Green Building Rating Systems (GBRSs)

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Green Building Rating Systems (GBRSs) are typically third-party, voluntary, and market driven standards that measure buildings' sustainability level by multi-criteria assessment, and encourage the adoption of environmentally, socially and economically sustainable practices in design, construction and operation of buildings (or neighborhoods). GBRSs aim at guiding and assessing the project throughout all its life cycle, thus limiting the negative impact on the environment, as well as on the building occupants' health and well-being, and even reducing operational costs. Hundreds of GBRSs are now available worldwide, varying in approaches, application processes, and evaluation metrics. BREEAM, CASBEE, Green Star and LEED are among the most applied worldwide. Despite some differences, they all adhere to the same general evaluation structure: project performances ares measured using a set of relevant indicators, grouped per topics such as water management, energy use, materials, site qualities. Each assessed requirement is assigned a score/judgment, the total of which determines the level of sustainability achieved. In addition to regular updates, a current trend is to improve the effectiveness of protocols, making them more comprehensive and accurate, while keeping them easy to use.

BREEAM CASBEE Green Star LEED multi-criteria assessment sustainable building

Growing attention to global environmental and societal challenges requires the construction sector to be more sustainable, because of its major impact on these challenges. Beyond regulations and policy enforcements, a voluntary effort is required of all the stakeholders to design, construct, run and manage buildings assuming a holistic approach to sustainability. This requires that the effect of construction features on the triple bottom line (planet, people, profit), as well as possible mitigation actions, are clearly understood. Accordingly, sustainability assessment has been recognized as a crucial mean to this end [1], and Green Building Rating Systems (GBRSs) have emerged as a valuable tool to assess and guide the whole construction process to be greener.

In a nutshell, GBRSs can be defined as third-party, voluntary, and market driven standards that measure buildings' sustainability by multi-criteria assessment, and encourage the adoption of environmentally, socially and economically sustainable practices in design, construction and operation of buildings (or neighborhoods).

Since the notion combines two different elements—Green Building and Rating System—examining them separately may help to provide a suitable definition for the whole. First, Green Building is a multifaceted notion that refers to a broad variety of issues. The World Green Building Council (World GBC) defines it as "a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life" [2]. Recurrent topics addressed by a green project are efficient use of energy, water, and other natural

resources; pollution reduction and waste management; good indoor environmental standards; sustainable use of materials along their life cycle; occupants health and well-being; design featured flexibility and adaptability to a changing environment; and quality of open spaces. Since its appearance in the early 1990s [3], the notion of Green Building has mainly addressed physical and functional features of an eco-architecture, encompassing only few elements of the broader view of sustainability and its multiple social, economic and institutional issues [4]. However, as the sustainability goals have been increasingly enlarged, a wider approach to Green Building has also emerged during the last decades. In fact, the recent ISO 15392:2019 Regulation (Sustainability in buildings and civil engineering works) set that sustainable construction works should consider sustainable development in terms of its three primary aspects (economic, environmental and social), while meeting the requirements for technical and functional performance [5].

A Rating System (RS) is a tool for classifying objects based on how well they comply with one or more relevant requirements, which are those that affect the object's performance whose level the system is intended to appraise. A RS evaluating the level of sustainability of a building must take into account several requirements, detecting the level of performance for each of them respect to a common baseline, which might be regulatory thresholds or a comparison benchmark with other buildings. In other words, a RS "rates or rewards relative levels of building performance or their compliance with specific environmental goals and requirements" [6].

Therefore, the vast range of green buildings' performances (i.e., different topics such as energy consumption, water use, indoor environmental quality, location) are evaluated by means of a specific baseline. Since only an overall assessment of the building's sustainability can make the system useful and effective, a GBRS must combine "apples and oranges" [7] into a score that expresses how much that project respects the environment, the building's occupants, and the local community (multi-criteria). Thus, the measures of these performances are weighted, using a balancing process specific to each scheme, and are combined into a single grade/judgment that shortly communicate the building's overall level of sustainability. As a result, the building is "classified" or "rated" by the organization who manages the GBRS (third-party).

Both in literature and practice, many names are used to designate these tools that assess the impact a construction has on both its local surrounding and the broader environment. Among the most common include, Green Building Rating Systems, Sustainable Building Rating Systems, Sustainable Rating Tools, Green Building Assessment systems, certifications, and protocols. Each of them has a few distinctions, as well as variations in approaches, methodology and applications that are found within the same family of tools. Therefore, it is difficult to give a unified definition of these tools. However, the World GBC has provided a description with the aim of being comprehensive: a GBRS is a tool "used to assess and recognize buildings which meet certain green requirements or standards" [8]. This leads to making the rating tools, whose adoption is often voluntary, a means to recognize and reward organizations or individuals who build and operate greener buildings (market-driven), thereby encouraging them to push the boundaries of sustainability forward.

The need to deal with growing global challenges is the context in which these tools have been developed. As the built environment is one of the main contributors to socio-ecological issues, above all of which is climate change,

the adoption of environmentally- and socially-friendly approaches in this sector has been recognized as crucial for decades.

This stems primarily from the significant impact the built environment makes in terms of energy and resource consumption, as well as emissions. In fact, the building sector accounts globally for 31% of the entire final energy use, 54% of the final electricity demand, and 23% of the global energy-related CO2 emissions, one third of which come from the direct consumption of fossil fuels [9]. Even in Europe, where a great effort has been put on reducing construction-related impact, buildings are still responsible for around 40% of the EU energy consumption and for 36% of greenhouse gas (GHG) total emissions [10]. The building industry also consumes more than 40% of the raw materials of the global economy every year, the majority of which are non-renewable, and generates over 35% of global waste [11]. Water use is also relevant, as over 17% of fresh water is used globally by the construction and operation of buildings [12]. In addition, the quality of the built environment affects building occupants' and local communities' health and well-being (e.g., by indoor VOC emissions, thermo-hygrometric discomfort, and lack of open spaces).

Although the energy demand of the building sector is higher than industry and transport, the construction has the highest potential of emission reduction, mainly due to the flexibility of its demand [13]. According to Berardi, large room for improvement may especially come from adoption of more sustainable building practices. This leads to the concept of environmentally-friendly building, which has gradually taken place worldwide [4].

As a result, regulations, codes, strategies, and tools have been developed in the last decades to push a rapid and effective transition in design and construction processes, with a particular stress on energy efficiency.

At a global scale, several goals of the 2030 UN Agenda for Sustainable Development addresses the issue [14], including but not limited to: SDGs n. 11 (Sustainable cities and communities), n. 9 (Industry, innovation and infrastructures), and n. 7 (Clean and affordable energy). In Europe, this path is mainly regulated by the EU Directives on Energy Performance of Buildings (EPBD III) 2018/844/EC [15] and Energy Efficiency (EED) 2018/2002/EU [16] that attempts to improve energy efficiency in both new and refurbished buildings across the Union. However, less than 40% of energy consumption and less than 50% of CO2 emissions from buildings are currently subject to mandatory performance policies [17]. Hence, beyond regulations, a great voluntary effort is needed to drive the change toward a more sustainable living environment.

Therefore, the construction industry has gradually taken important steps, especially boosting the market to improve the building environmental performances by considering the whole building life cycle, from raw material extraction to the potential reuse of the outputs coming from the dismissal. In this particular circumstance, sustainability building assessment systems have spread as a means to detect and mitigate the impacts.

Although the assessment of the building's environmental features such as air quality and indoor comfort had begun earlier, it was only with the introduction of multi-criteria assessment schemes (e.g., GBRS) that the problem was addressed as a whole, instead of one topic at a time, using separate indicators and criteria [1]. In this context,

GBRSs appeared as a more comprehensive, user-friendly, and informative way of spreading sustainable construction, as compared to the more accurate but time-consuming and extremely technical approaches such as Life Cycle Assessment (LCA) and comparable frameworks that use a set of complex indicators.

The first multi-criteria tool for this scope was developed by the Building Research Establishment (BRE Group) in the United Kingdom, as even prior to today the current concept of green building had entered international agendas. The British Building Research Establishment Environmental Assessment Method (BREEAM) was launched in 1993 for new building sustainable design [18]. Many other GBRSs have been developed following this example, though they have adopted different assessment schemes, metrics and indicators [19].

The Leadership in Energy and Environmental Design (LEED) was launched by the United States Green Building Council (USGBC) in 1998 [20]. The Japanese Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) made its appearance in 2001, three years after LEED [21].

The need to make these national instruments global soon emerged, pushing the Natural Resources Canada (NRC) to lead the development of SBMethod, at the end of 1990s. As a common protocol on whose scheme national and even regional adaptations could be made, SBMethod resulted in several applications, such as Verde (Spain), SBTool PT (Portugal), SBTool CZ (Czech Republic) and SBTool IT (Italy), this latest re-named ITACA protocol in 2011 [22].

The success of sustainability assessment tools had been so extraordinary that over 600 schemes were available worldwide in 2004, within just one decade from the first one that had been launched [13][23]. Although the reason for this abundance lies mainly in the need of each country to adapt the instrument to its peculiarities (e.g., climate and environmental priorities, type of building stock, culture, and local codes), this led each rating to adopt different parameters and metrics as well, making any cross comparison and transnational collaboration difficult [23]. Therefore, two important standards were developed in order to harmonize the many available assessment tools: ISO 21931–1, 2010 Framework for Methods of Assessment of the Environmental Performance of Construction Works [24] and ISO 15643–1, 2010 Sustainability Assessment of Buildings [25].

Furthermore, many other RSs have been developed and more are being developed by both public and private organizations. At present, the World GBC alone enlists 58 rating tools administered by its national Councils [8]: beyond the already mentioned BREEAM (UK), LEED (US), and CASBEE (JP), quite popular are also DGNB System (D-), Green Star (AUS), HQE (F), Green Globes (US and Canada), and GBTool (South Africa).

At present, thousands of buildings have been certified by GBRSs worldwide. **Table 1** shows key facts about the diffusion and application of the four most predominant, according to [12].

Table 1. Facts of most diffused GBRSs worldwide according to Say and Wood (2008).

GBRS	N. of Certified Buildings	Countries	Data Source
BREEAM (UK)—since 1993	594,011 (2021)	89	[18]
LEED (US)—since 1998	79,418 (2021)	all (mainly US)	[20]
CASBEE (JP)—since 2001	500 (2016)	JP	[21]
GREEN STAR (AU)—since 2003	2827 (2020)	AU + NZ + SA	[26]

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