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An expeditious method for comparing sustainable rating systems for residential buildings

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Abstract

Rating systems for sustainability (R.S.), started to be largely used in the assessment of built environment since the early '90s,.
The diffusion of these tools led to several benefits but also underlined some critical issues. One of the main hitches is the difficulty in comparing methods and results of different assessments, which have been developed at different times and places, following specific approaches.
This paper aims at proposing a method to compare different R.S. and their outcomes, by mapping what and how much they have in common, to identify a shared core of elements that could be considered the most representative in assessing the sustainability of the built environment, focusing particularly on residential buildings.
The predictable loss of accuracy due to the reduction of the considered indicators is analyzed, to define an acceptable level of reliability of the resulting concise R.S., whose simplification can, however, help to facilitate its wider application.

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Keywords: rating systems; sustainable buildings; ecodesign; environmental impacts; Active House; residential buildings.

1. Rating Systems and their limits

Several tools for assessing the sustainability of buildings -or some of its features- are available today [1]. They span from the evaluation of the environmental behavior of the building during its entire life cycle, to the appraisal of energy efficiency, or merely of energy consumption, assumed as the most important feature of the overall building performances.

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The more comprehensive approach, which include environmental, economic and social issues whose assessment, is based on multidimensional and multi-criterial analysis by which single factors are separately evaluated by specific indicators and then combined in order to give a final overall rating by scores, on the basis of predefined performance levels [2]. Because of this, they are known as sustainable building rating systems (R.S.). Among their many virtues and potentials in allowing an objective measure of sustainability, R.S. also show some issues [3], that can hinder the implementation of the good precepts from which they derive:

- Complexity of operations, due to the large number of variables that must be considered, which require several specialized auditors and long elaboration times in most cases, with subsequent high costs, which are often a key barrier to perform the assessment
- Relevant complexity and costs imply the weak application of the R.S. in small projects, such as in residential sector, which is the most penalized despite its high potential demand
- The almost total inability of comparison of the results issued from different R.S. due to a lack of homogeneity and cross-coherence between them

In order to both encourage the use of sustainable practices in housing sector and limit the unsuitable proliferation of R.S., it would be very beneficial to establish a simplified methodology, which is proven able to preserve the multi-criteria approach, an adequate level of reliability as well as a robust coherence with the R.S. currently in use. Extracting a core set of common criteria and indicators from the most representative R.S. it appears an effective way to reach such result. A simplified R.S. based on this set of criteria could permit the development of a methodology able to compare the results obtained from different systems, providing a basic common standard suitable to make comparable the sustainability assessment issued from different existing R.S.

This paper presents a procedure by which a set of criteria have been drawn up from different existing R.S., highlighting what criteria are in common and to what extent, in order to identify a core set of indicators applicable in particular to residential buildings.

2. Methodology for Rating Systems comparison

Despite almost all R.S. share common target and approach to the issue of sustainability assessment, their structures, indicators and metrics were developed independently and are extremely inhomogeneous. Therefore, it is impossible to map directly the matches between corresponding specifications, if not through the medium of an external "interface" which provides a common structure to which the specifications of individual RS can be referred. For this purpose:

- A common platform has been defined, which retains the basic features of “Active House”, an evaluation system developed in northern Europe specifically for housing, since 2007
- A limited set of current R.S. has been selected on the basis of specific criteria, in order to have a representative sample, to be subjected to the next stage of comparison
- Summary boards for each selected R.S. have been draw up, in which its main features were listed (such as the structure by areas of assessment, the criteria assigned to each area and the weight assigned to each criterion included in the areas). So, the correspondences among the evaluation structures of different Systems have been marked and the level of similarity (as a percentage) between them has been calculated
- A common platform of 11 evaluation areas has been identified and the level of importance assigned to each of them by each R.S. has been recorded, determining area by area the compliance of each system to the reference platform
- Final considerations on the obtained results have been deducted, with respect in particular to the Active House system, in order to verify the reliability of its simple evaluation structure in providing a reference for a common platform

2.1. Active House

Aiming to achieve the objectives of the Europe 2020 Strategy [4], Active House [5] leads to the production of nearly zero-energy buildings able to provide both effective environmental sustainability and excellent levels of user comfort. Active House ambition is to promote the adoption of the assessment as a common practice, as required by the regulations: for this purpose, its vision aims at long-term goals for building construction – from the construction phase till the decommissioning – but its assessment procedure is easier and simpler than other R.S. in use.

The Active House 17 assessment criteria are divided into three main categories: comfort, energy and environment, as shown in Table 1 [5].

Table 1. Active House evaluation criteria.

Principles	Criteria Group	Criteria
COMFORT	Daylight	Daylight Factor
		Direct Sunlight Available
	Thermal Environment	Maximum Operative temperature
		Minimum Operative Temperature
	Indoor Air Quality	Standard Fresh Air Supply
ENERGY	Energy demand	Annual Energy Demand
	Energy Supply	Origin of Energy Supply
	Primary Energy Performance	Annual Primary Energy Performance
ENVIRONMENT	Environmental Loads	Building's Primary Energy Consumption during entire Life Cycle
		Global Warming Potential (GWP) during Building's Life Cycle
		Ozone Depletion Potential (ODP) during B.L.C.
		Photochemical Ozone Creation Potential (POCP) during B.L.C.
		Acidification Potential (AP) during B.L.C.
		Eutrophication Potential(EP) during B.L.C.
	Fresh Water Consumption	Minimization of Fresh Water Consumption during Building's Use
	Sustainable Construction	Recyclable Content
		Responsible Sourcing

The limited number of criteria and the free sharing of both the system and the assessment tools within the enrolled users are the main reasons prompting the interest in this tool as a possible “third” basis for the comparison of different R.S. For this reason, Active House was taken as a reference: his few criteria can allow to easily compare the relative reliability of the evaluation performed by other, more complex, R.S..

2.2. Screening phase

Since a large number of R.S. for building sustainability are currently available worldwide (more than 600, according to BRE 2008 survey [6]), a smaller set of systems has been selected to perform the comparison. The selection criteria are those listed below:

- Minimum of certificates issued by the R.S, set at 500 units to be sure to process the most widely used R.S.

- Geographical boundary: the selection has been limited to European continent, for both climate and social reasons[1]
- Similarity in evaluation structures: the R.S. that were chosen had similar evaluation mechanisms and some analogies in final rating formulation, in order to limit the variables to be considered in the comparison
- Only those R.S. which provide a version dedicated to the evaluation of residential buildings, such as Active House has

The most relevant characteristics of the selected R.S. are summarized in the following tables (Tab.2, Tab.3).

Table 2. First step screening.

Origin	Name	Certification Data			Versions		Construction typology			
							New		Existing	
		Tot. buildings certified	In Italy	Outside origin	Residential version	Other countries suitability	Residential	Not residential	State of fact	Refurbishment
USA	LEED	27.816 [1]	67	N.A.	YES	YES	YES	YES	YES	YES
U.K.	BREEAM	558 [2]	26	2.594	YES	YES	YES	YES	YES	YES
France	HQE	266.000	N.A.	N.A.	YES	YES [8]	YES	YES	YES	N.A.
Germany	DGNB	>1160 [3]	0	146	NO [6]	YES [9]	NO[6]	YES	YES	N.A.
Italy	ITACA	619	619	0	YES	NO	YES	YES	YES	N.A.
Italy	CASACLIMA	1689 [4]	1686	3	YES	NO	YES	N.A.	YES	N.A.
Japan	CASBEE	> 450	0	0	YES	NO	YES	YES	YES	YES
Canada	GREEN GLOBES	816 [5]	0	689	NO [7]	YES [10]	NO7	YES	YES	N.A.
Qatar	QSAS	> 128	0	0	YES	NO	YES	YES	YES	N.A.

1: only "LEED HOME" certificate are considered, on a total of 78.379
2: only residential buildings are considered, on a total of 7.746
3: including both certificated and pre-certificated projects
4: 618 of these in Bolzano/Bozen Province
5: 88 for residential buildings in the USA
6: under realization
7: the system is however used for residential buildings
8: certifications out of France are made by third party companies
9: DGNB has an English version. The adaptation of the system to specific countries depends on the technical certifier
10: system available in Canada and USA only
N.A.: Not available data

At the end of the screening stage, five R.S. were chosen for comparison with Active House:

- GBC Home, LEED residential version for the Italy, 2014 edition [7]
- The Code for Sustainable Homes (CSH), BREAM residential version, 2010 edition [8]
- HQE Bâtiment Residentiel, HQE Residential version, 2014 edition [9]
- DGNB, 2011 edition [2] [10]
- Protocollo Itaca, adaptation for Italy of SBTool, 2011 edition [11]

2.3. Summary boards for the direct comparison

The main phase of comparative analysis among the selected R.S. was performed by a direct comparison of all the available criteria and parameters, in order to highlight the similarities between the evaluation structures. Then, a

[1] About this requirement, among the various systems that presented territorial adaptations in different countries, it was given priority to adaptation for the Italian territory;
[2] An exception was made for DGNB with respect to the requirements of the residential dedicated version which was not released yet, at the time of the research. The structure seemed to be, however, particularly suitable also for this type of applications.

summary board containing the list of all the parameters taken into account by the various R.S. has been drafted, indicating also the weight assigned to each criterion by each R.S., the relative benchmarks and the related scores, aiming at identifying all the parameters that systems have in common. The method used to make this comparison is entirely qualitative, as the correspondence between the criteria was arbitrarily estimated by studying in depth the systems manuals.

Table 3. Second step screening.

	Typology of criteria				Structure of the methodology				Certification procedure		
Name	Energetics	Environmental	Social	Economics	Subdivision into groups of criteria	specific weight to criteria / group of criteria	Production of a single judgment	Levels of judgment	Internal certifier	Third party certification	Self - certification
LEED	YES	YES	YES	NO	YES	YES	YES	4	YES	N.A.	NO
BREEAM	YES	YES	YES	NO	YES	YES	YES	6	YES	YES	NO
HQE	YES	YES	YES	NO	YES	YES	YES	4	NO	YES	NO
DGNB	YES	YES	YES	YES	YES	YES	YES	3	YES	YES	NO
ITACA	YES	YES	YES	NO	YES	YES	YES	4	NO	YES	NO
CASACLIMA	YES	YES[1]	NO	NO	YES	NO	YES	3	YES	N.A.	NO
CASBEE	YES	YES	YES	NO	YES	YES	YES	5	YES	YES	YES
GREEN GLOBES	YES	YES	YES	NO	YES	YES	YES	5	YES2	N.A.	NO
QSAS	YES	YES	YES	YES	YES	YES	YES	6	YES	N.A.	NO

1: a specific version for the environmental aspects evaluation is available N.D. : not available data

Analyzing two systems at a time, where in both system two criteria turned out to be exactly the same, the correspondence was marked as matching[3]. In these circumstances, the margin of error determining the correspondence between the criteria was near to zero.

In cases where, instead, the equivalence between two criteria was not so immediate, the comparison has been based on the purpose for which those specific criteria were used[4]. In case that the purpose of the two parameters is the same, the correspondence would be assigned. Moreover, presumed multiple correspondences were indicated between a single factor and a plurality of other similar parameters, to be sure to consider all possible matches.

Dealing with a multitude of parameters characterized by different metric units and using no instruments but personal discretion as a tool of judgment, it is plausible that the method could be affected by a residue of uncertainty, but the results still represent a good starting point for the following steps.

The Active House summary board (Fig.1 below) shows the issue that the adopted methodology produces: all the parameters have been listed in the first columns, as well as the specific weights of each criterion and the matches checkboxes between the system and the others analyzed. When the parameters of two different systems match, the

[3] For example, the Average Daylight Factor (DF) turned out to be the criterion used to express the indoor visual comfort in 100% of the analyzed cases

[4] For instance, assessing the criterion for determining the consumption of drinking water, it would be possible to face different parameters such as “percentage of the volume of drinking water saved for indoor use compared to the calculated basic needs” (Protocollo ITACA) [10] and “strategies that allow a 20-30-40% reduction of the water demand for the building, compared to a building taken as a reference” (GBCHome) [6]

checkbox of the analyzed system is marked by the identification code of the related criteria present in its structure. The symbol “X”, instead, indicates the mismatches. The percentage extent in which each parameter recurs also in the other analyzed systems is shown on the right side of the checkboxes. The lower part of the table shows, instead, the total correspondence between all the parameters of that specific system and the other analyzed systems taken individually.

2.4. Weighing tables definition

Some shrewdness has been adopted to establish the weighing tables for those systems whose values were not shown explicitly, or where some hypotheses were needed to assign a weight to criteria that does not have own.

Since Active House does not provide the assignment of ratings based on predetermined weighing factors, it gives equal importance to each family of criteria. The weights that appear in the Active House board below, have been attributed by assuming that each of the three families of criteria weighed 33.33%.

DGNB, instead, provides the weighing factors, but the "Site Quality" group doesn’t contribute to the final score. Since the "Site Quality" criteria have been considered suitable to be included in the comparison, the weights of all the parameters have been recalculated based on DGNB provided data, by adopting a specific procedure [5].

Even GBC Home has its own weighing system. However, since the sum of the available credits is equal to 110, the relative weights to a maximum equal to 100% has been calculated through a simple proportion.

Unlike the others, HQE does not have a weighing tables but a specific assessment method, enabling (or not) the possibility to achieve the result of Top Performing (TP) to the criteria belonging to each topic. Following what was done by ENERBUILD in the census of some rating systems [7], HQE weighing factors have been assumed as a percentage relative to the amount of TP point included in each topic.

The graphs below (Fig. 2) summarize what the boards points out, allowing an immediate interpretation of the priorities that these systems attribute to different families of criteria.

Pie charts below (Fig. 2) show the summary boards representing the weighing structures of (in order): Active House, DGNB, CSH, ITACA, GBC Home and HQE[6]. Different colors indicate different criteria categories showing the weight percentage in respect of the whole system. Each criterion has been marked with the relative identification code and the color shade of the criteria indicates the weight proportions within the group.

2.5. Direct comparison based on preselected common evaluation areas

In order to quantitatively estimate the importance that the R.S. attribute to the individual families of criteria [13], and to what extent Active House assesses these areas, a restricted number of evaluation areas has been selected, that are common to most of the analyzed R.S.

This process is inspired in the SBA study [14] on the definition of some "Common Metrics", which aim at reaching an assessment tool based on a shared approach. The 11 areas of assessment (see list below) have been defined for the selected R.S. by reallocating within them all available criteria, based on their characteristics and affinities:

1. *Design Quality - Users* includes the criteria for accessibility, security, presence and proximity to services and infrastructure, assistance to building management and functionality of outdoor spaces;
2. *Design Quality - Site* includes criteria related to environmental impacts on the project site, land reuse and management of outdoor spaces;

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[5] A weight to the whole family "Site Quality" has been given first, so, basing on the maximum cumulative score excluding the site, i.e. 860 points, and the maximum obtainable considering also the latter, i.e. 990 points, the value of the sixth group, i.e. 15, has been obtained by a simple proportion: “860: 100 = 990: X”. At this point, the weights of all the criteria has been recalculated, basing, this time, on the new total equal to 115%.

[6] The codes that have been assigned to each criterion within the pie charts refers to the summary boards realized for the systems (as Active House summary board) but they do not appear in this paper

3. *Materials and Products* includes criteria related to environmental impacts generated by supplied materials and products, recycled and recyclable materials, certification of raw materials and finished products;
4. *Energy* includes the criteria for energy supply and consumption, renewable energy sources, energy-saving features;
5. *Water* includes criteria related to the consumption of drinking water, water-saving strategies and management of water consumption;
6. *Atmospheric Loads* includes the criteria relating to environmental impacts on soil and atmosphere and strategies for impact reduction;
7. *IEQ* includes the criteria for visual, acoustic, olfactory, hygrothermal comfort and air quality;
8. *Economic Aspects* includes criteria related to Life Cycle Cost and economic sustainability;
9. *Management* includes criteria related to building operation and maintenance, monitoring and control of consumptions / emissions;

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Quantitative Parameters

LEGEND: Active House; ITACA; DGNB; GBC HOME; CSH; HQE Residentiel

Principles	Criteria Group	Criteria	DGNB	CSH	ITACA	GBC Home	HQE residential	Single Criteria Matches Percentage	Single Criterion Weight	Evaluation Area Weight
1. COMFORT	1.1. Daylight	1.1.1 Daylight Factor	3.1.5	7.1	4.3.1	5.4.1	10.2	5/5 100%	6,67%	33,33%
		1.1.2 Direct Sunlight Available	3.1.5	7.1	X	X	10.2	3/5 60%	6,67%	
	1.2. Thermal Environment	1.2.1 Maximum Operative temperature	3.1.2	X	4.2.1	X	8.2	3/5 60%	6,67%	
		1.2.2 Minimum Operative Temperature	3.1.1	X	X	X	8.1	2/5 40%	6,67%	
	1.3. Indor Air Quality	1.3.1 Standard Fresh Air Supply	3.1.3	X	4.1.1	5.1.1 5.1.2	11.2 13.2	4/5 80%	6,67%	
2. ENERGY	2.1. Energy demand	2.1.1 Annual Energy Demand	1.3.1 1.3.2	X	2.1.1 2.1.2 2.5.1	P.3.1 3.1.1 3.1.2	4.1.	4/5 80%	11,11%	33,33%
	2.2. Energy Supply	2.2.1 Origin of Energy Supply	1.3.2	X	2.2.1 2.2.2	3.2.1 3.1.1 2.2.1 2.3.1	4.1	4/5 80%	11,11%	
	2.3. Primary Energy Performance	2.3.1 Annual Primary Energy Performance	1.3.2	X	X	P.3.1 2.2.1 2.3.1	4.1	3/5 60%	11,11%	
3. ENVIRONMENT	3.1. Environmental Loads	3.1.1 Building's Primary Energy Consuption during Entire Lyfe Cylcle	1.3.1	1.2	2.1.1 2.1.2 2.5.1	3.1.1 3.1.2	X	4/5 80%	3,70%	33,33%
		3.1.2 Global Warming Potential (GWP) during Building's Life Cycle	1.1.1	1.1 6.1	3.1.1	5.3.1	2.2	5/5 100%	3,70%	
		3.1.3 Ozone Depletion Potentnial (ODP) during B.L.C.	1.1.2	X	X	5.3.1	2.2.	3/5 60%	3,70%	
		3.1.4 Photochemical Ozone Creation Potential (POCP) during B.L.C.	1.1.3	X	X	5.3.1	X	2/5 40%	3,70%	
		3.1.5 Acidification Potential (AP) during B.L.C.	1.1.4	X	X	5.3.1	2.2	3/5 60%	3,70%	
		3.1.6 Eutrophication Potential(EP) during B.L.C.	1.1.5	X	X	5.3.1	2.2	2/5 40%	3,70%	
	3.2. Fresh Water Consumption	3.2.1 Minimization of Fresh Water Consumption during Building's Use	1.3.3	2.1 2.2	2.4.1. 2.4.2	P.2.1 2.1 2.2	5.2 5.3	5/5 100%	3,70%	
	3.3. Sustainable Construction	3.3.1Recyclable Content	1.2.2	3.2 3.3	2.3.2 2.3.3 2.3.5	4.1.1 4.1.2	X	4/5 80%	3,70%	
		3.3.2 Responsible Sourcing	1.2.2	3.2 3.3 3.1	X	4.3.1 4.4.1	2.2	4/5 80%	3,70%	
		Common Matches	17/17	7/17	8/17	14/17	14/17	Tot:	100%	100%
		Matches Percentage	100,00%	41,18%	47,06%	82,35%	82,35%			

Fig. 1. Active House summary board

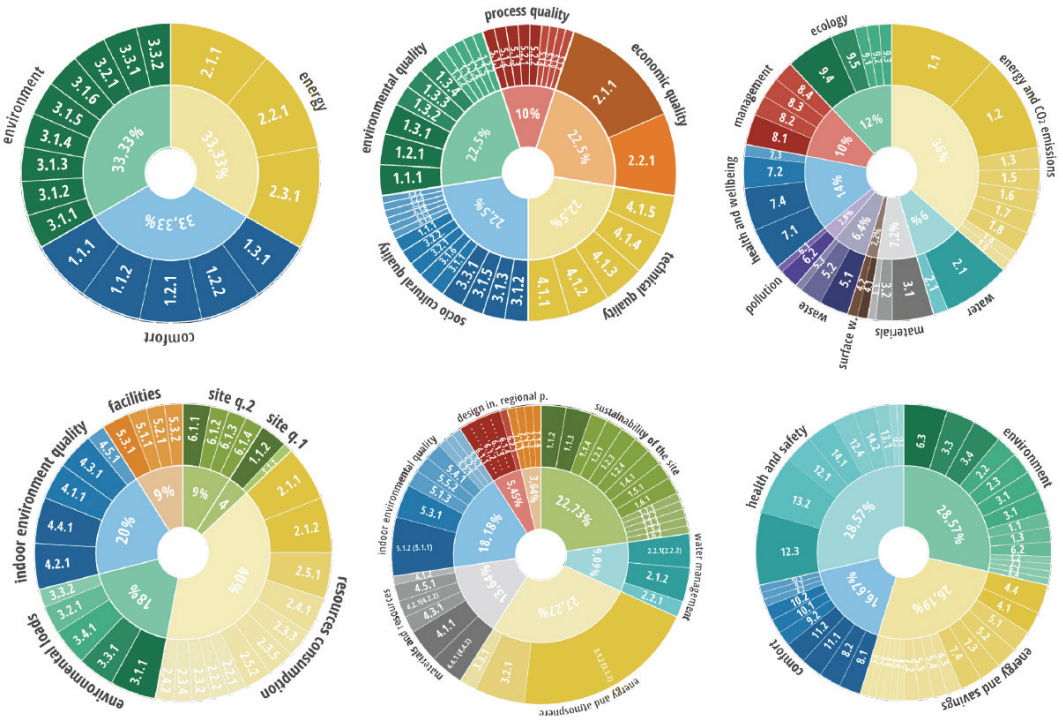

Fig. 2. Pie charts of the summary boards.

10. *Waste* includes the criteria related to waste management, collection areas and measures for waste reduction;
11. *Others:* includes all the criteria not considered in the previous categories.

The selected areas are represented by the icons below (Fig.3), in the same order they were mentioned.

Fig. 3. Icons of the selected evaluation areas.

Once the new areas of assessment were established, the reorganization of all the analyzed criteria was made, by reallocating them within new groups. Then a final board was built, in which the reordered criteria were listed, including their weighting factors and the percentage acquired by new groups of parameters.

Based on the processed data, two graphs make it possible to evaluate the effectiveness and reliability of the Active House approach towards other analyzed R.S.. The first one (Fig. 4) shows the overall importance (%) assigned to each evaluation area, allowing to identify which categories outweigh others, while the second graph (Fig. 5) points out the importance (%) given to the areas of assessment by each of the studied R.S., individually considered.

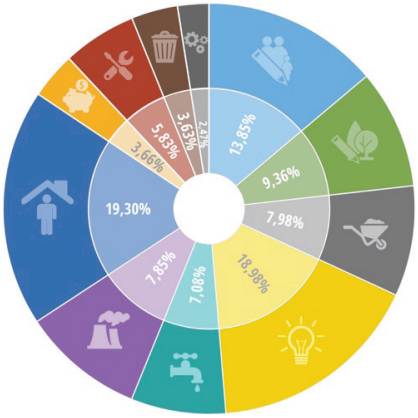

Fig. 4: Value of the total weights of the 11evaluation areas.

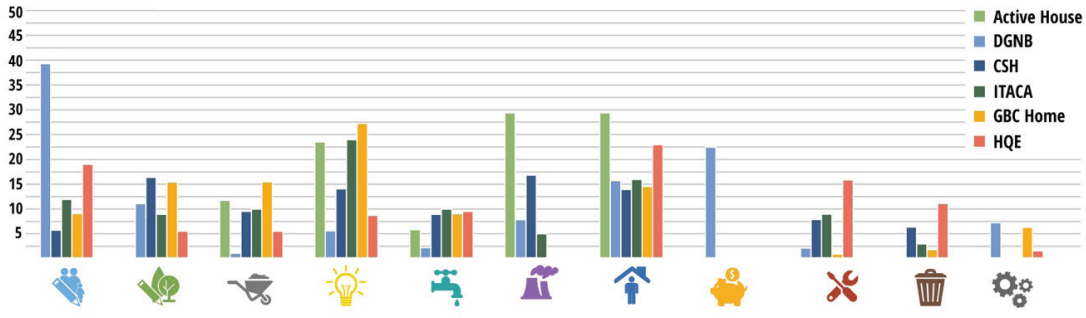

Fig. 5. Percentage value assigned to different areas of assessment by individual R.S.

3. Discussion

The method we have developed allows to identify to what extent a R.S. is matching the basic issues involved in the assessment procedures, by the means of a "set core" of most representative indicators, spread over 11 areas of assessment. So, the relative weight assigned to each area by each R.S. can be compared.

In addition, the indicators of each area have been classified based on the relative weight that is assigned to each of them by the R.S. to which they belong. This allows to class the indicators into 3 groups, by level of importance: Fig. 4 above shows that the most relevant categories (≥12%) are: *Design Quality for Users* (13,85%), *Energy* (18,98%) and *Indoor Environmental Quality* (19,30%), which is the overall prevailing category.

Looking at the most relevant areas, the structure issued from Active House appears to match all the main evaluation areas of the most common R.S., although implementing a significant reduction in the number of requirements compared to them. (see Fig.5 above) The Active House lack of criteria devoted to the evaluation of the site, does not seem to affect the overall system performance, nor reliability[7].

[7] According to Kurt Emil Eriksen (Active House General Secretary), the decision to omit this type of parameters in the evaluation comes by the intention to provide a system which would relate exclusively to the building and not with the surrounding context, besides being born by the need to simplify also in terms of time and costs of the assessment procedures. This information were collected during a phone interview conducted by the Authors on 28th November 2014.

4. Conclusion

The achieved results provide an original experimental contribution to the definition of “common metrics" which is evocated as a crucial issue for the wider application of sustainable building R.S. [14]

The comparison method which has been developed represent a rather promising starting point to develop a methodology by which the ratings produced by different systems can be compared, allowing them to communicate. The method is designed to allow its application to a larger set of R.S., in order to perform a further validation of the results which have been obtained.

Limiting complex calculations of an enormous number of indicators should stimulate the construction industry to focus more on the relevant performances of sustainability, by enhancing both the competition based on these features and a wider diffusion of R.S. applications within the market.

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