 Levels of LEED certification (adapted from [42])

Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation) linked to this association. General circularity principles such as adaptability and resilience have been considered, although not explicitly addressed by the employed 10-R framework. The taken approach involves correlating these general principles with one or more of the 10 strategies employed in the framework, and this information is presented in the tables for reference.

The results presented in the following tables indicate the estimations and opinions of the sub-group working on LEED. The process followed for the formulation of the listed results is the same as the one adopted for BREEAM and DGNB, including the way the associations presented in Tables 19.6 and 19.7 were identified.

The LEED sub-group comprised five members who expressed a range of opinions, varying in degree of similarity and difference. Notably, for LEED, the identification of circular economy association was facilitated by the presence of circular economy criteria and indicators accompanying certain *credits/prerequisites.* This established a direct link between circular economy and one or more principles outlined in the employed framework.

An important observation from Tables 19.6 and 19.7 is that approximately one-third of LEED *credits/prerequisites* are estimated to be directly related to the examined principles. However, some *categories* primarily address sustainability concerns rather than circular economy strategies and requirements. For instance, the Indoor Environmental Quality *category* focuses mainly on user comfort, rather than the circularity of resources. This is the reason why only one of its 12 *credits/prerequisites* is estimated to present an association (in fact an indirect association) with the employed framework. Sustainable Sites *category* follows, accounting for five *credits/prerequisites* estimated to present some kind of association (among which two are directly related and three indirectly) out of the 13 examined ones. In this *category* most of the concerns addressed are related to sustainability and site inherit characteristics.

On the other hand, the two *categories* presenting the highest number of *credits/prerequisites* directly related to the circularity framework, accounting for six *credits/prerequisites* each, are (i) Materials and (ii) Water Efficiency. In the case of Materials *category*, a total of 11 *credits/prerequisites* are available in the rating system, six of which are found to be directly related to circularity. This is due to the fact that those *credits/prerequisites* are based on CE principles, like Design for Flexibility, Construction and Demolition Waste Management, Building Life-Cycle Impact Reduction, and so on. "Rethink", "Reduce", and "Recycle" are the most associated principles/strategies with those *credits/ prerequisites.* It is important to remark that those identified as non-related in Materials *category* are *credits* specifically for healthcare facilities, not for the other typology of buildings. In regard to the Water Efficiency *category*, six of the total seven available *credits/ prerequisites* are estimated to be directly associated. "Reduce" is the principle that appears in all of the *credits/prerequisites*, once the main aim of the *category* is water reduction.

Location and Transportation as well as Energy and Atmosphere *categories* are estimated to be mostly related to the "Reduce" principle. Indirect associations were identified for five out of the existing eight *credits/prerequisites* in Location and

Table 19.6 *Credits/prerequisites* which are directly[8] associated with circularity (circular principles as reflected in the employed framework)

Category	Credit or prerequisite	Association with circularity (employed framework)	Level (site, material, design, construction, management)
Integrative Process (IP)	Integrative project planning and design	RETHINK: in terms maximising opportunities for integrated design. Utilising innovative approaches and techniques REDUCE: IPPD can contribute to circularity by encouraging stakeholders to consider resource efficiency from the early planning stages of a project through optimising the use of materials, energy, and other resources and cost-effective adoption of green design and construction strategies REUSE: by emphasising the importance of reusing materials and products whenever possible REFURBISH & REMANUFACTURE: incorporate to circularity by designing products or systems that are easy to maintain, upgrade, or repair RECYCLE: promote recycling as a way to keep materials and resources in circulation	Site & design
	Integrative process	RETHINK: Utilising innovative approaches and techniques REDUCE: the integrative process encourages all stakeholders including architects, engineers, and builders to work together to consult and design buildings in the early design stages to implement resource-efficiency which can lead to reducing the overall use of materials, energy, and water, consequently minimising resource consumption REUSE: Under this step, it is important to make the necessary integration according to Reuse principles	Site & design

(continued)

[8] Direct association: direct reference/description in the intent, indicator, benchmarks, and generally, in the structure and content of the criterion.

Table 19.6 (continued)

Category	Credit or prerequisite	Association with circularity (employed framework)	Level (site, material, design, construction, management)
Sustainable Sites (SS)	Rainwater management	REUSE & RECYCLE: water as a "product", apply rainwater management strategies such as using rainwater harvesting technologies can lead to water reuse and increase water efficiency REDUCE: runoff volume, flooding downstream RECOVER & REPAIR: Collecting rainwater, keeping it for a certain period of time for the necessary sanitation process, and then using it is important for recovery & repair	Site & design
	Joint use of facilities	RETHINK: rethink of traditional practices, emphasising the efficient use of resources, space, and infrastructure and promoting sharing as a concept REDUCE: the need for multiple entities to build and maintain separate infrastructure, such as buildings, utilities, and transportation systems, and as a result - resource consumption, energy use, and land use	Site & design & management
Water Efficiency (WE)	Outdoor water use reduction	RETHINK: multifunctional systems for efficient water consumption, develop landscape design strategies for harvesting and using rain water for non-potable purposes REDUCE water consumption and outdoor potable water REUSE: use captured rainwater or recycled water for irrigation purposes RECYCLE: recycle water	Site & design & management
	Indoor water use reduction	RETHINK: developing design strategies for optimising and reduce water consumption REDUCE: water consumption REUSE: use captured rainwater/ or recycled water for non-potable uses RECYCLE: recycle water	Design & management
	Building-Level water metering	RETHINK & REDUCE: metering provides an index that can help to predict and identify management strategies to reduce water consumption in the future	Design & management

(continued)

Table 19.6 (continued)

Category	Credit or prerequisite	Association with circularity (employed framework)	Level (site, material, design, construction, management)
	Outdoor water use Reduction	RETHINK: multifunctional systems for efficient water consumption, develop landscape design strategies for harvesting and using rain water for non-potable purposes REDUCE water consumption and outdoor potable water REUSE: use captured rainwater or recycled water for irrigation purposes RECYCLE: recycle water	Site & design & management
	Indoor water use reduction	REDUCE: water consumption REFUSE: using inefficient equipment (kitchen, washing mashines) which causes bigger water consumption	Design & management
	Optimize process Water Use	RETHINK: design strategies to reduce water consumption REDUCE water consumption REUSE: installing water treatment facilities to circulate indoor wastewater, use alternative water for cooling RECYCLE: recycle water	Design & management
	Water metering	RETHINK & REDUCE: metering provides an index that can help to predict and identify management strategies to reduce water consumption in the future	Design & management
Energy and Atmosphere (EA)	Minimum energy performance	RETHINK & REDUCE: adopting design strategies to optimise and reduce energy consumption	Design & management
	Optimize energy performance	RETHINK & REDUCE: adopting design strategies to optimise and reduce energy consumption and resources, as a result environmental and economic harms associated with excessive energy use and greenhouse gas emissions	Design & management
	Renewable energy	RETHINK: adopting strategies for transition to renewable & clean energy sources REDUCE fossil fuel consumption, GHG emission & carbon footprint	Site & design & management

(continued)

Table 19.6 (continued)

Category	Credit or prerequisite	Association with circularity (employed framework)	Level (site, material, design, construction, management)
Materials and Resources (MR)	Storage and collection of recyclables	RECYCLE: promote recycling practices by providing dedicated areas for collection and storage of recyclable materials REDUCE: waste storage and collection can lead to a reduction in the demand for new materials REMANUFACTURE: by adopting these strategies, valuable materials can be Remanufactured	Design & management
	Building Life-Cycle impact reduction	RETHINK: by using innovative and eco-friendly design principles and encouraging adaptive reuse REDUCE: reduce the environmental impact of construction and operation by using fewer materials and resources REUSE: adopting strategies for reusing materials and components from existing buildings RECYCLE: encourage recycling of construction materials, such as concrete, steel, and wood	Material & design & construction
	Sourcing of raw materials	REFUSE: by encouraging and supporting products and materials from responsible sources, which provides materials with lower environmental impact. And by refusing irresponsible sources RETHINK: design strategies, products and materials. And selecting materials that are easier to disassemble, repair, or recycle REDUCE: responsible sourcing contributes to circularity by promoting the closed-loop use of materials and reducing the demand for new raw materials REUSE: reused materials are encouraged RECYCLE: by encouraging the use of materials/ products with recycled content	Material & design & construction
	Material ingredients	REFUSE: by preventing hazardous materials use RETHINK: design strategies, products and materials. By knowing information about the product, it is assumed that this product can last longer, not be harmful to users and reduce the need to replace it	Material & design & construction

(continued)

Table 19.6 (continued)

Category	Credit or prerequisite	Association with circularity (employed framework)	Level (site, material, design, construction, management)
	Design for flexibility	RETHINK/ REPURPOSE: by encouraging adaptive reuse, flexibility and adaptability, and possibly reducing the repair needs REDUCE: by implementing strategies to increase building flexibility	Material & design & construction
	Construction and demolition waste management	RETHINK/ REPURPOSE: by applying design strategies to use CDW REDUCE: by adopting waste management strategies to reduce the generation of waste REUSE/ RECYCLE: reusing and recycling of demolition waste like metal, wood, glass, etc	Material & design & construction

Transportation *category*, while seven out of 10 *credits/prerequisites* (in which three are directly related and four indirectly) of Energy and Atmosphere *category* are included in Tables 19.6 and 19.7.

It is important to note, that as the LEED system is based on points awarded under the *categories*, and the number of possible points varies from *credit* to *credit*, the number of associations -by itself- within the circularity framework does not necessarily reflect the percentage of the available points that can be potentially achieved in the context of those *credits*.

Furthermore, the results presented in the tables highlight that certain principles, such as "Reduce" and "Rethink," appear in nearly all associations, while "Reuse" and "Recycle" also have a significant impact. Evidently, other principles and strategies have been listed in the preceding tables as well, outlining almost the whole spectrum of the considered framework.

19.3.5 Level(s)

Introductory remarks. The Level(s) framework is a comprehensive EU framework developed to establish a common language towards sustainability assessment in both new-built and renovation projects, with a particular focus on office and residential buildings. It is designed to align with the circular economy action plan and incorporates a lifecycle approach from cradle to cradle to ensure long-term resource efficiency. The framework also utilises a value and risk rating system to emphasise the importance of sustainability. While the core sustainability indicators of Level(s) primarily concentrate on the environmental performance of buildings throughout

Table 19.7 *Credits/prerequisites* which are indirectly[9] associated with circularity (circular principles as reflected in the employed framework)

Category	Credit or Prerequisite	Association with circularity (employed framework)	Level (site, material, design, construction, management)
Location and Transportation (LT)	LEED for neighborhood development location	REFUSE: reduce vehicle distance travelled, avoid development on inappropriate sites RETHINK: design strategies REDUCE: encourage the reduction of automobile usage, adopting cost-effective strategies	Site & design
	Sensitive land protection	RETHINK: by promoting compact, mixed-use developments can reduce urban sprawl, preserve open space, and promoting efficient land use patterns REUSE: redevelopment of previously contaminated or underutilised areas can promote urban revitalisation and reusing existing infrastructure	Site
	High-priority site and equitable development	REUSE/RECOVER: by encouraging developments in Previously Developed Land and promoting the remediation of brownfields REDUCE: undeveloped land use	Site

(continued)

[9] Indirect association: no reference/description in the intent, indicator, benchmarks, and generally, in the structure and content of the criterion. However, a clear connection of the following type can be seen: if this criterion is met, then, as a consequence, a circularity principle will be served.

Table 19.7 (continued)

Category	Credit or Prerequisite	Association with circularity (employed framework)	Level (site, material, design, construction, management)
	Surrounding density and diverse uses	REFUSE: promoting the reduction of vehicle distance travelled by encouraging development in areas with infrastructure RETHINK: design strategies REDUCE the use of the automobile by adopting cost-effective strategies REUSE: by promoting existing infrastructure. Higher urban density can reduce the overall consumption of land and resources per capita. Efficient land use minimises the need for transportation, lowers energy demand, and reduces the environmental footprint of urban areas REUSE/ REPURPOSE: diverse urban neighbourhoods often have older buildings that can be repurposed or adaptively reused for new functions which can preserve existing structures and reduce the need for new construction RECYCLE: urban areas with diverse uses can support robust recycling programs, allowing for the efficient collection and recycling of materials like paper, glass, and plastics	Site
	Access to quality transit	REDUCE/ REFUSE: reduce car dependency. Quality transit systems are typically more energy-efficient than private vehicles, which can lead to resource recovery and reduced energy consumption REPAIR/ REFUSBISH: regular maintenance and rehabilitation of transit vehicles and infrastructure extend their useful lifespan, allow for the reuse of existing assets rather than replacing them entirely, and reduce waste	Site

(continued)

Table 19.7 (continued)

Category	Credit or Prerequisite	Association with circularity (employed framework)	Level (site, material, design, construction, management)
Sustainable Sites (SS)	Protect or restore habitat	REUSE: Environmental Site Assessment promotes the preservation of natural site features like wetlands, forests, and topography, which can be considered as a form of reuse by maintaining the ecological functions of the site	Site
	Site master plan	REUSE: by encouraging the preservation and adaptive reuse of existing natural and built features on the site, such as trees, historic structures, or infrastructures. It can also reduce waste and conserve resources	Site & design
	Tenant design and construction guidelines	REDUCE/ REPAIR: Development of such plans, which include recommendations for maintenance, description of design solutions - prolong the life of materials and building	Design & management
Energy and Atmosphere (EA)	Fundamental commissioning and verification	RETHINK: commissioning plan can implement strategies to extend product's life, and reduce material-water-energy consumption REDUCE: the Operations and Maintenance Plan could reduce unnecessary repair/ refurbish for equipment and plan maintenance activities carefully	Design & construction & management
	Building-level energy metering	RETHINK/ REDUCE: by identifying opportunities for energy savings. Metering provides an index that can help to predict and develop management strategies to optimise energy consumption in the future	Design & management
	Enhanced commissioning	RETHINK: commissioning plan, strategies to extend product's life	Design & construction & management

(continued)

Table 19.7 (continued)

Category	Credit or Prerequisite	Association with circularity (employed framework)	Level (site, material, design, construction, management)
	Advanced energy metering	RETHINK/ REDUCE: by identifying opportunities for energy savings. Metering provides an index that can help to predict and develop management strategies to optimise energy consumption in the future	Design & management
Indoor environmental Quality (EQ)	Daylight	RETHINK/ REDUCE: by applying design strategies to use more natural light reduce energy consumption for lighting	Design

their lifecycle, the framework also encompasses aspects related to comfort, health, and lifecycle costs.

By adopting six macro-objectives, Level(s) translates them into 16 measuring indicators that contribute to key target areas set by the EU, such as energy efficiency, resource consumption, waste generation, water usage, indoor comfort and cost and risk assessments. This holistic approach allows the framework to provide building performance reports on individual aspects accompanying a project professional course since the conceptual design, through implementation and construction up to completion and operation. The end-of-life stage is also considered, particularly in macro-objective 2: Resource efficient and circular material life cycles, which includes indicators like design for adaptability (DfA) and design for disassembly (DfD). Additionally, the methodology incorporates a simplified Life Cycle Analysis (LCA) that encompasses inputs from macro-objectives 1, 2, and 3 as well as Life Cycle Cost Analysis (LCCA) in macro-objective 6. Table 19.8 presents an overview of the six macro-objectives of Level(s) framework along with their scope and objectives.

Level(s) framework supports the project development at three levels of performance assessment:

- Level 1: Conceptual design, which employs a qualitative assessment methodology primarily using simple checklists to report the intended implementation concepts.
- Level 2: Detailed design and construction performance, which utilises a quantitative assessment methodology to evaluate the designed performance and monitor construction according to standardised units and methods.
- Level 3: As-built and in-use performance assessment, which also employs a quantitative assessment for monitoring and surveying activities during the building's use stage after completion.

These levels enable a progression in terms of reporting accuracy and expertise, empowering stakeholders to continuously refine and improve the sustainability

Table 19.8 Level(s) Macro objectives scope

Macro objective	Scope
MO1. Greenhouse Gas Emissions Along a Building's Life Cycle	Aims to reduce a building's carbon footprint. Considering all life cycle stages of buildings, greenhouse gas emissions contributing to global warming potential are evaluated. These emissions are referred to as whole life cycle carbon and apply to building materials and their management processes (embodied carbon emissions) as well as operational carbon emissions. Improvement of the building's carbon footprint can refer to optimisation of material flows, enhancing productivity, reducing delays, eliminating waste, and minimising energy usage for heating and cooling
MO2. Resource Efficient and Circular Material Life Cycles	Aims to improve building's performance by considering circularity principles, limiting the use of raw materials, identifying opportunities for reuse or recycling, and ensuring that buildings can be readily adapted to occupants' needs change over time. The aim of macro-objective 3 (efficient use of water resources) is to make use of water resources more efficiently, particularly in areas of identified long-term or projected water stress [13]. Macro-objective 4 (healthy and comfortable spaces) aims to create buildings more comfortable, attractive, and productive to live and work in. In these ways, human health protection can be improved [13]. Macro-objective 5 (adaptation and resilience to climate change) aims to make new building resilient against projected climate changes and thus protect the health and comfort of occupiers. Moreover, long-term risks to property values and investments can be minimised [13]. Macro-objective 6 aims to optimise the life cycle cost and value of buildings. Considering this approach, the potential for long-term performance is improved. Moreover, costs related to inclusion of acquisition, operation, maintenance, refurbishment, disposal, and end-of-life treatment are reduced [13]
MO3. Efficient Use of Water Resources	Aims to make use of water resources more efficiently, particularly in areas of identified long-term or projected water stress [13]
MO4. Healthy and Comfortable Spaces	Aims to create buildings more comfortable, attractive, and productive to live and work in. In these ways, human health protection can be improved [13]
MO5. Adaptation and Resilience to Climate Change	Aims to make new building resilient against projected climate changes and thus protect the health and comfort of occupiers. Moreover, long-term risks to property values and investments can be minimised [13]
MO6. Optimised life Cycle Cost and Value	Aims to optimise the life cycle cost and value of buildings. Considering this approach, the potential for long-term performance is improved. Moreover, costs related to inclusion of acquisition, operation, maintenance, refurbishment, disposal, and end-of-life treatment are reduced [13]

performance of their buildings. The Level(s) common framework offers multiple advantages for three main groups of stakeholders: (1) Project design teams, including architects, engineers, quantity surveyors, and specialist consultants; (2) Clients and investors, such as property owners, developers, managers, and investors; and (3) Public policy makers and procurers at national, regional, and local levels.

To calculate each indicator at the three levels of assessment, Level(s) provides specific instructions and guidelines. These can be found in the respective user manuals for each indicator. To ensure comparability between buildings with the same function, the framework recommends the use of national tools and standards, along with renowned private ones, utilising common measurement units for indicator calculation. The manual for each indicator provides these recommendations. The framework does not introduce a new methodology for sustainability calculation; instead, it emphasises the importance of reporting and using appropriate tools and methods for fixed key parameters throughout the lifecycle using the three levels of assessment. The measurement unit varies across indicators, and the final scores are neither normalised nor accumulated to provide an overall sustainability or circularity score for benchmarking building performance.

To utilise the framework, a Level(s) project plan must be established by following these steps:

- Step 1: Define the macro-objectives to be addressed in the project and identify the indicators to be used for performance assessment and reporting under each macro objective.
- Step 2: Determine the performance level of assessment for the preselected indicators.
- Step 3: Plan the workflow requirements and resources needed for assessment at different lifecycle stages, including defining roles and responsibilities of stakeholders, discussing expertise, and training requirements, establishing management models for information and data acquisition and flow, and setting specific deadlines.

The framework provides multiple tables and reporting formats to support the development of these steps. Additionally, it offers a specific format for a complete building description, which includes information on location and climate, typology and age, building usage, and building model and characteristics. This information is necessary for the calculation of multiple indicators within the framework. Detailed guidance and supportive information are provided to assist in developing a comprehensive building description.

The level or levels of assessment can be determined based on the project's needs and priorities. It is possible to assess only one level or progress up to a specific level. Combining certain levels is also an option. The level definition can be applied to different indicators, allowing for assessment at various levels. However, the more levels that are addressed, the more accurate the understanding of the project's performance will be, including any gaps between design and the reality of the completed building. The framework also provides opportunities to further optimise performance in most indicators. This can be achieved by using input data with higher granularity, considering additional design and performance aspects, testing and comparing additional scenarios, or utilising more advanced calculation methods. Table 19.9 presents the main points addressed in each of the three levels of assessment in terms of project stages, assessment approach, reporting rules and steps, optional additional steps, and the need for a full building description.

Circularity implementation. The analysis of circularity implementation in this section focuses on the indicator level, which constitutes the third tier of the framework, following the thematic areas and macro-objectives, consequently. The examination involves assessing the alignment of 16 indicators in Level(s) V1.1, integrated within the six macro-objectives, with the 10-Rs principles. The findings of this assessment are summarised in Tables 19.10 and 19.11.

Table 19.10 provides an in-depth analysis of the direct relationships between the indicator scope, criteria, guidelines, and objectives within the 10-R framework. In contrast, Table 19.11 delves into the secondary impacts that indirectly contribute to circularity. In both tables, each of the 16 indicators is evaluated for its relevance to the 10-Rs circularity principles, with the results detailed in the final column in each table. Only the principles that are pertinent to each indicator are mentioned.

It is important to note that the examination results represent a consensus among three researchers in the field. However, these findings aim to provide a broad overview of the indicator framework's alignment with circularity principles without specifying their specific relationship to one or more of the three assessment levels of the framework. This is because all three assessment levels complement one another and ultimately support the same overarching logic and goal.

The sub-group working on Level(s) comprised three researchers in the field. The opinions expressed by these researchers shared notable similarities while also exhibiting some low to moderate differences on certain indicators. The primary points of contention revolved around the indirect relationships of specific indicators with circularity. Nevertheless, these differences predominantly arose due to varying subjective interpretations of sustainability and circularity concepts, and the inherent, undefined interplay between them without clear delineation of their scope. However, it is important to note that these differences in opinions were expected and were effectively addressed through extensive discussions and the exchange of perspectives to refine the results and determine which indicators had a direct association and which had an indirect connection to the 10-R principles of circularity.

The indicators that exhibit the strongest direct links to circularity implementation are the four indicators within Macro Objective 2, "Resource-efficient and circular material life cycles." These indicators concentrate on design and engineering to promote lean and circular material flows, extend product service life and material utility, and minimise environmental impacts. However, it is important to recognise that the majority of the remaining circularity-relevant indicators in the other Macro Objectives are influenced by the indicators within Macro Objective 2.

A more detailed explanation on the indicators that establish direct circularity association (Indicators 2.1, 2.2, 2.3 and 2.4) and their indirect impact on the framework's other indicators is provided in the subsequent paragraphs. This is followed by paragraphs explaining LCA and LCC indicators in Macro Objectives 1 and 6,

Table 19.9 Important aspects addressed in each of the three levels of assessment in Level(s) framework

	Level 1 Conceptual design	Level 2 Detailed design and construction	Level 3 As-built and in-use
Project stages	• L1a. Project definition and brief • L1b. Concept design	• L2a. Outline design (spatial planning and permitting) • L2b. Detailed design (tendering) • L2c. Technical design (construction)	• L3a. As-built design • L3b. Commissioning and testing • L3c. Completion and handover • L3d. Occupation and use
Assessment type	Qualitative assessment using checklists and reporting formats	Quantitative assessment using the provided reference calculation methods and the common units of measurement	
Reporting rules and steps	• Complete a Level(s) project plan, following steps 1–3 • Specify which design concepts have been addressed • For renovation projects, report on the baseline survey, using the format provided	• Complete a Level(s) project plan, following steps 1–3 (if not done before) • Complete the building description • For renovation projects, report on the baseline survey, using the format provided • Report on the results of the assessment of each indicator using the respective formats • Report on the method used and the main assumptions for each indicator using the respective formats	• Complete a Level(s) project plan, following steps 1–3 (if not done before) • Complete the building description (if not done before) • Report on the results of the assessment of each indicator using the respective formats • Report on the method used and the sampling strategy used for each indicator using the respective formats
Optional additional steps	• Select and report on the results of steps that go further	• Select and report on the results of recommended optimisation steps in indicators' manuals	• Select and report on the use of any of the recommended optimisation steps in indicators' manuals • Report on the results of surveys of occupant satisfaction
The need for a complete building description	No	Yes	Yes

Table 19.10 Criteria which are directly associated with circularity (circular principles as reflected in the employed framework)

Thematic Area	Macro objective	Indicator	Association with circularity (employed framework)
1. Resource use and environmental performance	MO1. Greenhouse gas emissions along a building's life cycle	1.1 Use Stage Energy Performance (kWh/m^2/year)	REDUCE: • The primary goal of this indicator is to promote the reduction of energy consumption and the associated environmental impacts, such as greenhouse gas (GHG) emissions, during a building's operational stage • Reducing energy consumption during the usage stage is closely linked to resource efficiency. Lower energy use translates to reduced resource consumption for energy production
		1.2 Life Cycle Global Warming Potential (CO2 eq./m^2/year)	REDUCE: • The indicator aims to reduce the building's life-cycle GWP and embodied carbon levels • Products with lower GWP often require fewer resources, such as raw materials and energy, during their production and use • Contemplating adaptive reuse and renovation in this indicator helps reduce the additional resources required for these activities and therefore reduces the lifecycle GWP compared to a new building

(continued)

Table 19.10 (continued)

Thematic Area	Macro objective	Indicator	Association with circularity (employed framework)
	MO2. Resource efficient and circular material life cycles	2.1 Bill of Quantities, Materials and Lifespans	RETHINK: • The indicator aims to achieve material savings by considering shared elements REDUCE: • The indicator aims to achieve material savings by reducing floor-to-ceiling heights to minimise structural material use and save resources • The indicator aims at reducing the material footprint by incorporating passive thermal devices and renewable energies to lower the energy consumption, cost and carbon emissions • The indicator aims at optimising the use of fit-out materials that cater to occupants' needs while avoiding unnecessary materials that might end up as waste • By using materials efficiently, minimising waste production during construction, and designing for deconstruction, the industry can reduce its impact on resource consumption REUSE: • The indicator aims to enhancing material efficiency by optimising the load-bearing capacity of structural elements (beams, columns and floor plates) to facilitate a building's future adaptive reuse • It promotes the compliance with design for disassembly requirements and future element reuse, reducing the need for new resources REPAIR: • The indicator aims at enhancing material durability to extend the building life service by designing for easy repair • The indicator allows to record material and component service lifespans, and schedule replacement and repair • Repairing and maintaining existing structures can extend their lifespan and reduce the need for demolition, reconstruction and new construction REFURBISH: • The indicator aims at enhancing material durability to extend the building life service and support potential refurbishments • The indicator suggests using recycled content from reclaimed resources to support building refurbishment projects REMANUFACTURE: • The indicator suggests using recycled content from reclaimed resources in product remanufacturing and integration into new or renovated building projects REPURPOSE: • The indicator suggests using recycled content from reclaimed resources supporting product repurpose to be used in the same or different industry

(continued)

Table 19.10 (continued)

Thematic Area	Macro objective	Indicator	Association with circularity (employed framework)
		2.2 Construction and Demolition Waste	REDUCE: • The indicator aims to shape the outline Waste Management Plan (WMP) and thus allowing to reduce the quantities of CDW generated REUSE: • The indicator aims to promote and allow users to systematically plan for the reuse of materials and waste REPAIR: • The indicator aims to promote and allow users to systematically plan for elements repair and maintenance REFURBISH: • The indicator aims to promote and allow users to systematically plan for elements and building systems refurbishment REMANUFACTURE: • The indicator aims to promote and allow users to systematically plan for elements recovery and therefore facilitating their remanufacturing REPURPOSE: • The indicator aims to promote and allow users to systematically plan for safe elements recovery and therefore facilitating their repurposing for different applications RECYCLE: • The indicator aims to promote and allow users to systematically plan for facilitated recycling RECOVER: • The indicator aims to promote and allow users to systematically plan for possible material and energy recovery from CDW

(continued)

Table 19.10 (continued)

Thematic Area	Macro objective	Indicator	Association with circularity (employed framework)
		2.3 Design for Adaptability and Renovation	RETHINK: • The aim of this indicator is to motivate designers to think about multiple alternatives and appraise the ones that facilitate potential adaptability and renovation REDUCE: • By promoting the design of buildings with extended lifespan, a great reduction in resource consumption, waste generation and environmental impact occur REUSE: • Extending the lifetime of buildings entails facilitates multiple uses and adaptive reuse REPAIR: • Applying the principles of DfA enables facilitated access to elements to repair, maintenance and replacement REFURBISH: • DfA allows to extend the lifetime of building by facilitating refurbishment and renovation

(continued)

Table 19.10 (continued)

Thematic Area	Macro objective	Indicator	Association with circularity (employed framework)
		2.4 Design for Deconstruction	REFUSE: • This indicator allows to achieve circularity by enabling the recovery of components for reuse in multiple cycles possibly in multiple buildings or building systems RETHINK: • The intentional design of buildings for deconstruction implies an upfront lifecycle thinking on how to use building components and products to their highest extent REDUCE: • DfD aligns with the reduce principle of circularity by minimising the amount of resources needed and waste generated during a building's or product's life cycle REUSE: • This indicator promotes circularity by enabling the recovery of building elements for future reuse REPAIR: • DfD facilitates easy repair and maintenance through access zones REFURBISH: • Easy recovery of building elements and products facilitate their refurbishment • Easy access to damaged elements that need replacement of maintenance provide proper conditions for efficient building refurbishments REMANUFACTURE: • DfD principles enable facilitated elements recovery and use of discarded products or products part to manufacture new products with similar function REPURPOSE: • DfD principles enable facilitated elements recovery and use of discarded products or products part to manufacture new products with different functions RECYCLE: • DfD encourages easy separation and recycling of materials and components and continuous circulation into the production process

(continued)

Table 19.10 (continued)

Thematic Area	Macro objective	Indicator	Association with circularity (employed framework)
	MO3. Efficient use of water resources	3.1 Use Stage Water Consumption (m^3/occupant/year)	RETHINK: • The indicator supports appraising lower water consumption alternatives over water-intensive processes or products considering a full lifecycle perspective REDUCE: • The indicator contemplates reducing water consumption during the use stage for more efficient use of this critical resource, especially in areas with water scarcity • Reducing water consumption will reduce the embodied environmental impacts of delivering water to the point of demand
2. Health and comfort	MO4. Healthy and comfortable spaces	4.1 Indoor Air Quality	N/A
		4.2 Time Out of Thermal Comfort Range	N/A
		4.3 Lighting	REDUCE: • Applying design strategies as to allow more natural light to enter spaces reduces energy consumption for lighting and the associated GHG emissions
		4.4 Acoustics	RETHINK: • Acoustics performance is directly related to material used and structural architecture of the building

(continued)

Table 19.10 (continued)

Thematic Area	Macro objective	Indicator	Association with circularity (employed framework)
RE3. Cost, value and risk	MO5. Adaption and resilience to climate change	5.1 Life Cycle Tools: Scenarios for Projected Future Climatic Conditions	RETHINK: • The information provided by life cycle tools for climate scenarios can help appraise among multiple design options the alternative that better suits its environment minimising resource consumption and environmental impact REDUCE: • If the building is designed to meet future climate change, its lifetime will be extended and the probability of maintenance and repair will be lower reducing resource consumption and environmental impact
		5.2 Increased Risk of Extreme Weather	RETHINK: • The consideration of the increased risk of extreme weather can help appraise among multiple design options the alternative that better suits its context minimising therefore resource consumption and environmental impact REDUCE: • If the building is designed to meet future climate change particularly the risk of extreme weather, its lifetime will be extended and the probability of maintenance and repair will be lower thus reducing resource consumption and environmental impact
		5.3 Sustainable Drainage	RETHINK: • The indicator implies a creative approach to how sustainable drainage systems can mitigate the increased risk of flooding caused by urbanisation

(continued)

Table 19.10 (continued)

Thematic Area	Macro objective	Indicator	Association with circularity (employed framework)
	MO6. Optimised life cycle cost and value	6.1 Life Cycle Costs (€/m^2/year)	REDUCE: • LCC analysis considers the total costs related to resource consumption over the lifecycle of a product, which can help to optimise and reduce resources consumption
		6.2 Value Creation and Risk Factors	RETHINK: • The appraisal of product selection based on their future value help minimise risks, costs and resources REDUCE: • If an asset is designed to maximise its value and value retention over time, the probability of its lifetime to be extended will be higher. This will indirectly contribute to the reduction of resource consumption and environmental impact

Table 19.11 Criteria which are indirectly associated with circularity (circular principles as reflected in the employed framework)

Thematic Area	Macro Objective	Indicator	Association with circularity (employed framework)
1. Resource use and environmental performance	MO1. Greenhouse gas emissions along a building's life cycle	1.1 Use Stage Energy Performance (kWh/m^2/year)	RECYCLE: • Energy efficiency can indirectly impact recycling. Products that consume less energy during their usage stage might have a reduced carbon footprint, making them more environmentally friendly in terms of recycling processes. However, recycling energy-intensive products can pose greater challenges

(continued)

Table 19.11 (continued)

Thematic Area	Macro Objective	Indicator	Association with circularity (employed framework)
		1.2 Life Cycle Global Warming Potential (CO_2 eq./m^2/year)	REUSE: • The indicator contemplates future adaptive reuse, which, in comparison to new construction, will result in lower embodied and operational GHG emissions and GWP • Products with low GWP may have a minimal environmental footprint over their lifecycle, making them more likely to be reused REPAIR: • The indicator contemplates future adaptive reuse, which, in comparison to new construction, will create a circular path of preserved and recovered materials to be repaired REFURBISH: • The indicator considers future adaptive reuse of existing buildings and materials to be refurbished, aiming to reduce both embodied and operational GHG emissions and GWP REMANUFACTURE: • The indicator contemplates future adaptive reuse, which, in comparison to new construction, will create a circular path of recovered materials to be remanufactured • Products with low GWP are better candidates for remanufacturing because they have a smaller carbon footprint REPURPOSE: • The indicator contemplates future adaptive reuse, which, in comparison to new construction, will create a circular path of recovered materials to be repurposed RECYCLE: • The indicator contemplates future adaptive reuse, which, in comparison to new construction, will create a circular path of recovered materials to be recycled. Recycling products with low GWP can help reduce the overall carbon emissions in the product lifecycle

(continued)

Table 19.11 (continued)

Thematic Area	Macro Objective	Indicator	Association with circularity (employed framework)
	MO2. Resource efficient and circular material life cycles	2.1 Bill of Quantities, (BoQ) Materials and Lifespans	RECYCLE: • Compiling a BoQ properly support facilitated and efficient recycling of construction and demolition waste RECOVER: • Compiling a BoQ properly facilitate the streaming of non-recyclable or non-reusable components of construction and demolition waste for energy recovery
		2.2 Construction and Demolition Waste	The elements listed in Table 19.1 under indicator 2.2 can be categorised as having both direct and indirect impacts on circularity
		2.3 Design for Adaptability and Renovation	REDUCE: • Creating buildings and products that can be easily adapted and renovated rather than replaced, can reduce the need for new resource consumption and minimises waste REUSE: • Applying reusable products and material in buildings promote their adaptability and lifespan extension RECYCLE: • Designing buildings for adaptability and renovation often involves the use of recyclable materials and components which ensure that materials can be recycled at the end of their life, reducing waste and conserving resources
		2.4 Design for Deconstruction	RECOVER: • DfD minimises CDW to be sent to energy recovery. However, it facilities the process by efficient and effective separation of recoverable and unrecoverable waste for the last to be streamed for energy recovery

(continued)

Table 19.11 (continued)

Thematic Area	Macro Objective	Indicator	Association with circularity (employed framework)
	MO3. Efficient use of water resources	3.1 Use Stage Water Consumption (m^3/occupant/year)	REDUCE & REUSE: • Employing technologies such as rainwater harvesting and grey water filtering supports the reduce and reuse principle REDUCE & REPAIR: • Repairing water infrastructure such as leaky pipes or malfunctioning water systems, can help reduce water waste during the Use stage
2. Health and comfort	MO4. Healthy and comfortable spaces	4.1 Indoor Air Quality	N/A
		4.2 Time Out of Thermal Comfort Range	REDUCE: • Applying strategies such as passive energy technologies for heating and cooling provides thermal comfort while reduces energy consumption and GHG emissions
		4.3 Lighting	N/A
		4.4 Acoustics	N/A
3. Cost, value and risk	MO5. Adaption and resilience to climate change	5.1 Life Cycle Tools: Scenarios for Projected Future Climatic Conditions	N/A
		5.2 Increased Risk of Extreme Weather	RETHINK: • The consideration of the increased risk of extreme weather can help appraise among multiple design options the alternative that better suits its context minimising therefore resource consumption and environmental impact REDUCE: • If the building is designed to meet future climate change particularly the risk of extreme weather, its lifetime will be extended and the probability of maintenance and repair will be lower thus reducing resource consumption and environmental impact

(continued)

Table 19.11 (continued)

Thematic Area	Macro Objective	Indicator	Association with circularity (employed framework)
		5.3 Sustainable Drainage	REDUCE: • It indirectly allows to reduce the use of freshwater in the building REUSE: • Sustainable drainage practices like rainwater harvesting and greywater recycling can promote water reuse for irrigation or non-potable uses
	MO6. Optimised life cycle cost and value	6.1 Life Cycle Costs (€/m^2/year)	REDUCE: • The indicator can contribute to achieving a reduced environmental impact because higher initial capital costs may be required to achieve lower life cycle running costs • The development of a maintenance and replacement plan by applying circularity design and material concepts can support more cost effective management of assets and subsequently, reduced overall building-associated costs through the whole lifecycle REUSE: • The indicator encourages the reuse of materials when it is cost-effective RECYCLE: • The indicator encourages the recycle of materials when it is cost-effective
		6.2 Value Creation and Risk Factors	RECYCLE: • A value can be created when contemplating recycling of waste

respectively, which are also of great importance to circularity particularly the (R2) Reduce strategy, despite being well known for sustainability assessments.

Indicator 2.1. Bill of quantities, materials and lifespans. The scope of this indicator encompasses data for all construction products and materials procured for constructing new buildings or renovating existing ones. With regard to circularity, this indicator offers recommendations for the following project aspects:

1. Achieving material savings by considering shared elements (**Rethink R1**) based on building typology, such as common sidewalls, and by reducing floor-to-ceiling heights to minimise structural material use (**Reduce R2**).
2. Enhancing material efficiency by optimising the load-bearing capacity of beams, columns and floor plates to align with client needs. These decisions influence the future options for adaptability and renovation (indicator 2.3) facilitating adaptive reuse of the building (**Reuse R3**).
3. Reducing the material footprint by incorporating passive thermal devices and renewable energies to lower the energy consumption, cost and carbon emissions (**Reduce R2**).
4. Enhancing material durability to extend the building life service by designing for accessibility for **repair (R4)**, disassembly (indicator 2.4), and potential **refurbishment (R5)** to support adaptability (indicator 2.3).
5. Optimising the use of fit-out materials that cater to occupants' needs while avoiding unnecessary materials that might end up as waste (**Reduce R2**), as calculated in indicator 2.2 Construction and demolition waste.
6. Ensuring compliance with design for disassembly requirements and future element **reuse (R3)**. The indicator also suggests using recycled content from reclaimed resources (supporting product **refurbishment (R5)**, **remanufacture (R6)** and **repurpose (R7)**) and integrating it into new or renovated building projects.

While this indicator does not rely on specific inputs from other indicators, the information gathered for it provides reporting requirements to several other Level(s) indicators, notably:

- 1.2. Life cycle global warming potential and/or any Life Cycle Assessment (LCA) by supplying material and product life service information as inputs to LCA analysis, controlling and **reducing (R2)** environmental impacts and carbon footprints through links between BoQ with LCA inventories or environmental databases like EPD.
- 2.2. Construction and demolition waste and materials by converting the BoQ to bill of materials (BoM), aiming to minimise and **reduce (R2)** waste production and natural resource usage.
- 6.1. Life Cycle Costs (LCC) analysis by providing material and product life service information, enabling BoQ to BoM conversion for costs breakdowns of each material or product, critical for cost control and **reduction (R2)**.

Decisions made in this indicator regarding material selection significantly impact the efficiency of other circularity design indicators, specifically, 2.3 Design for adaptability and renovation and 2.4 Design for deconstruction for which material and product lifespans supply crucial inputs.

Indicator 2.2. Construction and demolition waste and materials. In line with the waste hierarchy, this indicator assesses the total volume of waste and materials generated from construction, renovation, and demolition activities. This assessment subsequently helps facilitate and enable systematic planning for waste **reduction (R2)** as well as the **reuse (R3)**, **recycling (R8)**, or recovery of components for **repair (R4)**, **refurbishment (R5)**, **remanufacturing (R6)**, and **repurposing (R7)** of materials and waste through the separate collection of CDW during construction, renovation, and demolition activities. For unrecoverable waste, the indicator helps streamline unrecoverable waste for material and energy **recovery (R9)**.

This indicator relies on critical inputs from indicator 2.1. Bill of quantities, materials and lifespans. It also closely relates to indicators 2.3 "Design for Adaptability and Renovation" and 2.4 "Design for Deconstruction," as the design concept significantly influences waste management throughout construction, utilisation, and end-of-life stages.

Indicator 2.3. Design for adaptability and renovation. The projected service life of a building holds significant implications for the extent of functional utility achievable through the initial investment of materials and resources in its construction. Deliberate considerations in designing a building for future adaptability indicate a primary focus on optimising resource utilisation to maximise the building's functionality over an extended period **(Rethink R1)**.

Incorporating contemplations of future flexibility and adaptability from the early design stages holds tremendous potential in effectively addressing emerging changes over the building's lifecycle. Consequently, this approach contributes to the **reduction (R2)** of environmental impacts and material consumption throughout the entire lifecycle of both the building and its constituent elements.

The concept of Design for Adaptability (DfA) enables more efficient utilisation of space and building structures by providing the essential prerequisites to extend the lifespan of the main building structure and components. This extension facilitates multiple applications through adaptive **reuse (R3)**, **repair (R4)**, and **refurbishment (R5)**. In essence, this indicator plays a pivotal role in mitigating CDW (Indicator 2.2), which typically arises from premature demolition when a building no longer aligns with evolving user and environmental requirements.

DfA goes hand in hand with DfD (indicator 2.4) as both indicators share some important design concepts such as accessibility to services for easy maintenance, **repair (R4)** and replacement of components.

Indicator 2.4. Design for Deconstruction. The indicator evaluates the capacity of a building's design to enable the efficient recovery of materials for future reuse or recycling. It involves assessing the ease of disassembling essential building components, followed by evaluating the ease of reusing and recycling these parts, as well as their associated sub-assemblies and materials.

This indicator allows to achieve circularity by enabling the recovery of components for **reuse (R3)** in multiple cycles possibly in multiple buildings or building systems **refuse (R0)**.

Ensuring easy accessibility to the different elements allows for easy **repair (R4)** and recovery of components that can be **reused (R3)**, **refurbished (R5)**, **remanufactured (R6)**, **repurposed (R7)** and **recycled (R8).**

The intentional design of buildings for deconstruction implies an upfront life-cycle thinking on how to use building components and products to their highest extent **(Rethink R1)** which is essential to **reduce (R2)** the environmental impacts and material use and resource consumption subsequently impacting the amount of waste generated from multiple building activities during construction, operation and maintenance and end-of-life phases (indicator 2.2).

Furthermore, the circularity indicators namely design for adaptability and renovation (indicator 2.3) and design for deconstruction (2.4) have an important indirect impact on the indicators in macro objective 4 by enabling facilitated possibilities to meet the healthy and comfort requirements to users by allowing a certain level of flexibility and upgradability to meet any emergent needs to meet these requirements along the lifecycle of a building.

Indicator 1.1 Use stage energy performance. This indicator measures the energy performance of a building based on the calculated (in design stage) or actual energy consumption (in operational stage) in order to meet the various energy requirements associated with its use. Reporting on this indicator can provide useful insights on the implication of circularity practices on production and use stages related to material use, replacement and refurbishment. By balancing the relationship between circularity and environmental impacts, the most beneficial circularity design and material selection options can be appraised to **reduce (R2)** the environmental impacts since the early design decisions by proactive thinking about the whole lifecycle performance.

Indicator 1.2 Life cycle Global warming potential. This indicator measures the greenhouse gas (GHG) emissions and the global warming contribution associated with the building at different stages along the life cycle from cradle through to grave. Cradle to grave consideration allows contemplating the most beneficial design solutions to balance the levels of embodied carbon and use stage carbon emissions. It helps identify design and material aspects that contribute the most to GHG emissions along a building lifecycle. It therefore, helps improve the design concepts and material selection by recommending relevant circularity aspects to reduce the embodied carbon and use stage emissions. Applying the circularity design and material concepts (Macro objective 2) since the design stage has great influence on **reducing (R2)** embodied carbon levels by contemplating future adaptive reuse of the building itself during the operational stage and creating circular path of recovered materials through reuse, recycling and disposal in the end-of-life deconstruction stage.

Indicator 6.1 Life cycle costs. Life Cycle Costing is a technique that enables comparative cost assessments to be made over a specified period of time, taking into account initial capital costs and future operational and asset replacement cost. It is particularly relevant to achieving an improved environmental performance (relevance with Macro objective 1 indicators 1.1 and 1.2) because higher initial capital costs may be required to achieve lower life cycle running costs **(Reduce R2)**. This indicator allows stakeholders to understand the relationship between upfront capital costs and use stage costs. The development of a medium to long-term maintenance and replacement plan by applying circularity design and material concepts (Macro objective 2 indicators) can support more cost-effective management of assets and subsequently, reduced overall building-associated costs through the whole lifecycle. In the conceptual design stage, this indicator recommends implementing a lifecycle thinking to appraise specific design and material decisions (relevance to Macro objective 2 indictors and indicators 1.1 and 3.1) based on their long-term impact on the overall lifecycle costs.

Indicator 3.1 Use stage water consumption. In addition to the previous indicators, indicator 3.1 Use stage water consumption also establishes an important direct connection to circularity. This indicator measures the total consumption of water for an average building occupant, with the option to split this value into potable and non-potable water. From a lifecycle perspective, this indicator helps appraising lower water consumption alternatives over water-intensive processes or products **(Rethink R1)**. Reducing water consumption will reduce the embodied environmental impacts of delivering water to the point of demand **(Reduce R2).**

19.3.6 SBTool

Introductory remarks. SBTool (Sustainable Building Tool) is a constantly evolving international framework for the assessment of buildings' environmental performance, under the responsibility of iiSBE (international initiative for a Sustainable Built Environment) since 2002. It is the successor (in essence, the evolution) of GBTool, which constituted the computational implementation of the GBC (Green Building Challenge) assessment method. The contribution of researchers and organisations of several countries has been one of the basic pillars for the development of the method and its evolution over time. One important aspect is that SBTool is a generic rating framework or toolbox that only becomes efficient after contextualising the scope, weights and benchmarks [31]. It has been reported to have been used in several countries and regions [31]. Fully functional, adjusted to the local conditions and priorities versions of the method are available for, among others, Italy (Protocollo ITACA), Portugal (SBTool-PT) and Czech Republic (SBTool-CZ).

The process of contextualisation consists of the selection of the most relevant *criteria*, the allocation of weights to each *criterion* to reflect local priorities, and the definition of benchmarks based on local conditions. This tool was specifically designed to allow users to reflect on different priorities and to adapt it to the environmental, socio-cultural, economic and technological context for its application [32]. The result is a framework that can measure the sustainability level of buildings, concerning the context in which it is located.

The family of iiSBE frameworks entails specific tools for buildings, neighbourhoods, and other applications allowing to assign sustainability scores in those different scales. The tools' structure consists of a hierarchy of parameters with the following main characteristics: all the examined parameters (for each scale a different set of problems are examined) are classified into major *performance issues* (referred to also as *issues* from now on); each issue includes several *performance categories*, which, in turn, are consisted of a number of *performance criteria* (referred to also as *categories* and *criteria*, respectively, in the following). The latter represent the level of the tool's structure where the assessment takes place via the examination of the respective indicator and assessment scale.

SBTool for Buildings 2022 [25], which is examined in this work, is consisted of seven *issues* (i. Site Regeneration and Development; ii. Energy and Resources Consumption; iii. Environmental Loading; iv. Indoor Environmental Quality; v. Service Quality; vi. Social Cultural and Perceptual Aspects; vii. Costs and Economic Aspects), 20 *categories*, and more than 100 potentially active *criteria* (depending on the scope of the analysis selected, on the phase of the life cycle of the building, on the building uses and on other factors). The methodology also dictates that in the context of the contextualisation, KPIs need to be determined [26]. The evaluation performed by SBTool can be applied to the four fundamental phases of the construction cycle: pre-design, design, construction or operations, and up to three different occupancy types separately or in a single project can be taken into account. It also considers new or renovation projects.

As previously mentioned, the assessment takes place at the *criteria* level. Each *criterion* is assigned a score ranging from -1 to + 5 (with the exception of those characterised as mandatory, for which the minimum potential score is higher than 1, to a degree decided by the third party contextualising the tool). In this assessment scale, the benchmark of score "0" corresponds to the minimum acceptable performance (established by legislation, standards, or existing performance levels) and 5 represents a value for excellent or ideal performance (where 3 identifies a best-practice value). In other words, each "score" is the outcome of a comparison between the building under consideration and national / regional references. Databases from many sources are used to calculate the score of each criterion. For the calculation of the scores of higher structural levels (*performance categories* and *issues*, total score), the approach used in the SBTool is to weigh the scores of the individual *criteria* and apply a weighted aggregation process. The weighting variables are set at the national/ regional level, in order to achieve the tool's adjustment to the local conditions. The approach adopted enables international comparisons of buildings from various countries [32].

Obviously, the process of weighing and benchmarking are fundamental stages of the process of contextualisation for further assessment on a local/national level. Different weighting systems are used in different adapted versions of the generic tool; in the one reviewed in this study, the weighting takes place at the criteria level.

The application (adaptation) of SBTool is divided in 4 steps:

1. Selection of criteria (local authorities or applicant, among others: selection of issues, criteria and indicators)
2. Weight definition
3. Benchmark definition

4. Indicators assessment

The framework is materialised in two interconnected Microsoft Excel workbooks. The first one (file A) is used to set locally relevant weights, benchmarks, laws, and standards for generic building types in their own region; in other words, this workbook forms the frame, the basis and the context for each local assessment, it is the centre of the methods' contextualisation and adjustment to local conditions (the input in the first file, where the region, occupancy type, weights and benchmarks are determined, are in the local context). The second workbook (file B) is used to compile information about a single project during the assessment. The second file contains particular project weights and benchmarks that are used to perform project information, performance targets, and simulations. A single file A can correspond to any number of files B; for example, file A for office buildings in a given region can be used for the evaluation of any number of office buildings (each one corresponding to its own file B) in this area.

The assessment results contain an extended set of data regarding the performance of the examined building [29]. Specifically, the results of the assessment are represented by a spider web diagram that describes the sustainability level achieved in each one of the *issues* and an overall score of the sustainability performance of the building. Other important aspects of the examined building's performance are summarised in the results report, such as the individual scoring by *issue*, and the project information. It is important to note that not only the derived values relative to the zero benchmark are provided, but also absolute results are shown. Also, occupancy-specific outcomes are provided [29]. In the results report, data regarding central components of the assessment (e.g. relative weights of the active *issues*) is also presented.

Circularity implementation. The implementation of circularity criteria is developed with a detailed evaluation of each indicator in the SBTool framework. This issue is crucial and is at the core of this report. The intention is to understand HOW this circularity is put forward, in practice, or implemented within the framework of analysis.

The *criteria* listed in SBTool are associated with the circular economy 10-R framework of circular economy strategies and are classified in Tables 19.12 and 19.13. Table 19.12, consists of the *criteria* that have been found to have a direct association with CE, while Table 19.13 shows the *criteria* that have an indirect relation. The association was established based on the description and evaluation of each *criterion* (aim, benchmark, indicators, etc.). Additionally, the tables mention which specific principles/strategies were associated with each one of the criteria, as well as the step of the building life cycle in which it is situated. A significant clarification in relation to the referred strategies is that general circularity principles (adaptability, resilience, etc.) have also been considered; in fact, they were "correlated" with one or more of the 10 strategies involved in the employed 10-R framework and appear accordingly in the following tables.

The same approach as in the other methods was employed in cases where disagreements among the members of the sub-group working on SBTool occurred regarding

Table 19.12 *Criteria* which are directly[10] associated with circularity (circular principles as reflected in the 10-R framework)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
A. Urban, site and infrastructure systems	A.1 Site regeneration and development	A1.1	Protection and restoration of wetlands	REPAIR / REFURBISH: restoring damaged wetland provides higher scores within the assessment scale of the criterion	Site
		A1.2	Protection and restoration of coastal environments	REPAIR/ REFURBISH: restoring damaged coastal environments provides higher scores within the assessment scale of the criterion	Site
		A1.3	Reforestation for carbon sequestration, soil stability and biodiversity	REPAIR/ REFURBISH: restoring damaged forested areas provides higher scores within the assessment scale of the criterion	Site
		A1.5	Remediation of contaminated soil, groundwater or surface water	REPAIR/ REFURBISH: the restoration of contaminated soil is promoted REMANUFACTURE: Strategies of treating contaminated soil or groundwater consist in the remanufacturing of contaminated matter	Site
	A.2 Urban design	A2.1	Maximising efficiency of land use through development density	REDUCE use of land (considering land as a resource) RETHINK urban environments for a more efficient use of urban land and services	Site & design

(continued)

[10] Direct association: direct reference/description in the intent, indicator, benchmarks, and generally, in the structure and content of the *criterion*.

Table 19.12 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
	A.3 Project infrastructure and services	A3.1	Supply, storage and distribution of surplus thermal energy amongst groups of buildings	RETHINK: the redistribution of surplus thermal energy from buildings in the zone to other buildings (aiming at the optimisation of its supply, storage and distribution for space heating amongst groups of buildings) is under consideration REDUCE: Rethink strategies can be focused on energy consumption reduction	Site & design & management
		A3.2	Supply, storage and distribution of surplus photovoltaic energy amongst groups of buildings	RETHINK: the redistribution of surplus electrical energy generated by PV in the zone to other buildings (aiming at the optimisation of its supply, storage and distribution amongst groups of buildings) is under consideration REDUCE Rethink strategies can be focused on energy consumption reduction	Site & design & management

(continued)

Table 19.12 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
		A3.3	Supply, storage and distribution of surplus hot water amongst groups of buildings	RETHINK: the redistribution of surplus hot water generated from photovoltaic sources on site among buildings (aiming at the optimisation of its supply, storage and distribution amongst groups of buildings) is under consideration REDUCE: Rethink strategies can be focused on resources consumption reduction	Site & design & management
		A3.4	Supply, storage and distribution of surplus rainwater and greywater in groups of buildings	RETHINK: the redistribution to other buildings of the surplus rainwater and greywater generated from roof or site catchment areas or from sanitary waste is considered REDUCE: Rethink strategies can be focused on resources consumption reduction	Site & design & management

(continued)

Table 19.12 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
		A3.7	Composting and re-use of organic sludge	REUSE: the existence of an effective composting facility in the project to handle the organic sludge produced and measures regarding its reuse in or off site are assessed RECYCLE: if composting will be considered as a type of recycling	Site & design & management
		A3.8	Provision of split grey / potable water services	REDUCE the use of potable water REUSE greywater	Site & design & management
		A3.10	On-site treatment of rainwater, stormwater and greywater	REDUCE the use of potable water REUSE & RECYCLE greywater/rainwater	Site & design & management
B. Energy and resource consumption	B1. Total life cycle non-renewable energy	B1.1	Embodied non-renewable energy in original construction materials	REDUCE resources consumption (the non-renewable embodied energy, as estimated by an acceptable LCA method, is assessed)	Materials
		B1.2	Embodied non-renewable energy in construction materials for maintenance or replacement(s)	REDUCE resources consumption (the non-renewable embodied energy, as estimated by an acceptable LCA method, is assessed)	Materials

(continued)

Table 19.12 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
		B1.4	Consumption of renewable energy for all building operations	REDUCE resources consumption (criteria: renewable energy for building operations)	Design & management
	B3. Use of materials	B3.1	Degree of re-use of suitable existing structure(s) where available	REUSE/REDUCE of existing structures for new constructions. Reduce embodied energy and construction costs	Design
		B3.3	Material efficiency of structural and building envelope components	REDUCE: Reduce the need for new materials, reduce embodied energy and costs. (Increase efficiency of materials)	Design & materials
		B3.4	Use of virgin non-renewable materials	REDUCE: Reduce consumption of non-renewable resources and encourage the use of recycled/refurbished/remanufactured products	Design & materials
		B3.5	Efficient use of finishing materials	REDUCE resources consumption (elimination or reduction in use of finishing materials, whether virgin, re-used or recycled)	Design & materials
		B3.6	Ease of disassembly, re-use or recycling	REDUCE/RECYCLE: Promotes recycling, reusing, refurbishing, and repurposing of building components	Design & materials

(continued)

Table 19.12 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
	B.4 Use of potable water, stormwater and greywater	B4.2	Use of water for occupant needs during operations	REDUCE water consumption	Design
		B4.3	Use of water for irrigation purposes	REDUCE/RECYCLE: Reduce potable water consumption, encourage reuse and repurpose of greywater and rainwater for irrigation	Design & management
		B4.4	Use of water for building systems	REDUCE: Reduce the use of potable water, encourage reuse and repurpose of greywater and rainwater	Design & management
C. Environmental loadings	C.3 Solid and liquid wastes	C3.1	Solid waste from the construction and demolition process retained on the site	REDUCE: Reduce solid waste from construction diverted to the waste management system RECYCLE/REUSE: Recycling and reuse of construction waste	Materials & construction
		C3.5	Liquid effluents from building operations that are sent off the site	REDUCE Liquid waste sent off site for treatment	Construction
	C.4 Impacts on project site	C4.3	Recharge of groundwater through permeable paving or landscaping	REPAIR/REFURBISH: Recharging restoring groundwater	Site & design
E. Service quality	E.2 Functionality & efficiency	E2.7	Spatial efficiency	RETHINK: Optimise spatial use of building	Design
		E2.8	Volumetric efficiency	RETHINK: Optimise spatial use of building	Design

(continued)

Table 19.12 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
	E.4 Flexibility and adaptability	E4.1	Ability for building operator or tenant to modify facility technical systems	REPURPOSE/REMANUFACTURE of spaces in the building by the possibility to relocate HVAC, lighting and control systems	Design
		E4.2	Potential for horizontal or vertical extension of structure	REPURPOSE/RETHINK: flexibility of the structure design to be extended when needed. Reduce resources consumption when extension is needed	Design
		E4.3	Adaptability constraints imposed by structure or floor-to-floor heights	REPURPOSE/REMANUFACTURE of spaces in the building by the possibility to adapt to other uses	Design
		E.4.4	Adaptability constraints imposed by building envelope and technical systems	REPURPOSE/REMANUFACTURE of building envelope and HVAC and electrical systems in the building by the possibility to adapt to other uses	Design
		E4.5	Adaptability to future changes in type of energy supply	REPURPOSE/REMANUFACTURE of spaces in the building by the possibility to update energy systems	Design

(continued)

Table 19.12 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
	E.5 Optimization and maintenance of operating performance	E5.2	Adequacy of the building envelope for maintenance of long-term performance	REDUCE the need for maintenance by ensuring durable design of building envelope	Design
		E5.4	Existence and implementation of a maintenance management plan	RETHINK/REDUCE: Ensure the reduction of energy and water consumption over time by developing a maintenance plan	Design & management
G. Cost and economic aspects	G.1 Cost and economics	G1.3	Life-cycle cost	REDUCE/RETHINK: Life cycle assessment is implied in circular economy	Design, construction & management

Table 19.13 *Criteria* which are indirectly[11] associated with circularity (circular principles as reflected in the 10-R framework)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
A. Urban, site and infrastructure systems	A.1 Site regeneration and development	A1.6	Shading of building(s) by deciduous trees	REDUCE: reduce energy needed for cooling of buildings RETHINK The use of trees for carbon sequestration	Site
		A1.7	Use of vegetation to provide ambient outdoor cooling	REPAIR / REFURBISH: restoring damaged wetland provides higher scores within the assessment scale of the criterion	Site
		A1.10	Provision and quality of children's play area(s)	REDUCE: Indirect relation with the reduction of fuel consumption/CO_2 emissions by reducing transportation needs	Site
		A1.12	Provision and quality of bicycle pathways and parking	REDUCE: indirect relation with the reduction of fuel consumption/CO_2 emissions by reducing transportation needs	Site
	A.2 Urban design	A2.2	Reducing need for commuting transport through provision of mixed uses	REDUCE: indirect relation with the reduction of fuel consumption/CO_2 emissions by reducing transportation needs	Site
		A2.3	Impact of orientation on the passive solar potential of building(s)	REDUCE energy consumption via passive solar systems	Design

(continued)

[11] Indirect association: no reference/description in the intent, indicator, benchmarks, and generally, in the structure and content of the *criterion*. However, we see a clear connection of the type: if this *criterion* is met, then, as a consequence, a circularity principle will be served.

Table 19.13 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
		A2.5	Impact of site and building orientation on natural ventilation of building(s) during warm season(s)	REDUCE energy consumption from the need of mechanical ventilation systems	Design
		A2.6	Impact of site and building orientation on natural ventilation of building(s) during cold season(s)	REDUCE energy consumption from the need of mechanical ventilation systems	Design
	A.3 Project infrastructure and services	A3.9	Provision of surface water management system	REDUCE the impact of water sewage systems RETHINK: improve flood resilience capacity of the site	Design
		A3.13	Provision of on-site parking facilities for private vehicles	REDUCE: indirect relation with the reduction of fuel consumption/CO_2 emissions by reducing transportation needs	Design
B. Energy and resource consumption	B1. Total life cycle non-renewable energy	B1.3	Consumption of non-renewable energy for all building operations	REDUCE: reduces resources consumption	Design & management
	B2.Electrical peak demand	B2.1	Electrical peak demand for building operations	REDUCE: reduce resources consumption, often obtained from fossil-fuel generated electrical power	Design

(continued)

Table 19.13 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
		B2.2	Scheduling of building operations to reduce peak loads on generating facilities	REDUCE: Related with indicator B1.1	Management
C. Environmental loadings	C.1 Greenhouse gas emissions	C1.1	GHG emissions from energy embodied in original construction materials	REDUCE: Reduction of GHG emissions considering the entire life cycle of materials	Materials
		C1.2	GHG emissions from energy embodied in construction materials used for maintenance or replacement(s)	REDUCE: Reduction of GHG emissions considering the entire life cycle of materials	Materials & management
		C1.3	GHG emissions from primary energy used for all purposes in facility operations	REDUCE: Reduction of GHG emissions from calculated energy use in the building	Materials, construction & management
	C.2 Other atmospheric emissions	C2.1	Emissions of ozone-depleting substances during facility operations	REDUCE: reduction of emissions, which are considered as an impact, consequence of the implementation of other circularity indicators	Design & management
		C2.2	Emissions of acidifying emissions during facility operations	REDUCE: reduction of emissions, which are considered as an impact, consequence of the implementation of other circularity indicators	Design & management
		C2.3	Emissions leading to photo-oxidants during facility operations	REDUCE: reduction of emissions, which are considered as an impact, consequence of the implementation of other circularity indicators	Design & management

(continued)

Table 19.13 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
	C.3 Solid and liquid wastes	C3.2	Solid non-hazardous waste from facility operations sent off the site	RECYCLE: considering future recycling of construction waste	Materials & construction
	C.5 Other local and regional impacts	C5.1	Impact on access to daylight or solar energy potential of adjacent property	REDUCE of resources consumption considering solar power potential	Site & design
E. Service quality	E.1 Safety and security	E1.3	Risk to occupants and facilities from flooding	Related to resilience as a general circular economy principle. Hence, associations with principles of the employed framework are implied: REDUCE resources consumption for repair REUSE/REPAIR facilities	Site & design
		E1.4	Risk to occupants and facilities from windstorms	Related to resilience as a general circular economy principle. Hence, associations with principles of the employed framework are implied: REDUCE resources consumption for repair REUSE/REPAIR facilities	Site & design
		E1.9	Maintenance of core building functions during power outages	REDUCE: related to resilience	Management
	E.3 Controllability	E3.1	Effectiveness of facility management control system	REDUCE (indirect impact on energy consumption)	

(continued)

Table 19.13 (continued)

Issue	Category	Criterion		Association with circularity (employed framework)	Level (site, material, design, construction, management)
		E3.2	Capability for partial operation of facility technical systems	REDUCE (indirect impact on energy consumption)	Design & management
		E3.3	Degree of local control of lighting systems	REDUCE (indirect impact on energy consumption)	Design & management
		E3.4	Degree of personal control of technical systems by occupants	REDUCE (indirect impact on energy consumption)	Design & management
	E.5 Optimization & maintenance of operating performance	E5.5	On-going monitoring and verification of performance	REDUCE: ensure the reduction of energy and water consumption over time	Management
F. Social, cultural and perceptual aspects	F.2 Culture and heritage	F2.4	Use of traditional local materials and techniques	REDUCE: could encourage reduction of the use of high embodied energy materials, raw-materials consumption	Design & construction
G. Cost and Economic aspects	G.1 Cost and economics	G1.2	Operating and maintenance cost	REDUCE water and energy consumption	Management

the existence and type of association of each criterion with the 10-R framework. As also indicated in all other methods, the outlined associations in the following tables are those that were estimated to exist for each criterion by at least one member of the sub-group working on SBTool.

The sub-group working on SBTool consisted of five members. In the analysis of each of the *criteria* many differences were found between the members of the sub-group, mainly in the indirect association with circular economy due to the subjectivity of interpretation of the *criteria*. In SBTool, there is no direct mention of circular economy or consideration of CE in the evaluation of the *criteria* but is implied in the formulation of the tool since it considers criteria for the entire life cycle process of buildings.

The *criteria* that were more evidently related to CE to all the members of the group, were the ones that considered life cycle assessment and that were oriented to optimisation, flexibility and adaptability, reduction and efficiency strategies. Finally, just over a quarter of the total number of criteria considered are presented in Table 19.12 indicating the direct association.[12] For instance, within the Flexibility and Adaptability *category*, all five *criteria* were found to be directly associated with circularity. A similar approach emerged in the Use of Materials *category*, where all five *criteria* (with the exception of one underdeveloped criterion, aligned with the principles of optimisation and minimisation, which was not considered in the present analysis anyway) are directly contributing to the circular economy concept. The following *categories* were also represented by a large number of *criteria* with a direct association in Table 19.12: Use of Potable Water, Stormwater and Greywater (all three *criteria* available), Project Infrastructure and Services (seven out of 11 available), Total Life Cycle Non-Renewable Energy (three out of 4 available). As well as some specific single *criteria* of the following categories are present in Table 19.12: Urban Design, Solid and Liquid Wastes, Impacts on Project Site, Optimization and Maintenance of Operating Performance, Life-cycle cost and others. Regarding the seven examined *issues*, it is evident that some of them, like A. Urban, Site and Infrastructure Systems and B. Energy and Resource Consumption are more strongly represented in Tables 19.12 and 19.13 than for example G. Cost and Economic Aspects. It is also important to note that this domination could be also related to the number of accompanied *credits* in each *issue.*

The *criteria* that were defined with an indirect relationship and approximately account for just over one-sixth of the total number of *criteria*, are the ones related with the GHG, energy consumption and waste reduction since there was a discussion in the differentiation between circularity and sustainability. This is demonstrated in categories such as Greenhouse Gas Emissions and Other Atmospheric Emissions (all three *criteria* in each category), Controllability (all four *criteria*), and Electrical peak demand (all two *criteria*). In the above-mentioned Urban Design *category* there are also *criteria* with indirect association, which account for the majority of those available for assessment (four out of five *criteria*). Site Regeneration and Development is characterised by the same number of direct and indirect associations concerning circularity, four for each type out of twelve possible. The remaining *criteria* are found individually within their respective *categories.*

The concept of "Reduce" dominates in indirect associations, while in direct associations, it occurs, but not so often, typically in combination with other concepts of the employed framework. Additionally, there are some *criteria* that can be included as CE strategies but do not meet the requirements of proposed methodology, as they could not be related to the strategies of the 10-R framework, but could be included in a new aspect, resilience, as seen in the case of the Service Quality *issue.*

[12] The numbers of *criteria* referred to in this section are based on the maximum scope of application of the examined version of SBTool for new buildngs; the underdeveloped *criteria* were not included in the analysis, while no separate or in any sense special consideration was provided for *criteria* applicable for specific cases (large projects, etc.).

In the *issue* A. Urban site and infrastructure, the most common associations are with the strategies of "Repair" or"Refurbish", regarding site regeneration and "Reduce" or 'Rethink" when it comes to *criteria* related to resources consumption for the urban adaptation of buildings. Also, regarding the *issues* B. Energy and resource consumption, C. Environmental loadings and G. Cost and economic aspects, the association with CE is mainly regarding the reduction of resources consumption.

19.4 Conclusions

In this chapter, a first approach to the investigation of the way circularity principles and concepts are implemented into the structure of well-known buildings' sustainability assessment methods is attempted. Under this light, observations related to the sustainability and circularity relationship, as well as the latter's representation in the examined methods can be drawn.

A first conclusion lies in the difficulty of establishing clear expert opinions of what is actually circular within a sustainability-oriented context when specific issues and criteria are examined. This difficulty was expected, also based on the various approaches existing for the relationship between sustainability and circularity and its complex nature, as analysed in the respective section of the chapter. Indeed, as noted in the respective sections, disagreements among the members of each expert group examining a method arose. In fact, an absolute consensus in every case was not reached, at least easily. Indicative of the various expert opinions expressed is the fact that the specific principles found to be associated with each criterion by the individual members of each expert group were not the same in all cases.

Of course, differences in the expressed opinions, in terms of whether a type and a scale (and which one) of association exists for specific issues, can be detected in the results derived by each group. However, the central issues do present a degree of homogeneity in the way they were approached in each method. At this point it has to be highlighted that the whole content of the examined level of each method (*criterion*, *issue*) was taken into consideration; this explains the fact that while a criterion in one tool seems to be associated with the employed CE framework, a criterion with a similar title in another tool does not. Differentiations among the evaluation implementation and obstacles encountered for the examined methods arose also due to the fact that their structures are varying, and that the examination took place at the lowest autonomously scored level. For example, for DGNB this means the *criterion* level, with each *criterion* encompassing a number of different indicators, while for SBTool it corresponds to the *criterion* level, with each *criterion* being based on one indicator (i.e., in fact having a narrower scope). Some differentiations were based on the approaches adopted in each method; for example, in DGNB CE bonuses are explicitly related to specific *criteria.*

Another challenge that arose during the process consisted in associating widely accepted building circularity principles (such as adaptability and resilience) or other concepts (e.g. upcycling) with specific circularity strategies of the employed framework. Relevant expert comments and explanations can be found in the "circularity implementation" section of each method, in the tables and or in the text. One possible explanation for this difficulty could be related to the fact that the employed 10-R framework is not oriented towards the building sector exclusively; however, it is important to note that the scope of the analysis considered both building products and buildings as products, mitigating this issue for the majority of cases. Clear matching in such cases may warrant further research and discussion. Furthermore, the development of frameworks capable of comprehensively addressing the complexities of the built environment may be a future goal.

It is interesting to note that the age of the tools may also, to some degree, be reflected in the language used in its assessment. Early tools such as BREEAM were created when the waste hierarchy consisted of three levels, reduce, reuse and recycle. On the other hand, Level(s)' more explicit alignment with 10-R principles could be related to its more recent formation, and its adoption of the expanded waste hierarchy from the literature. In the context of the afore-mentioned example including the oldest and the most recent methods among the assessed ones in this work, it is worth noting that i) the head of the Building Research Establishment is reported in stating that BREEAM will be aligned with Level(s) and ii) BREEAM have recently expanded their tool to be more explicit in measuring circularity. The latter fact shows the flexibility which all these tools exhibit, allowing them to adapt and improve on their sustainability measurements.

Finally, in the majority of the criteria estimated to have an association with circular economy, more than one level (site, material, design, construction, management) was found to be implicated. This fact reveals the complexity of the involved issues and scopes.

It's worth noting that alternative approaches could have been adopted in the context of this work, employing a more "narrow" or "broad" interpretation of whether and to which degree circularity is represented in each criterion. In any case, the presented results should be treated as indications and preliminary findings, as well as a potential basis for future work. This might include the broader participation from stakeholders and researchers, as well as expanded examination of the different methods by a larger and more diverse group of experts, with almost equivalent number of examiners for each method. Furthermore, the scope of the study could be extended to encompass other sustainability assessment methods, other aspects (e.g., existing buildings), and other scales (e.g., neighbourhood or urban scale).

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