Comparison Among Different Green Buildings Assessment Tools: Application to a Case Study

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Abstract

The concept of green building plays a role of primary importance in the reduction of the use of resources, water, and materials, as well as on the reduction of impacts on human health and the environment, during the building lifecycle. A large number of countries has already developed energy certification procedures in order to rate the building energy performance; furthermore, a range of green building assessment tools and protocols has been developed in the past 20 years, with the aim of reducing energy consumption and the environmental impact in both the building construction and management phases. This paper compares the results of the application of three green building assessment methods on both the energy and environmental performance. Some of the most spread rating systems were chosen: Istituto per l'innovazione e Trasparenza degli Appalti e la Compatibilità Ambientale (ITACA, Italy), Comprehensive Assessment System for Built Environment Efficiency (CASBEE, Japan), and Green Star (Australia). The analysis was developed on a residential building located in central Italy, constructed by taking into account the international principles of sustainability and bioclimatic architecture. Starting from previous studies developed by the Authors, by which these protocols were compared and their scores normalized, the proposed study assesses the sustainability of the case-study building thanks to a point-based methodological approach. It is based on the identification of six common macro-areas that allow the homogeneous comparison of the three green building assessment tools. The study aims to assess the impact of these new normalized categories on the overall sustainability performance of the building.

1. Introduction

Buildings are responsible for a considerable part of the energy consumption and greenhouse gas emissions, and according to Swan and Ugursal (2009), they account for 40 % of the total energy consumption of the European Union. This problem involves all the advanced countries in different ways, not only in terms of air pollution but also with regard to the availability of primary energy resources and balance between imported and exported energy. As a result, several actions for the energy and environmental preservation and for the rational use of resources have been recently undertaken by the national governments: in Italy the energy efficiency of buildings is the primary goal, while energy labelling is gaining importance all over the world. Several findings in literature affirm that increasing the buildings energy efficiency is a primary goal (Boyanoa et al., 2009; Evangelisti et al., 2015a) and many solutions have been introduced aiming at reducing the building sector environmental impacts (Gori et al., 2016; Evangelisti et al., 2015b; Mattoni et al. 2015). Furthermore, in the last years, the so-called green rating systems have been developed in order to estimate the buildings sustainability level in a

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broader way, including other aspects in addition to energy consumptions. The sustainability concept is defined by ISO 15392:2008 in three ways: economic, environmental, and social. Recently the attention is focused on environmental sustainability, and different programs and methods related to this aspect are flourishing all over the world. The Life Cycle Analysis, for example, initially developed in the industrial world, is now being spread also to the building sector with the goal of quantifying the potential environmental impacts linked to the construction process. The private sector has promoted different initiatives both at a national and international level. In this framework, a huge number of green building assessment tools and protocols has been developed in the past 20 years. Among these, the most famous sustainable protocols at international level are LEED (Leadership in Energy and Environmental Design) from the U.S., CASBEE (Comprehensive Assessment System for Built Environment Efficiency) from Japan, Green Star from Australia, and BREEAM (Building Research Establishment Environmental Assessment Method) from the UK. In Italy also the public sector has promoted a sustainability protocol called ITACA (in English: Institute for Transparency of Contracts and Environmental Compatibility). Some of these protocols, such as LEED and BREEAM, are applied all over the world with different specifications according to the features of the local country. The protocols aim at defining standards and parameters to evaluate the level of sustainability in the building sector and to reduce the energy use during the life cycle of the buildings at a prescriptive and voluntary level. They consist in methodological approaches that analyze energy consumptions, the characteristics of the site, the indoor well-being, and the effects on human health. The different calculation methods and credits of the labelling tools can lead to significant differences in the final sustainability scores of a building (Suzer, 2015; Bahaudin et al., 2014). These differences are both at a national and regional level: in fact, in a country it is possible to find also different versions of the same protocol. ITACA, for example, is a federation of different protocols of the Italian regions characterized by a common methodology and by common technical-scientific requirements. This diversification allows us to take into account local peculiarities, like climate characteristics or constructive practices. Despite the need of considering the distinctive features of each territorial context, the building sustainability level in the globalized world should be hopefully comparable among different countries. This objective could be achieved by defining common targets, aims, and requirements.

In this framework, the present study applies the well-known rating systems ITACA, CASBEE, and Green Star to the green building complex “Le Violette”, located in Foligno, Perugia (Italy) with the aim of highlighting differences and similarities between the rating tools. The original and latest editions of these rating systems were taken into account considering only the residential building versions of these protocols.

The application of these systems to a real case allows us to understand which issues have more influence on the final performance rate of each protocol. The work also gives some suggestions for the reduction of the dissimilarities between the rating systems, and for the definition of a common “sustainability language”.

2. Method and Tools

The goal of this paper is to evaluate the results obtained through the application of the original tools and to make a comparison among the studied protocols by means of a point-based system. In this new methodological approach, the original credits of the protocols were grouped into six new common macro-areas (Table 1). This approach allows to overcome the differences between the original categorizations of the three-certification procedures, and to assess the impact and the influence of these new normalized categories on the final sustainability performance of each analyzed rating system.

Table 1 – New categories of impact

Macro-Areas	Description
Site	Influence of the site characteristics on the building
Water	Total water use
Materials	Impact of building materials from cradle to grave
Energy	Energy use and renewable energy production
Comfort and safety	Indoor human well-being and functional characteristics of interior spaces and safety
Outdoor quality	Impacts on the outdoor environment

2.1 The Methodological Approach

The comparison among the chosen green building rating systems was carried out in order to underline similarities and differences in their approaches. Each tool is characterized by a certain number of macro-areas that are divided into credits achievable on the basis of the building characteristics; each credit is also characterized by a "weight" that stands for the importance given to the specific credit on the final score. Moreover, each rating system allows us to achieve a building labeling on the basis of the reached final score, which is the sum of the points gained for each credit, previously multiplied for their specific weights. It is worthy to notice that each certification system is characterized by a certain point total amount and it is distinguished by a precise number of achievable credits. Fig. 1 shows the original rating systems macro-areas; in this analysis only the credits related to the new residential buildings were considered. Starting from previous studies (Asdrubali et al., 2015; Bisegna et al., 2016), this work presents the comparison among ITACA, CASBEE, and Green Star sustainability rating scores by applying the six new macro-areas (see Fig. 2).

CASBEE

Q1	Weight	Q2	Weight	Q3	Weight	L1	Weight	L2	Weight	L3	Weight
	0.4		0.3		0.3		0.4		0.3		0.3
Q1.1 - Noise & Acoustics	0.15	Q2.1 - Service Ability	0.4	Q3.1 - Preservation & Creation of Biotope	0.3	LR1.1 - Building Thermal Load	0.2	LR2.1 - Water Resources	0.2	LR3.1 - Consideration of Global Warming	0.33
Q1.2 - Thermal comfort	0.35	Q2.2 - Durability & Reliability	0.3	Q3.2 - Townscape & Landscape	0.4	LR1.2 - Natural Energy Utilization	0.1	LR2.2 - Reducing Usage of Non-renewable Resources	0.6	LR3.2 - Consideration of Local Environment	0.33
Q1.3 – Lighting & Illumination	0.25	Q2.3 - Flexibility & Adaptability	0.3	Q3.3 - Local Characteristics & Outdoor Amenity	0.3	LR1.3 - Efficiency in Building Service System	0.5	LR2.3 - Avoiding the Use of Materials with Pollutant Content	0.2	LR3.3 - Consideration of Surrounding Environment	0.33
Q1.4 - Air quality	0.25					LR1.4 - Efficient Operation	0.2				

GREEN STAR

Management	Pt	Indoor environmental quality	Pt	Energy	Pt	Transport	Pt	Water	Pt	Materials	Pt	Land Use Ecology	Pt	Emissions	Pt
Green Star Accredited Professional	1	Indoor Air Quality	4	Greenhouse Gas Emissions	20	Sustainable Transport	10	Potable water	12	Life Cycle Impacts	7	Ecological Value	3	Storm water	2
Commissioning and Tuning	4	Acoustic Comfort	3	Peak Electricity Demand	2					Responsible Building Materials	3	Sustainable sites	2	Light pollution	1
Adaptation and Resilience	2	Lighting Comfort	3							Sustainable Products	3	Heat Island Effects	1	Microbial Control	1
Building information	2	Visual Comfort	3							Construction and demolition waste	1			Refrigerant impacts	1
Commitment to performance	2	Indoor Pollutants	2												
Metering and Monitoring	1	Thermal Comfort	2												
Construction environmental Management	1														
Operational waste	1														

ITACA

Site Quality	Pt	Resource consumption	Pt	Environmental Loads	Pt	Indoor Environmental quality	Pt	Service Quality	Pt
Seervice Accessibility	4	Primary non-renewable energy required during the lifecycle	32.1	CO_2 equivalent emissions	6.1	Ventilation	4.55	Manteinance of operational performance	3.5
		Energy from renewable sources	6.2	Waste water	11.40	Thermal Comfort	4.55	Domotic systems	3.2
		Eco-friendly materials	9.70			Acoustic Comfort	4.55		
		Drinking Water	5.60			Visual Comfort	4.55		

Fig. 1 – Original rating systems macro-areas

The credits included in the original macro-areas of each system were distributed into the new six ones and their scores were normalized in order to make the tools comparable. In the normalization process the credits related to the management aspects were not taken into account because they include bureaucratic issues that do not match the purpose of this study. Similarly, also the innovation extra points that allow to get up to 10 extra points in each protocol, were not considered in the analysis.

CASBEE					
SITE	***WATER***	***ENERGY***	***COMFORT AND SAFETY***	***MATERIALS***	***OUTDOOR QUALITY***
Q3.1 Preservation and conservation of Biotope	LR2.1 Water Resources	LR1.1 Control of heat load	Q1.1 Sound Environment	LR2.2 Reducing use of none renewable resources	LR3.1 Consideration of global warming
Q3.2 Townscape and landscape		LR1.2 Natural Energy utilization	Q1.2 Thermal comfort	LR2.3 Avoiding the use of materials with pollutant content	L3.2 Consideration of local environment
		LR1.3 Efficiency in building service systems	Q1.3 Lighting and Illumination		L3.3 Consideration of sorrounding environment
		LR1.4 Efficient operation	Q1.4 Air Quality		Q3.3 Local characteristics and outdoor amenities
			Q2.1 Service Ability		
			Q2.2 Durability and Reliability		
			Q2.3 Flexibility and Adaptability		
GREEN STAR					
SITE	***WATER***	***ENERGY***	***COMFORT AND SAFETY***	***MATERIALS***	***OUTDOOR QUALITY***
Ecological value	Potable water	Greenhouse gas Emission (ENERGY)	Indoor Air Quality	LCA	Microbial control
Sustainable sites		Peak electricity demand reduction	Acoustic comfort	Responsible Building Materials	Refrigerant Impacts
Stormwater			Lighting comfort	Sustainable products	Heat island Effects
			Visual comfort	Construction and Demolition waste	Light pollution
			Indoor pollutants		Sustainable transport
			Thermal comfort		
ITACA					
SITE	***WATER***	***ENERGY***	***COMFORT AND SAFETY***	***MATERIALS***	***OUTDOOR QUALITY***
Service accessibility	Drinking Water	Primary non-renewable energy required during the lifecycle	Ventilation	Eco-friendly materials	CO_2 equivalent emissions
	Waste water	Energy from renewable sources	Thermal Comfort		
			Acoustic Comfort		
			Visual Comfort		
			Domotic systems		

Fig. 2 – Distribution of credits for the new six macro-areas

2.2 The Applied Green Building Rating Systems

2.2.1 ITACA

In Umbria, where the building analyzed in this work is located, the regional law number 17 (2008) introduces the certification of the environmental sustainability in the building sector. The law is mandatory for public buildings and voluntary for the private ones. The evaluation of the buildings is realized by means of 22 technical sheets inspired by the ITACA protocol and customized to the local features. The protocol is divided into five macro-areas: quality of the site, resource consumption, environmental loads, indoor environmental quality, and service quality.

A score is associated to every sheet from "poor" (-1) to excellent (+5); the sum of the scores, calibrated by the different weights given to every sheet, determines the score of each macro area. In the ITACA protocol the resource consumption has the heaviest weight (53.6 %), followed by Indoor environmental quality (18.2 %) and Environmental loads (17.5 %); service quality (6.7 %) and site quality (4 %) have the lowest weight. The sum of the scores of the macro areas gives the final score that classifies the building according to one of the five classes of sustainability provided: A+, A, B, C, D (see Table 2). If a building is in the D class, it is to be considered uncertified.

Table 2 – Final achievable scores in ITACA

Total Score	Class
100-85	A+
84-70	A
69-55	B
54-40	C
<40	D

2.2.2 CASBEE

In Japan, the governmental and academic project that worked on the CASBEE protocol was developed in 2001 by two organizations: The Japan Green Build Council (JaGBC) and the Japan Sustainable Building Consortium (JSBC). CASBEE identifies two main vectors that are considered incompatible and inversely proportional: the improvement of the environmental quality (Q) and the building environmental loads (L). The certification is not based on the sum of scores obtained from the different elements analyzed but on a simple scalar indicator named "Building Environmental Efficiency" (BEE) indicated and calculated as the ratio Q/L.

In CASBEE, the Environmental Quality (Q) measures the following assessment fields: quality of the indoor environment (Q1), the building service quality (Q2), and the quality of the surrounding site within the hypothesis space (Q3). On the other hand, the Environmental Load (L) measures the following assessment fields: energy load on the environment (L1), the resources and material loads (L2), and the building environmental loads outside the enclosed space (L3). The classification of the building is realized through a special graph (Fig. 3) in which the domains of every class are represented, the Q result should be set on the vertical axis (y-axis) and the L result should be set on the horizontal axis (x-axis). Therefore, the efficient building is the one that is characterized by the least environmental load and the highest environmental quality. The ranks provided are S (excellent), A (very good), B+ (good), B- (fairly poor), and C (poor).

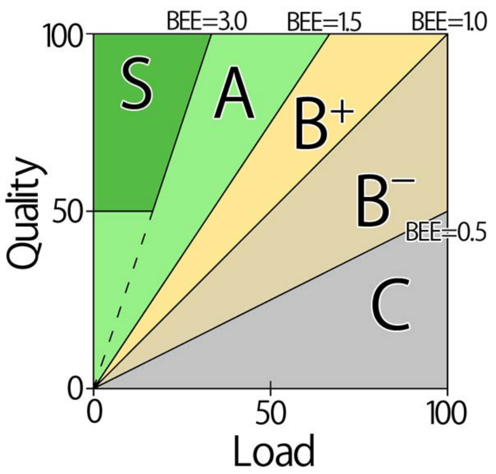

Fig. 3 – Graph for CASBEE classification

2.2.3 Green Star

Green Star was launched in 2003 by the Green Building Council of Australia and then, after having been customized and adapted to the local contexts, was adopted also in New Zealand and South Africa. The protocol identifies nine macro-areas: management, indoor environment quality, energy, transport, water, materials, land use & ecology, emissions, and innovation. Every category gives credits that address specific aspects of a sustainable building design, construction or performance with a total of 156 un-weighted points available for distribution to eight categories. Five extra points are available for the Innovation category but they are not considered in this paper. The weights of every category are: Management 9 %, Indoor Environmental Quality 17 %, Energy 19 %, Transport 8 %, Water 10 %, Materials 21 %, Land use & ecology 5 %, Emissions 11 %. The sum of the credits allows to classify the sustainability level of the building expressed through a number of Green Stars rating from 1 to 6 (Table 3). In this paper the "Design and As built" certification scheme was considered. This version of the protocol allows to certificate buildings only from Four to Six stars: scores under 45 points are insufficient for certification.

Table 3 – Green Star rating scores

Score	Rating	Category
10-19	One Star	Minimum Practice
20-29	Two Stars	Average Practice
30-44	Three Stars	Good Practice
45-59	Four Stars	Best Practice
60-74	Five Stars	Australian Excellence
75+	Six Stars	World Leadership

3. Case Study

The case study is represented by the green building complex "Le Violette", located in Foligno, in the region of Umbria (Italy). It was built by taking into account the principles of sustainability in terms of both structural and technical solutions (Fig. 4). The building is characterized by a modern style but, nevertheless, it is well integrated in the surrounding landscape. The structure has a regular shape (organised on four floors) and has a total of twelve flats sized are 71 and 90 m^2. Moreover, the building has 12 basement garages.

External solar shading systems are installed; the building is equipped both with "roof garden" and inclined roofs in order to allow the positioning of solar and photovoltaic panels. The heating system is centralized and characterized by radiant floors. It is powered by geothermal energy and heat pumps. The envelope of the building is well insulated through the employment of wood panels and expanded polystyrene.

Fig. 4 – The case study: "Le Violette" complex

4. Results and Discussion

The first step of this study was the application of the original rating systems to the analyzed building. It can be seen that the building achieved 57.71 % of the total score applying the ITACA protocol, and is certified "B level" (Table 4); the CASBEE system gave a score equal to 1.8 BEE index, which represents the "A" level (4/5 Stars) (Table 5). Finally, the application of Green Star gives 45 % of the score that corresponds to a rating of "Four Stars" (Best Practice) (Table 6).

Table 4 – Points achieved by applying the original version of ITACA

Original Areas	Points
Site quality	0.80
Resource consumption	34.14
Environmental loads	15.12
Indoor environmental quality	6.37
Service quality	1.28
Certification Level: B	57.71

These dissimilarities in the results can be referred on one side to the different range of achievable credit points and on the other side to the number and typology of credits available for the sustainability assessment. For example, Green Star has a narrow range of points and generally assigns one or zero points for each credit; thus, if the building cannot achieve the strict requirements defined by the credit, the score obtained is 0.

Table 5 – Points achieved by applying the original version of CASBEE

Original Areas	Points
Q1 Indoor environment	3.6
Q2 Quality of service	3.2
Q3 Outdoor environment on site	3.5
LR1 Energy	4.2
LR2 Resources & Materials	2.8
LR3 Off-site environment	3.7
Certification Level: A	BEE:1.8

On the contrary, both CASBEE and ITACA are characterized by a wider range, and it is easier to get a better score (0÷5 points for CASBEE and -1÷5 for ITACA): even though the maximum points cannot be reached, halfway performance can be assessed anyway with a medium score (i.e. 3 points). Furthermore, CASBEE takes into account more aspects and sustainability issues compared to Green Star and ITACA. These motivations influenced the final score of CASBEE, which results in being the highest one.

In the second step, the results gained by the three rating tools were compared by applying the new six macro-areas to highlight the main differences in the composition of the total score.

Table 6 – Points achieved by applying the original version of Green Star

Original Areas	Points
Management	6
Indoor environment quality	13
Energy	4
Transport	1
Water	3
Materials	6
Land use & Ecology	3
Emissions	5
Innovation	4
Certification Level: 4 Stars	45

Once the new macro-areas were filled with credits, the scores were normalized on the basis of 100, in order to verify the importance that each rating method gives to the different aspects.

Fig. 5 shows the points achieved in each rating system after the application of the new six macro-areas. The figure allows us to understand the percentage points achieved for each new macro-area by the studied building, compared to the maximum achievable.

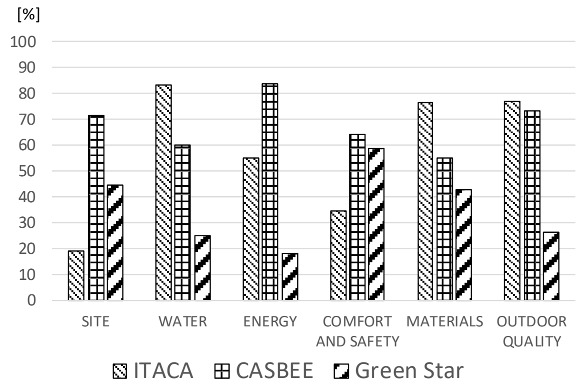

Fig. 5 – Comparison among ITACA, CASBEE and Green Star results (new macro-areas).

Moreover, Fig. 5 provides the comparison among the rating systems and highlights that:

- By applying ITACA, the building obtained the highest percentage of the reachable score in Water category (83.56 %), followed by Materials (76.60 %) and Outdoor Quality (77.20 %) categories, compared to the other protocols. On the other hand, the lowest scores were achieved in Site (where this rating system obtains a score lower than 20 %) and Comfort and Safety (where ITACA reaches a score of about 35 %);
- By employing CASBEE, the building results as the most efficient only in Energy category (84 %), Site (71 %) and Comfort and safety (63 %), compared to the other rating systems. It is possible to observe that CASBEE results are high and comparable among the six new macro-areas: all its scores range between 55 % and 84 % and, due to this, the building scores the best certification level;
- By using Green Star, the building always achieved the lowest scores, compared to the other protocols, except for the Site and Comfort and Safety categories, in which the worst was given by ITACA. In particular, by using Green Star, the building obtains scores lower than 20 % in Energy and lower than 30 % in Water. On the contrary, the highest scores were achieved in Comfort and Safety (about 60 %) and Site (about 44 %).

It can be noticed that the highest final score reached by applying the CASBEE rating system (Level A-very good) is related to the fact that a high and homogenous amount of points in the six macro-areas was obtained (as mentioned, it ranges between 55 % and 84 % of the total achievable points). On the contrary, for the other two systems, the obtained scores for each macro-area have high variabilities. Despite the fact that ITACA is the most widely applied green rating tool in Italy and we should expect to gain the best certification level through its application, ITACA scores range between 19 % and 84 %, highlighting results that are not comparable between the new six macro-areas. Also by employing Green Star the score was quite unsatisfying, it is homogenous with ITACA, in fact it ranges between 18 % and 60 %.

5. Conclusion

This paper proposes a comparative study among three building environmental assessment methods, ITACA, CASBEE, and Green Star.

The tools were firstly applied to a residential building located in Italy; then, the results were compared by using a methodological approach based on the definition of six new macro-areas.

This approach allowed us to underline the main differences and analogies among the protocols, by subdividing and distributing their credits into the six new categories (site, water, energy, comfort and safety, materials, and outdoor quality) and by normalizing them on the basis of 100. The building achieved very different final scores with the three systems: the best was CASBEE while the worst was Green Star.

It is a bit surprising that the building achieved a better score with the CASBEE method than with ITACA, considering the fact that the latter is widely adopted in Italy. This circumstance is probably related to the different range of achievable credit points and the number and typology of credits available for the sustainability assessment.

It is worthy to notice that by analyzing in detail each macro-area, high differences among the performance rates given by each tool were observed. It is therefore possible to assert that it is difficult to achieve a common sustainability language due to different calculation models, different credits, and weights applied by each green rating systems. There is therefore the need to homologate the targets of sustainability by defining a set of sustainable issues regulated by common principles shared all over the world.

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