Comparison of sustainability rating systems for buildings and evaluation of trends

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Summary

Sustainable policies are pushing the building sector for an increasing attention in the assessment of practices. The paper describes available rating systems for sustainability measurement of buildings. It compares criteria of most famous systems considering the environmental, social and economic dimensions of sustainability. Available rating systems span from simple energy consumption evaluation to life cycle analysis and total quality assessment, with an increasing complexity of the analysis. A multi-dimension approach is used in most complex rating systems where several performances are evaluated before being composed together. A sum point approach is adopted assigning scores to performance results and sustainable material adoptions. The paper looks at the peculiarities of sustainability assessment in the construction sector compared to other sectors. Trends in sustainable rating systems such as the expansion of time and boundaries of the analysis are discussed.

Keywords: sustainability assessment, rating systems, green buildings

1. Introduction

The construction sector is characterized by a large inertia toward product and process assessments [1]. The increasing attention towards sustainability is pushing the sector toward rapid changes. Policies, laws and regulations around the world are asking the sector to adopt sustainable innovation in terms of products and processes to encourage more sustainable buildings [2]. This attention for the building sector arises from its energy consumption and GHG emissions which, in developed countries, are 30% and 40% of the total quantities, respectively [3]. Forecasts of the International Energy Authority show that energy consumption in buildings is increasing at a rate comparable with those of the industrial and transportation sectors [4]. However, according to [3], the building sector has the highest energy saving and pollution reduction potential, given the flexibility of its demands. This highlights why sustainable buildings are often considered a priority for a sustainable world.
The main scope of this paper is to review sustainability assessment practices for the building sector. The paper focuses on the evaluation criteria in rating systems. The paper endeavours to discuss the current state of sustainability assessment in the construction sector. Section II contains an introduction to the sustainability assessment. This implies a description of the diffusion of sustainable assessments for buildings around the world. Section III contains a description, before a comparison among different kinds of assessment systems. Finally, in section IV trends of rating systems are discussed.

2. Sustainability assessment

2.1 Diffusion of sustainability assessment

Sustainability assessment of building products and processes is necessary to increase the diffusion of sustainable buildings [5,6]. Unfortunately, the construction sector is no really familiar with performance measurements, and although many assessment systems already exist worldwide, their diffusion is still low in absolute terms. However, sustainability measurements, in the building sector, are receiving a large amount of attention worldwide, rapidly moving from fashionable certifications to implemented practices: 650 million square meters obtained a sustainability certification in 2010, with projections for 1100 million in 2012 and for more than 4600 million in 2020, around the world [7]. Countries with a sustainability building certification programme or a sustainability rating system have a worldwide diffusion, with the only exceptions being Africa.

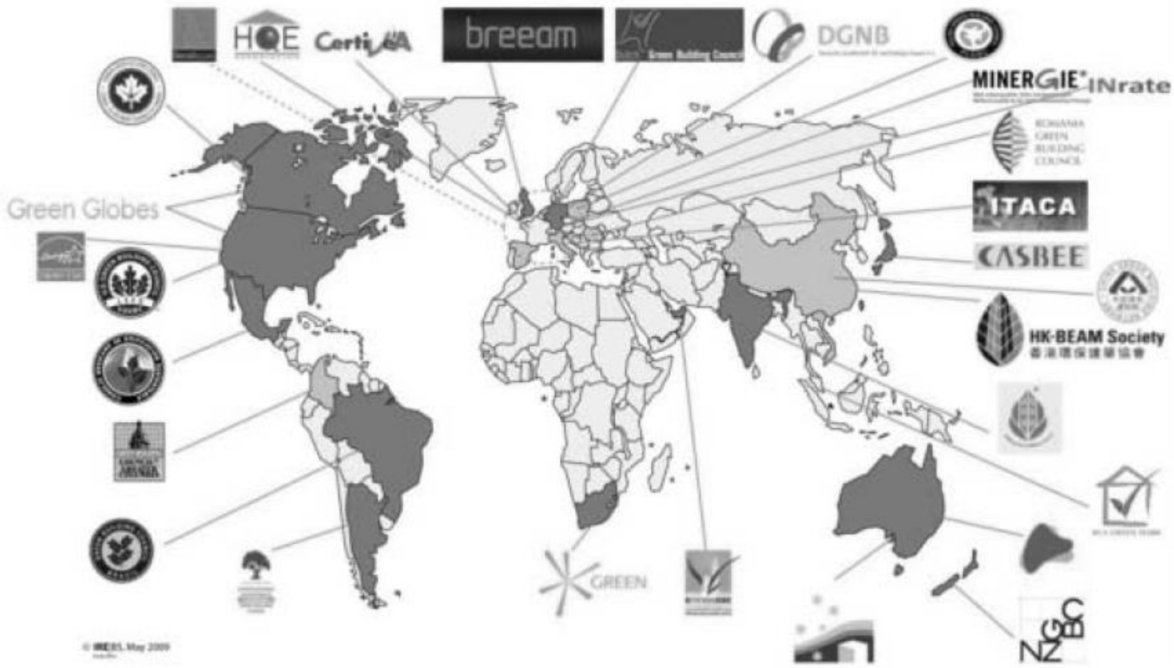

Fig. 1 Sustainability assessment systems around the world

The diffusion of sustainability certification is currently growing: several examples of certified buildings exist, and constitute a competitive advantage for experienced firms and actors [8]. Referring to the model for innovation diffusions, proposed by Rogers and reinterpreted in “Crossing the chasm” by Moore, the diffusion of sustainability assessment of buildings has reached visionaries, but still needs to conquer the pragmatists’ vision [9].

2.2 Possible approaches to sustainability assessment

Sustainable buildings may been broadly defined as buildings which encompass social, economic, biophysical and technical aspects with superior performance [10]. Although the above definition could be clear, it is often unclear how to categorize and recognize sustainable buildings. In fact, a frequently discussed topic regards how sustainability should be measured. After the energy crisis in the ’70s, regulations promoted energy consumption limits for buildings around the world. As a result, energy consumption became the sustainability requirement in building assessment. Meanwhile, sustainability consciousness has evolved, and nowadays, assessments generally consider energy consumption as just one among other parameters. The complexity of a building often suggested a multidisciplinary approach in sustainability assessment [10]. This is also because buildings cannot be considered as assemblies of raw materials, but they are high order products which incorporate different aggregations of technologies, assembled according to unique

processes [6]. The sustainability of a building should, therefore, be evaluated for every subcomponent, for the integration among them in functional units and assembled systems (e.g. the air conditioning system, the envelope), and for the whole building too.
A possible approach to sustainability evaluation is given by the analysis of building products, i.e. a sustainability assessment at product level. This assessment approach is internationally established for many kinds of products, and only regards environmental evaluations. Three types of product environmental labels exist and are defined in ISO 14020 [11]. These are the eco-certification of environmental labels (type I), the self-declared environmental claims (type II), and the environmental declarations (type III). Among these, type III is the most common label for building products. However, environmental evaluations of products are rarely performed by manufacturers of building products, and the diffusion of environmental product declarations (EPD, defined in EN 15804) in the building sector is still low [9].
Product eco-certification programmes have been developed in different countries: among others, there is the US Green Seal, the European Eco-Label, the Frances NF-Environment mark, the German Blue Angel, and the Japanese Eco Mark. Moreover, specific evaluations for building products exist, such as timber or concrete certifications. Previous labels have a binary evaluation and indicate a sustainable product without the ability to measure its greenness rate or to stress the pros and cons.
Since 2011, the new Construction Products Directive (CPD) in Europe states that a sustainable resource use evaluation is part of the assessment for the CE mark [12]: this should imply a larger diffusion of environmental assessments in the construction sector.
Energy labels for equipment represent another way of assessing the sustainability of materials, although these are only useful for a few categories of products (e.g. heat pumps). Finally, the adoption of certified sustainable materials is not sufficient in obtaining a sustainable building, because its complexity requires a holistic and integrated evaluation [6]. For example, the sustainability assessment of a product into a building needs to consider difficulty predictable factors such as transportation distance or use wastes. In this sense, product labels can only constitute a database for a sustainable assessment.
Researches state that sustainability in the construction sector can be better evaluated by looking at the building as a process, because it never finishes but evolves through occupancy. Construction is a complex input-output sector where the material flux in and out from building site is difficult to standardize and, rarely, a priori programmed [13]. Weather, orientation and local parameters influence the operation needs of the building. Moreover, buildings are constructed according to a specific design, defined according to the client’s requests. Previous aspects prevent buildings being considered as manufacture standardized products. Finally, construction stakeholders constitute a unique network of subjects [14], and the differences among them imply several possible points of view in sustainability assessments. In this sense, Cole stated that sustainability varies according to stakeholders [13]: a community aims at low construction wastes whereas an occupant looks at indoor environmental quality.

3. Sustainability rating systems

According to ISO 15392, construction sustainability includes considering sustainable development in terms of its three primary aspects (economic, environmental and social aspects), while meeting the requirements for technical and functional performance [15]. More than 600 sustainability rating systems are available worldwide for the assessment [16]. Many new systems are continually proposed and the most diffused receive a yearly update. This evolving situation has led to the release of the standard “Sustainability in building construction - Framework for methods of assessment for environmental performance of construction works - Buildings” ISO 21931-1, 2010) [17]. Systems for sustainability assessment span from the energy performance evaluation to a multi- dimensional quality assessment. These systems can be grouped into three categories [18]:
• Cumulative energy demand (CED) systems which focus on energy consumption;
• Life cycle analysis (LCA) systems which focus on ecological aspects;
•Total quality assessment (TQA) systems which evaluate ecological, economical and social aspects.
Previous classification should not be strictly considered. In fact, many assessment systems do not fit into one category perfectly. CED systems are often mono-dimensional and aim at measuring the sustainability of the building through energy, or energy related, measurements. LCA systems

define the impact of the building over the environment by assessing one or more environmental substances, so that they can have one or more evaluation parameters. Finally, TQA are generally multi-dimensional as they assess several parameters. The first two categories of systems have a quantitative approach to the assessment, whereas TQA generally have a qualitative or quantitative approach for different criteria. In the following section TQA systems are described and compared.

3.1 Total quality assessment systems

TQA systems aim at considering the three aspects of sustainability of buildings: ecological issues (such as GHG emission and energy consumption), economical reasons (such as investment and equity), and social requirements (such as accessibility and quality of spaces). The most common TQA systems are the multi-criteria systems. These base the evaluation over criteria measured by several parameters and, generally, compare real performances with reference ones. Multi-criteria rating systems generally use checklist and benchmark comparisons. Any criteria has a certain amount of available points over total assessment and the overall evaluation of building sustainability comes out of summing the results of the assessed categories.

Multi-criteria systems are generally easy to understand and can be implemented in steps for each criteria. Moreover, a step implementation is allowed during the analysis: in fact, these systems enable to assess the building at several stages, from the concept design to the final construction, and they can be used during construction too. Building activities are difficult to fully plan and TQA systems often consider both a preconstruction evaluation and post-construction check.

Multi-criteria systems assess sustainability aspects through the evaluation of criteria, such as site, energy, water, materials, indoor air quality, waste and transportation. A critical aspect of multi-criteria systems is their additional solution structure, as they often assign scores for positively evaluated elements [19]. Multi-criteria systems are largely increasing the attention for sustainable buildings, as they seem well related to market interests and stakeholders' culture [20].

Several total quality multi-criteria systems exist to assess building sustainability worldwide. As many are just the adaptation of more famous ones to regional level or for a specific scope, only the most worldwide adopted systems are considered here: these are BREEAM, LEED, CASBEE, SBTool and Green Globes. The main criterion for the selection has been a combination between worldwide diffusion and use. However, other famous rating systems exist: among these are the Chinese Three Star, the U.S. Assessment & Rating System (STARS), the Australian Building Greenhouse Rating (ABGR), and the South African Sustainable building assessment tool (SBAT).

The United Kingdom was the first country to release a multi-criteria system for sustainability assessment, before this concept entered into the agenda of international policies, with the Rio Conference. The British Building Research Establishment Environmental Assessment Method (BREEAM) was planned at the beginning of the '90s by the British Research Establishment, and was released in 1993. The system has a large diffusion in the United Kingdom, where almost 10,000 buildings have been certified[1] . Since 2009, as a consequence of the worldwide attention for this system, an international version has been available, and currently, BREEAM has adapted versions for Canada, Australia and Hong Kong. The system is differentiated for building typologies: courts, ecohomes, ecohomes XB (existing), healthcare, healthcare XB (existing), industrial, multi-residential, prison, offices, retail and educational. BREEAM evaluation is expressed in percentage: measuring classifications are at least 25% for pass, 40% for good, 55% for very good, 70% for excellent, 85% for outstanding. The evaluation categories are: management (commissioning, monitoring, waste recycling, pollution minimization, materials minimization), health and wellbeing (ventilation, humidification, lighting, thermal comfort), energy (sub-metering, efficiency and CO2 impact of systems), transport (emissions, alternative transport facilities), water (consumption reduction, metering, leak detection), materials (asbestos mitigation, recycling facilities, reuse of structures, facade or materials, use of crushed aggregate and sustainable timber), land use (previously used land, remediated contaminated land), ecology (land with low ecological value or minimal change in value, maintaining major ecological systems, minimization of biodiversity impacts), pollution (leak detection systems, on-site treatment, local or renewable energy sources, light pollution design, ozone depleting and global warming substances) and innovation.

[1] Detailed information on the website http://www.breeam.org/page.jsp?id=203

A largely spreading rating system and probably the most famous system is LEED (Leadership in Energy and Environmental Design) which was released in 1998 by the U.S. Green Building Council (GBC)[2]. This system is currently available for several typologies of buildings: new construction and major renovations, existing buildings, commercial interiors, core and shell, schools, existing schools, retail, healthcare, homes, neighborhood. There are six evaluation categories to obtain the 110 available points of the standard (in the version 3): sustainable site, water efficiency, energy and atmosphere, material and resources, indoor environment quality, innovation and regional specificities. LEED points lead to the following categories: at least 40% of available points for certificated buildings, 50% for silver, 60% for gold, and 80% for platinum. Although released in the United States, GBC has spread worldwide over the years, and recently the World GBC has opened regional chapters in many countries in Europe, Africa, America and Asia. Almost 20,000 buildings are registered for certifications, and requests for new certifications regard buildings in 110 countries.

CASBEE (Comprehensive Assessment System for Building Environmental Efficiency)[3] is a Japanese rating system developed in 2001, but available in English too. CASBEE covers a family of assessment tools based on a life cycle evaluation: pre-design, new construction, existing buildings, and renovation. This system is based on the concept of closed ecosystems. It distinguishes building performance and environmental load. Building performance covers criteria such as indoor environment (noise and acoustics, thermal comfort, lighting and illumination, and air quality), quality of services (functionality and usability, amenities, durability and reliability, flexibility and adaptability), outdoor environment (preservation and creation of biotope, townscape and landscape, and outdoor amenities), whereas building environmental loads cover criteria such as energy (thermal load, use of natural energy, efficiency of systems, and efficient operations), resources and materials (water conservation, recycled materials, sustainably harvested timber, materials with low health risks), reuse and reusability, off-site environment (air pollution, noise and vibration, odour, sunlight obstruction, light pollution, heat island effect, and local infrastructure). By relating the previous two main criteria, CASBEE results are presented as a measure of eco-efficiency on a graph with environmental loads on one axis and quality on the other. Sustainable buildings for CASBEE have the lowest environmental loads and highest quality. Each criterion is scored from 1 to 5, 1 corresponds to minimum requirements, 3 to typical technical and social levels, and 5 to high levels of achievement. Less than 100 buildings have been certified with this system, but the number is quickly increasing.

At the end of the ’90s, the Sustainable Building Council promoted an internationalization of rating systems under the leadership of the Natural Resources Canada (NRC). Towards this initiative several countries have developed a common protocol, SBMethod. Using the general scheme, several countries have proposed national versions of this system, such as Verde in Spain, SBTool PT in Portugal, SBTool CZ in the Czech Republic. In Italy, this protocol was implemented in 2000 as the SBTool IT. It is now known as ITACA and it is maintained by a national chapter of the international initiative for Sustainable Built Environment (iiSBE). Moreover, ten Italian regions have already adopted modified versions of the protocol to better cover regional specificities and priorities. According to the general SBMethod, for each evaluation parameter, a value from -1 (negative evaluation) up to 5 (excellent performance) is available.

In 2005, adapting the Canadian version of BREEAM, the Green Globe Initiative (GBI) launched a new rating system, known as Green Globes. Criteria of this include: project management (integrated design, environmental purchasing, commissioning, emergency response plan), site (site development area, ecological impact, enhancement of watershed features, site ecology improvement), energy (energy consumption, energy demand minimization, “right sized” energy-efficient systems, renewable sources of energy, energy-efficient transportation), water (flow and flush fixtures, water-conserving features, reduce off-site treatment of water), indoor environment (effective ventilation systems, source control of indoor pollutants, lighting design and integration of lighting systems, thermal comfort, acoustic comfort), resource, building materials and solid waste (low environmental impact, consumption and depletion of material resources, re-use of existing

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[2] Detailed information on the website http://www.usgbc.org/DisplayPage.aspx?CategoryID=193
[3] Detailed information on the website http://www.ibec.or.jp/CASBEE/english/index.htm

structures, durability, adaptability and disassembly, reduction, re-use/recycling of waste).
A critical aspect of multi-criteria systems regards the selection of criteria and the weights given to each criteria: in fact, reasons for these choices are generally not explicit. In this paper, among the many aspects through which a comparison of sustainability rating systems could be done, the criteria and their weights are considered. This allows us to know which aspects are given more consideration in sustainability assessments. Fig. 2 shows the weights assigned by the above six systems grouping the criteria of each into seven main categories. The selection of these categories was based on main sustainability building aspects [10]: site selection, energy efficiency, water efficiency, material and resources, indoor environmental quality, waste and pollution and others. When more than one version existed for the same system, that for new construction was selected. The attribution of each system criteria into previous categories resulted in some difficulties, because both the system structures were not always easily accessible and criteria among different systems did not perfectly overlap. For this reason, the attribution was performed by the author, and then repeated by two sustainability experts to check coherence in attribution of criteria in the seven categories. The category 'others' contains criteria which do not fit into the other six categories. In particular, management and innovation aspects have been included in this category. For example, LEED assigns 7% of its credits to innovations, BREEAM has 15% for construction and construction waste management, Green Globe has 12.5% of its points in 'others' to include project management, CASBEE includes points for mitigation and off site solar energy gain which have been included in 'others', GBTool has the largest percentage of points in 'others', as the system considers the cultural perception of sustainability. The results of the weights comparison among rating systems agree with other studies [16,21] .

It is interesting to note that energy efficiency among assessment systems in fig. 2 is always considered the most important category (weight average among the 6 systems 25.5%), followed by IEQ (17.7%), waste and pollution (15.9%), sustainable site (13.2%) and material and resources (11.5%). These statistics are generic as, obviously, averages do not have any rigorous meaning. However, studies have shown many similarities among sustainability rating systems [22], which increases the value of the above averages. It should be remembered that weights and evaluation criteria are just one of the ways to compare rating systems: [21] Fowler and Rauch compared the above systems for other properties (applicability, usability, and communicability), again finding many similarities [21]. The different approaches among the systems have led to the foundation of the Sustainable Building Alliance to establish common evaluation categories and to improve comparability among systems.

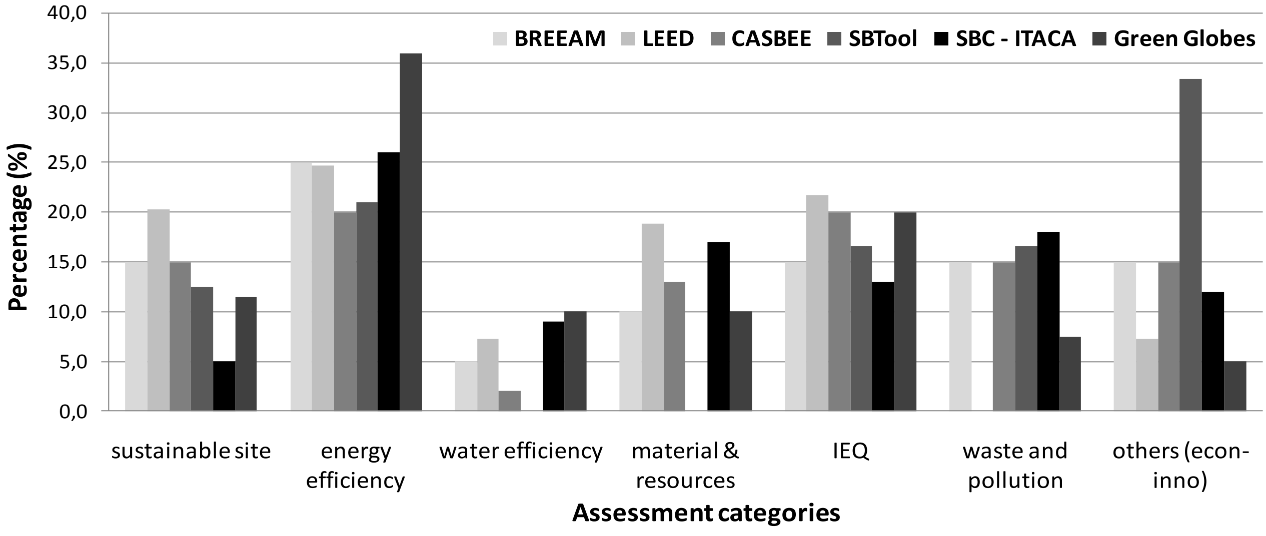

Fig. 2 Percentages of the weights assigned by 6 sustainable rating systems grouping the respective criteria into 7 categories.

From categories in fig. 2, it is clear that environmental aspects receive a larger attention than economic and social ones. Recently, some multi-criteria rating systems more closely related to a total quality assessment have been released. For example, the Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), available since 2009 in Germany, aims at evaluating sustainability through the quality of the building. Economic aspects emerge explicitly. Moreover, in the category of technical quality, paradigms such as performance, durability, ease of cleaning, dismantling and recycling are considered. More attention to social aspects than in other rating systems is also given. Functional aspects such as space efficiency, safety, risk of hazardous incidents, handicap accessibility, suitability for conversion, public access, art and social integration are also considered.

4. Trends in sustainability assessment and conclusion

Trends of sustainability assessment systems have been of interest since Crawley and Aho's study [23]. Evaluation was originally based on a single or few criteria. However, assessments through a single dimension have received many critics [24,25], as a single criterion is generally unable to measure the sustainability complexity. An increasing awareness of externalities, risk and long-term effects and the importance of social issues suggest a larger diffusion for multi-criteria systems. However, multi-criteria systems have also been accused of a lack of completeness as they neglect some criteria: for example, they rarely take into account the economic dimension of the development. This lack constitutes a limit for sustainability rating systems [6], as it prevents the evaluation of the economic consequences of sustainable choices. By neglecting the evaluation of economic aspects, systems contradict one of the development dimensions and allow the additive logic for adoption of sustainable products which has often been criticized in sustainability rating systems. This limit affects any system. The importance of economic and social evaluations has recently emerged in defining systems for developing countries where it is more evident that the environment cannot be the only assessment category, but economic and social equity are fundamental [26]. This could re-establish a sustainability prospective to assessment systems which actually seem too focused on the environment. Although the lack of assessment of some sustainability aspects, the research of a comprehensive approach to the evaluation has led to design systems which require much detailed information. For example, GBTool comprises more than 120 criteria. The complexity of criteria has been pointed out as a limit for the diffusion of sustainable rating systems [27]. In fact, complexity is one of the five barriers highlighted by Rogers in innovation diffusion theory [28] and if sustainability and its rating systems are perceived as too complex by building stakeholders (above all design team, general contractors and suppliers) then, sustainability practices will be slowly adopted. A balance between completeness in coverage and simplicity of use is hence necessary to spread sustainability building assessment systems. The larger diffusion of multi-criteria TQA systems than LCA ones is probably given by their simplicity and check list structure. LCA analysis are often more rigorous, but still complex to be understood. The importance of simple systems is emerging making them useful as design tools. In fact, sustainability rating systems should be introduced early in the construction process, and they must be structured so as not to need detailed information before they are generated.

An open aspect of sustainability rating systems regards possible regional adaptations in assessment criteria. Adaptations represent a way of improving the diffusion [28], and in fact, also a rigid system as the German Passivhaus has shown regional adaptations [29]. The SBC-ITACA shows that regions are adapting the original system to local characteristics. The last version of the LEED system, since 2009, has introduced points for Regional Priority to assess local priorities.

An important trend in sustainability assessment is given by the increasing attention given to neighborhood and construction site. First assessment systems considered the building as a manufacture product, and evaluated it almost in isolation. However, the importance of surrounding site is largely increasing, for example passing from 15 to 23 % of available points from version 2.2 to version 3 of LEED. Also energy requirements are becoming stronger in last versions of sustainability assessment, as consequence of more rigid requests of energy regulations worldwide. Limits of sustainability assessments suggest that more complete rating systems are necessary to assess the multi-dimensional aspects of sustainability and to improve the triple bottom line of buildings.

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