# *CEDES: a complete, legitimate and seamless GBRS that also serves as building design system with the highest sustainable/ecological standards.*

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**Abstract**

This paper proposes a new more complete, rigorous and seamless GBRS (*Green Building Rating System*) than the currently used systems, known as CEDES (*Comprehensive Environmental Design and Evaluation System*). The system has the following characteristics: 1) it is complete, i.e. there are no missing *categories* or *indicators* as in many existing GBRS; 2. None of its *categories* or *indicators* can be considered superfluous; 3. The relative weight of each *indicator* is justified and legitimized and is determined by the rest of the *indicators* and by a complete *life cycle assessment* (LCA) of all aspects of the construction process. 4) CEDES serves both to evaluate buildings and as a guide to building design with the maximum ecological and sustainable level. This paper describes CEBES’ conceptual structure and its operational dynamics for both evaluating and guiding the design process.

**Keywords**

architecture, categories, CEDES, engineering, GBRS of the future, indicators, LCA, new GBRS, sustainable design process, taxonomic structure

**1. Introduction**

The current GBRS vary widely in their structure and operation, which makes it difficult to carry out a comparative study with the objective of their improvement [1, 2] and indicates that their designers interpret the concept of sustainability very differently [3]. It is neither acceptable nor desirable that for the same concept has so many different quantification methods and this calls into question the usefulness of many of the GBRS designed so far.

All the GBRS have different *indicators*, with different relative importance [1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16]. In some cases the *indicators* are ambiguous, which allows personal interpretations [3, 17, 18, 19]. All the GBRS use different nomenclatures for apparently similar concepts, which means that many of them overlap [15]. As if that were not enough, many systems have *indicators* that have nothing to do with ecology and sustainability, so that no-one knows exactly what the different existing GBRS are actually measuring.

Initially, the GBRS had purely ecological *indicators*, which were complemented with economic *indicators* to evaluate a building’s level of sustainability However over time, “social”, “political” and “cultural” *indicators* were added, which could hardly be associated with the concept of sustainability [20, 21].

As a result of the great disparity between the different GBRS, the same building can obtain substantially different ratings, depending on the GBRS used. And this clearly demonstrates that all of them are deficient.

The fact that the different GBRS are so different from each other also means that there is no agreed definition of the concept of “sustainability” and this causes multiple interpretations and speculations, indicating a faulty design process [3, 22, 23].

However, several works have concluded that using certain GBRS does not provide any environmental improvement [24, 25, 26, 27, 28]. For example, 44 articles on LEED were reviewed in a recent publication [29] and 10 of them estimated that buildings designed with LEED have certain energy savings, but only in its highly certifications (“gold” and “platinum”), since its lowly certification (“certificate”) offered no advantages. On the other hand, 8 articles concluded that the energy consumption of LEED certificated buildings is no lower than the consumption of a conventional building. These studies concluded that LEED certification is hardly beneficial for the environment and the certification process is not worth the time or money spent on it

Other works are even more critical of LEED and conclude that the energy consumed by LEED-certified buildings is not on average significantly less than that consumed by conventional buildings [30, 31]. LEED buildings use significantly more energy than was estimated in the initial design simulations [32]. As if that were not enough, they show that LEED-certified buildings use relatively more electricity than other buildings, so that there are no energy savings [26, 27, 28, 30, 31, 32, 33].

Many professionals believe not only that LEED is useless but also that it does considerable harm to the construction sector and to professionals. In fact, several professionals and promoters have taken legal actions against it [34].

Many critical studies doubt the validity of the current GBRS systems due to the fact that they do not consider architectural design in their scoring system. A good architectural design can ensure the internal comfort of a building without the need to incorporate energy-consuming devices (heating, air conditioning and ventilation), saving between 40 and 70% of the energy required by a conventional building [17, 24, 35, 36, 37, 38, 39, 40, 41].

Several researchers have harshly criticized all the existing GBRS and suggested that all should be combined and completed in a common basic structure, although this concept would require a general agreement on “sustainability” [42, 43]. Many works also conclude that the current GBRS are not much use, since as compared to conventional buildings there is no substantial energy saving nor is there an optimal use of resources. They thus indicate that it is not worth the time and money to invest in the GBRS, since they do not guarantee a sustainable building and only provide a certificate that does not guarantee anything [26, 27, 28]. However, other researchers have suggested that comparative studies are useless and what should be done is to compare GBRS-designed buildings with conventional buildings [15].

The great number of criticisms and deficiencies found in the current GBRS thus call into question their validity to evaluate a building’s level of sustainability [17, 25, 27, 28, 30, 31, 32, 33, 34, 35, 40] and imply that their use could be perceived as a tool to legitimize certain political and economic interests.

It is therefore necessary to reflect deeply on the issue. The concept of "sustainability" should be agreed on and more appropriate, robust, complete, legitimate and seamless universally applicable GBRS must be designed from scratch. These systems should serve above all to guide a correct design process to obtain buildings of the maximum ecological and sustainable level. In this case the evaluation would simply consist of a free administrative check, as should have been done from the beginning.

**2. State of the Art**

Many researchers have questioned both the design and usefulness of the current GBRS and several proposals have been made to improve them and to create new and more suitable criteria.

One of their worst shortcomings is that they do not give importance to building design (and in general to the thermodynamic behavior of the building) but do give excessive importance to their devices. For this reason, several proposals have been made to restructure the current GBRS, including design aspects, to integrate them into the architectural design process in a more appropriate way [12, 44, 45, 46, 47]. On the other hand, other studies have gone further and have proposed new GBRS [43, 48, 49, 50, 51, 52, 53, 54, 55]. Some works even use very complex techniques to determine the *indicators*, such as fuzzy logic [56], or artificial intelligence algorithms [57].

Some studies conclude that a global consensus must be achieved, and a simple framework and a rating mechanism must be proposed to reduce the heterogeneity within the market [43].

From our point of view, some of the previous proposals to improve the current GBRS are not sufficiently demanding. In some cases, small changes are suggested that do not substantially improve the GBRS, while in others big changes transform them in a complex way, making it more effective and easier to design new GBRS from scratch.

From our point of view, the GBRS proposals continue to have serious shortcomings, since they do not consider important aspects of the life cycle of all aspects of the construction of buildings, and above all, they continue without giving the importance to architectural design that it deserves. It must be taken into account that there are houses and buildings with a special design that offer adequate internal thermal comfort without significant extra costs, without requiring heating, air conditioning and ventilation devices [24, 35, 36, 38, 39], which deserves to be given adequate importance. Finally, we believe that GBRS should above all actually be design tools, i.e. strategies to guide the building design process and ensure that the buildings have the highest possible sustainable level at the lowest possible price, in which case the evaluation would simply be a free administrative check.

For this reason, and after 20 years of experience, a new GBRS known as CEDES (*Comprehensive Environmental Design and Evaluation System*) was developed.

In 2003 the first version of CEDES was implemented [17, 35, 38, 40] and also served as a guide for the design process of sustainable buildings. This initial system has been used by several Spanish architects’ offices and in several Latin American countries. This system has also been also used to train more than 500 architects and engineers in the *Advanced Master’s Degree in Sustainable Architecture* [58], run by the *National Association for Sustainable Architecture* (ANAS) based in Spain and in Latin America [59].

After 20 years of experience, in 2023 a more complete, effective and robust one has been developed based on the initial version of CEDES.

**3. Construction process life cycle**

All the GBRS must have a structural core based on the *life cycle assessment* (LCA) of the construction process, which has been analyzed in many studies [60, 61, 62, 63, 64, 65] and is even standardized as to several international regulations [66]. Several GBRS have been designed worldwide based on the original version.

To design the most effective, appropriate and complete GBRS, an existing structure of the LCA of all materials, components and processes used in building construction has been improved. All the possible aspects of construction have been taken into account and all the details have been specified. Particular emphasis has been placed on all processes capable of maximizing the durability of both the building and its components, and all their possibilities of reuse, so that a complete structure of the life cycle of building construction has been created (Figure 1).

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**Figure 1.** Improved and detailed *Life Cycle Assessment* (LCA) of the construction process.

Based on this improved LCA structure, it is possible to determine how to optimize the use of materials, reduce energy consumption at each stage, reduce waste and emissions, make use of natural energy, as well as minimize the impact on human health.

The improved and detailed *Life Cycle* is shown in Fig. 1, proceeding clockwise, and is analyzed below. It begins with the possibility of using less elaborate natural materials (1), but since they are hardly usable in our current society, elaborate and optimized materials must be used (2). For manufacturing, it is essential that both the components (a) and the construction itself (b) have the greatest possible durability, in order to minimize the environmental impact per unit of time. To achieve this, maximum use must be made of recover-repair-reuse strategies, and ultimately recycle (c). Finally, when recycling is no longer possible, the waste must be dismantled and properly treated (d), to finally return to the ecosystem and be biodegraded (e). And again, a new life cycle begins:

1. *Natural construction.* Without a doubt, the ideal ecological construction is based on the use of materials that are obtained directly from both the ecosystem (tree trunks, branches, grass, straw, leaves, skins, etc.) and from the physical system (stones, sand, clay, etc.) and have not been highly processed. In this natural construction hardly any energy is needed to use natural resources and hardly any waste or emissions are generated. Buildings made with less elaborated natural elements can have a long life and flexibility, since their components can be reused several times, and they are also easily biodegradable once their useful life has ended. In general, this type of natural construction has almost no environmental impact, but very low durability. This type of natural construction cannot satisfy the demands of a complex and overpopulated society, in which a lot is demanded of buildings, especially those that must house a large number of people (safety, robustness, durability, functionality, etc.).

2. *Optimized construction.* The alternative to *natural construction* is optimized construction based on *manufactured* *components* which has a much greater environmental impact. Manufacturing optimized components requires a significant amount of energy and resources and generates emissions and waste. For this reason, and to minimize the environmental impact per unit of time, the main strategy that must be followed is to maximize the materials’ durability, reducing energy consumption, maintenance and the generation of emissions and waste to the maximum.

To maximize the durability of a building (with the least maintenance and lowest energy consumption possible), 5 main structured strategies must be followed at different stages of its useful life.

*a. Component manufacturing*. The first stage to achieve optimized constructions is based on component manufacturing, which allows the production of an enormous variety of components and the use of a greater amount of materials, but requires a great deal of of energy, produces a great amount of emissions and waste, increases the economic cost, and can impact animals’ well-being. Three strategies must be used to minimize the environmental impact of this stage,.

- *Design*. Components must be designed in such a way that they can be easily assembled and disassembled for easy repair and reuse. The number of components should not be very large, and they should be able to be used in several different types of constructions.

- *Site*. The site where components are manufactured must be perfectly chosen in order to minimize their environmental impact.

- *Durability*. Durable materials must be used that have a simple treatment to facilitate biodegradation in the last stage of their useful life.

b. *Object Manufacturing*. A wide variety of buildings (or objects) can be manufactured in the second stage, using the previously manufactured components with the lowest possible environmental impact, for which three different strategies can be followed.

- *Design*. The quantity and variety of components necessary in a building must be reduced to the minimum.

- *Optimization*. The design of buildings must guarantee that they consume the least possible amount of energy, require the least possible maintenance and generate the lowest possible emissions and waste.

- *Durability*. Buildings must be designed with a flexible architectural structure so that they have the greatest possible durability and can be easily reconfigured, adapting to the conditions of each stage of their useful life.

c. *Maximum extended useful life*. In the third stage, and once the construction of a building (or object) has been completed, its useful life can be extended to the maximum using several consecutive strategies.

- Firstly, all its components can be repaired and reused when they have deteriorated. To do this, building components must have been designed in the previous stage so that they can be extracted, repaired and reused with the greatest possible ease and the least possible amount of energy and resources.

- Secondly, the extremely deteriorated components of buildings can be used repeatedly in increasingly less demanding buildings (migration), thereby maximizing the durability of both the components and the buildings (or objects).

- There will come a time when the components will be so deteriorated that they can no longer be used in any type of building, so they must be recycled. It must be taken into account that the recycling process involves the use of a large amount of energy and resources and generates waste and emissions, so components should only be recycled when their reuse possibilities have been exhausted. Newly recycled components must be designed so that they can be used in the widest possible variety of buildings.

d. *Useless object*. In the fourth stage, there will come a time when some components can no longer be recycled again, since some of their properties (mechanical, physical or chemical) will have decreased considerably These must be biodegraded so that their basic components can be returned to Nature, for which they must be disassembled and treated appropriately to facilitate their biodegradation, using the least possible amount of energy and generating the least possible amount of emissions and waste.

e. *Waste biodegradation*. Useless components will continue to biodegrade naturally and after a certain time they can be extracted again, repeating a new cycle as described in (Fig. 1).

The improved and detailed LCA structure allows the basic structure of a new GBRS to be designed to evaluate and design ecological buildings. However, given that human beings are integrated into a complex global economic system, to adequately design a GBRS that allows buildings to be evaluated and designed with the highest possible sustainable level, appropriate economic and social criteria must be added, as in the design of the CEDES.

**4. Conceptual base of CEDES design**

CEDES was designed to integrate perfectly into the overall strategy to achieve sustainable development, in particular to design buildings with the highest possible sustainable level. This general strategy consists of 5 stages and is based on the strategy identified in the *United Nations Conference on Environment and Development* of Rio de Janeiro in 1992 [67] (Fig. 2).



**Figure 2.** Conceptual base for the design of the CEDES system.

*Stage 1*

In the first stage the desired environmental construction objectives must be defined. These objectives must include all the possible parameters identified in the improved and detailed LCA of the construction process, and must also include all the economic and social parameters necessary to guarantee the well-being and balance of anynvironment. These objectives must be specified precisely, weighted and adequately detailed, since otherwise it would not be possible to know whether they have been achieved or not, executing all possible actions throughout the process.

In our case the defined objectives are as follows:

*1. Use natural resources and optimize the use of manufactured resources*

*2. Reduce energy consumption as much as possible*

*3. Make the most of solar energy and other natural energy sources*

*4. Minimize emissions and waste generated as much as possible*

*5. Maximize health and well-being*

*6. Maximize the durability of buildings*

*7. Minimize the need for maintenance as much as possible*

*8. Reduce the economic cost to the maximum*

Obviously, it is desirable for the set of objectives is complete and seamless to ensure that buildings have the highest possible sustainable level.

The general objectives identified must also be divided into more defined sub-objectives and in turn these must be divided into new sub-objectives until unitary, well-defined, simple and non-overlapping objectives are achieved. These simple unitary sub-objectives will be associated with *indicators* in order to evaluate whether or not they have been achieved and to what extent.

*Stage 2*

A complete set of *indicators* must be identified to evaluate the sustainable level of each aspect of the building construction process. These aspects can be associated with each of the sub-objectives identified in the previous section. In this way, it is possible to know how far one is from achieving the initial objectives. In the same way, each *indicator* can be associated with a set of further *actions* (Stage 4) necessary to raise the desired sustainable level of each aspect of the building.

Establishing *indicators* in multidimensional entities is a very complex task. For one-dimensional entities, one *indicator* is sufficient (for example, the *indicator* “kilogram” is appropriate and sufficient to identify the weight of an object). On the other hand, for multidimensional entities it is necessary to use several *indicators* (for example, to measure the quality of a pencil, several measurement *indicators* can be established, such as “weight”, “diameter”, “robustness”, “ length”, the “blackness of the lead”, the “material”). ", etc, each with a different unit of measurement and a different specific weight. In fact, assigning the appropriate weight to each indicator is the biggest problem when evaluating multidimensional entities.

The number of *indicators* must be identified in such a way that none are missing, and the relative importance of each of them must be established. Each *indicator* must be determined in such a way that it does not partially overlap with any of the others, while the *indicators* must be chosen so that they are able to evaluate as simply as possible. The evaluation by each *indicator* must be carried out without doubt and in a simple and robust way to make it available to anyone, without a need for specialized knowledge. The evaluation of a certain aspect should not be confused with the actions (associated with the *indicators*) that must be carried out to improve its sustainable level.

*Stage 3*

The building must be evaluated in several aspects by the *indicators* identified in the previous stage. To do this, a very simple evaluation system must be identified, and the specific weight of each *indicator* must be determined. Determining the specific weight of each *indicator* is the most complex task in the design of any GBRS, the biggest problem of all the existing GBRS.

Let us imagine that we want to evaluate the quality of a pencil, which is the most important *indicator*? Its weight, diameter, length? Each *indicator* can be broken up into several *sub-indicators*. In this case, the weight of a pencil depends on the weight of the lead, the weight of its protection, the weight of the paint. But, which of these three *sub-indicators* is the most important?

As it is a complex issue, comparative studies must be carried out to determine the specific weight of each *indicator* and each *sub-indicator*. For example, to determine the specific weight of each *indicator* to evaluate the quality of a pencil, comparative studies should be carried out on durability, user satisfaction, robustness, etc.

As the evaluation of the ecological and sustainable level of a building is a much more complex task, establishing the most appropriate *indicators* and their relative specific weight is much more complex. To do this, information must be collected from a large number of comparative studies of the different aspects of the construction process throughout its entire life cycle. To determine the common specific weight of heterogeneous *indicators*, *Multi-Criteria Decision Making* (MCDM) techniques can be used [68, 69, 70, 71], of which SAW and COPRAS (*scoring methods*), TOPSIS and VIKOR (*distance based methods*), and MIVES (*utility/value methods*) stand out [72, 73].

*Stage 4*

Based on the results of the evaluation, action policies must be identified, executing a set of specific actions with the aim of improving the level of sustainability of a building.

A varied set of actions, of variable effectiveness and economic cost, can be associated with each *indicator*.

The actions can be very simple or they can be very complex, and they can be very direct or very innovative, but in any case they must be directly associated with a certain *indicator*, or group of *indicators*.

The different actions must therefore be implemented sequentially, from the most effective and economical to the least effective and most expensive. It is very important to determine this sequential process of choosing actions ineffective and expensive actions are often carried out, leaving aside other more economical and less effective actions (Fig. 4).

*Stage 5*

The results thus obtained must be evaluated periodically, and based on this, the actions can be modified or new ones carried out. This evaluation must be carried out in a short period of time, comparing the sustainable level achieved with respect to the economic cost invested, as well as the collateral problems generated. Some actions can be really expensive and ineffective, while others can be very effective and economical. Therefore, actions must be classified according to their environmental effectiveness and their cost to be able to choose the most appropriate ones (the most economical and most effective). The environmental effectiveness is deduced from the weight of the indicators associated with the environmental actions to be carried out.

**3. CEDES**

 The new GBRS guarantees that planned buildings have the highest sustainable level at the lowest possible price so that the process can be reduced to a simple administrative check.

Most GBRS are based on a 4-level top-down hierarchical structure that includes: *categories* (CAS), *problems* (ISS), *criteria* (CRS) and *indicators* (IDS) [1] (Fig. 1).

Some GBRS have only two of the four levels, others have three, and others have four (although some systems have different names). However, the two most important levels and common to all systems are the *categories* and the *indicators*.

To design CEDES a taxonomic structure was implemented that consists only of *categories* and *indicators* based on the exhaustive identification of the objectives and sub-objectives necessary to achieve high-level sustainable buildings. For this, the 8 objectives shown in the previous section were restructured and divided into several sub-objectives, creating 4 levels of abstraction. A general taxonomic framework was created to structure the necessary *indicators* and capable of evaluating the degree of compliance with the previously identified objectives.



**Figure 3.** Overview of the scoring process common to several GBRS

(Andújar 2020) [1].

It was taken into account that there was no aspect left out of the evaluation, including all the improved LCA *stages* of all aspects of the construction process. Also taken into account was that the number of *indicators* is complete, none are over or missing, that they do not overlap and are easy to evaluate. They were structured hierarchically in 4 levels of abstraction in order to give them their most appropriate specific weight. These *indicators* can be evaluated simply, scoring with values of between 0 and 5.

In this way, a triple evaluation can be carried out: a general evaluation of the building can be made, an evaluation can be made for each of the 8 *categories*, or an evaluation can be made by specific *sub-categories*, depending on the aspect of interest.

The taxonomic system created can be used as a guide to the design process of sustainable buildings from the first sketch until the final design. For this, the possible actions associated with the different *indicators* have been classified according to their economic value. In this way, a new taxonomy can be created that orders the different actions from the most economically and environmentally effective, to the most expensive and least effective (*inverted pyramids model*) [35, 36, 37, 38, 39, 40] (Fig. 3).



**Figure 4.** “Inverted pyramid model” relates the economic cost with environmental effectiveness of the possible actions to improve the sustainable level of buildings. It should be noted that the most effective actions are the cheapest, and the least effective are the most expensive and also the most promoted.

**4. Description of the taxonomic structure of *categories* and *indicators***

Based on the strategy shown in the previous section, a complete taxonomic structure for CEDES has been defined. This structure has been the result of a progressive refinement process, attempting to encompass the complete LCA of all possible aspects of the construction process. The 8 CEDES categories (first level) have been divided into subcategories. When some of these subcategories cannot be divided, they become indicators (second level), and if they can be divided, they are divided into sub-subcategories. When some of these sub-subcategories cannot be divided, they become indicators (third level), and if they can be divided, they are divided into indicators (fourth level) (Tables 1, 2, 3, 4, 5, 6, 7 and 8).

|  |
| --- |
| ***1. Optimization of resources*** |
| *1.1. Use of natural resources* |
|  *1.1.1. Water* |
|  *1.1.1.1. Rain water* |
|  *1.1.1.2. Groundwater* |
|  *1.1.2. Vegetation* |
|  *1.1.2.1. Wild vegetation* |
|  *1.1.2.2. Unprocessed wood* |
|  *1.1.2.3. Vegetable waste* |
|  *1.1.3. Soil* |
|  *1.1.3.1. Not elaborated stones* |
|  *1.1.3.2. Soil* |
|  *1.1.4. Choice of site* |
|  *1.1.4.1. Use of not arable land* |
|  *1.1.4.2. Accessibility* |
|  *1.1.4.3. Positive impact on the site* |
| *1.2. Resource optimization* |
|  *1.2.1. Amount of resources needed* |
|  *1.2.1.1. Resources needed in construction* |
|  *1.2.1.2. Resources needed throughout the lifecycle of the building* |
|  *1.2.1.3. Resources needed for building maintenance* |
|  *1.2.1.4. Abundance of resources used for component manufacturing*  |
|  *1.2.2. Durability level of components and materials*  |
|  *1.2.3. Waste utilization level* |
|  *1.2.4. Reusability of components* |
|  *1.2.4.1. Use of previously used components* |
|  *1.2.4.2. Component reparability level* |
|  *1.2.4.3. Component reusability level*  |
|  *1.2.4.4. Disassembly level. Reconfigurability and expandability* |
|  *1.2.5. Component recycling* |
|  *1.2.5.1. Use of recycled components* |
|  *1.2.5.2. Use of recycled grey water* |
|  *1.2.5.3. Component recycling level* |
|  *1.2.6. Level of exploitation of resources* |
|  *1.2.6.1. Refined design* |
|  *1.2.6.2. Industrialization level* |
|  *1.2.7. Functional durability of components* |
|  *1.2.8. Functional adaptation of components*  |

**Table 1.** *Sub-categories* and *indicators* of “*optimization of resources*” *category*

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| --- |
| ***2. Reduction in energy consumption*** |
| *2.1. Energy consumption in obtaining materials* |
| *2.2. Energy consumption in the transportation of materials* |
| *2.3. Energy consumption in the transportation of labor*  |
| *2.4. Energy consumption in building construction process* |
| *2.5. Energy consumption by building throughout its lifecycle*  |
|  *2.5.1. Energy consumption in building accessibility*  |
|  *2.5.1.1. Accessibility to the area*  |
|  *2.5.1.2. Accessibility to the rooms of the building* |
|  *2.5.2. Energy consumption by building devices* |
|  *2.5.2.1. Heating* |
|  *2.5.2.2. Air-conditioning* |
|  *2.5.2.3. Human technological adequacy*  |
|  *2.5.2.4. Ventilation systems* |
|  *2.5.2.5. Lighting* |
|  *2.5.2.6. Home appliances* |
|  *2.5.2.7. Telecommunication systems* |
|  *2.5.3. Energy consumption in building maintenance* |
|  *2.5.3.1. Cleaning* |
|  *2.5.3.2. Repairs* |
|  *2.5.3.3. Improvements* |
| *2.6. Bioclimatic architectural design* |
|  *2.6.1. Location* |
|  *2.6.1. Correct N-S orientation* |
|  *2.6.2. Appropriate architectural typology* |
|  *2.6.3. Efficacy of sun protections* |
|  *2.6.4. Architectural heating systems* |
|  *2.6.5. Architectural cooling systems* |
|  *2.6.6. Proper thermal inertia of building* |
|  *2.6.7. Proper building insulation* |
|  *2.6.8. Natural ventilation* |
|  *2.6.9. Thermal bridges* |
| *2.7. Energy consumption in the process of demolishing/disassembling the building* |

**Table 2.** *Sub-categories* and *indicators* of “*reduction in energy consumption*” *category*

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| --- |
| ***3. Use of natural energy sources*** |
| *3.1. Solar energy* |
|  *3.1.1. Thermal solar energy* |
|  *3.1.2. Photovoltaic solar energy* |
| *3.2. Geothermal energy* |
|  *3.2.1. Geothermal energy without heat pump* |
|  *3.2.2. Geothermal energy with heat pump* |
| *3.3. Renewable energies for the natural ecosystem* |
|  *3.3.1. Wind power* |
|  *3.3.2. River and sea energy* |
|  *3.3.3. Energy from underground sources* |

**Table 3.** *Sub-categories* and *indicators* of *“use of natural energy sources*” *category*

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| ***4. Reduction of waste and emissions*** |
| *4.1. Waste and emissions generated in obtaining construction materials* |
| *4.1.1. Waste* |
|  *4.1.2. Emissions* |
| *4.2. Waste generated in the manufacturing of components* |
|  *4.2.1. Waste* |
|  *4.2.2. Emissions* |
| *4.3. Waste generated in the transportation of components and materials* |
|  *4.3.1. Waste* |
|  *4.3.2. Emissions* |
| *4.4. Waste and emissions generated in construction process* |
|  *4.4.1. Waste* |
|  *4.4.2. Emissions* |
| *4.5. Waste and emissions generated in building maintenance* |
|  *4.5.1. Waste* |
|  *4.5.2. Emissions* |
| *4.6. Waste and emissions generated in building demolition* |
|  *4.6.1. Waste* |
|  *4.6.2. Emissions* |

**Table 4.** *Sub-categories* and *indicators* of “*reduction of waste and emissions*” *category*

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| --- |
| ***5. Increased health and quality of life of building occupants*** |
| *5.1. Harmful emissions to natural ecosystem* |
| *5.2. Harmful emissions to human health* |
| *5.3. Number of illnesses of building occupants* |
| *5.4. Degree of well-being of building occupants* |

**Table 5.** *Sub-categories* and *indicators* of “*increased health and quality of life*” *category*

|  |
| --- |
| ***6. Economic cost*** |
| *6.1. Direct economic cost in building construction* |
| *6.2. Indirect economic cost* |
| *6.3. Economic cost in maintenance* |
|  *6.3.1. Materials* |
|  *6.3.2. Labor* |
|  *6.3.3. Technological equipment* |
|  *6.3.4. Cleaning* |
| *6.4. Cost of emissions and waste management* |
| *6.5. Cost of treating diseases and illnesses* |
| *6.6. Economic revaluation of the building* |
| *6.7. Economic revaluation of the environment* |
| *6.8. Construction speed* |

**Table 6.** *Sub-categories* and *indicators* of “*economic cost*” *category*

|  |
| --- |
| ***7. Social adequacy*** |
| *7.1. Local level of economic development* |
| *7.2. Local technological level* |
| *7.3. Local quality preferences* |
| *7.4. Local design preferences* |
| *7.5. Local preferences for construction systems* |
| *7.6. Local type of family unit* |

**Table 7.** *Sub-categories* and *indicators* of “*social adequacy*” *category*

|  |
| --- |
| ***8. Complementary sustainable aspects***  |
| *8.1. Adaptability to change and flexibility of the building* |
| *8.2. Social aesthetic appeal of building* |
| *8.3. Ecological regeneration of environment* |

**Table 8.** *Sub-categories* and *indicators* of “*complementary sustainable aspects*” *category*

**5. Internal structure and scoring system of CEDES**

The CEDES scoring system is extraordinarily simple. Each *indicator* can have an integer score, from 0 to 5.

*Score 0: no score*

*Score 1: very bad*

*Score 2: bad*

*Score 3: normal / acceptable*

*Score 4: good*

*Score 5: very good*

Therefore, a building will be evaluated using all the *indicators*, giving each one a score from 0 to 5.

The score of each *indicator* must be multiplied by a coefficient that measures its specific weight with respect to the specific weight of the others. Finally, all the scores must be added together, obtaining a general score between 0 and 5. If desired, it can be multiplied by two to obtain a score from 0 to 10.

Scoring all indicators gives the overall sustainability level of a building. However, it is also possible to score only the indicators in a certain category, and thus obtain the sustainability level of a building in a specific category (for example, “reduction in energy consumption”). It is also possible to score only a subcategory (for example, “energy consumed by the building throughout its useful life”).

Determining the relative specific weights of the *categories* and *indicators* is the most complex task of all when designing a GBRS. There is a risk of granting a specific weight that is too high or too low, whether involuntarily or voluntarily, and therefore the resulting evaluation would be erroneous.

Significant errors can be generated inadvertently, since quantifying the specific weight of the different *indicators* of a multidimensional system is always a huge problem, and a huge disparity of criteria are applicable. But none will be perfect.

On the other hand, voluntarily, due to social interests, a specific weight could be given that is too high to those *indicators* whose associated actions are desired to be executed, and a specific weight that is too low to those *indicators* whose associated actions are not desired to be executed. That is, the voluntary and premeditated increase or reduction of the specific weight of each *indicator* can turn a given GBRS into a tool capable of justifying and legitimizing certain political and economic interests (even if they have little environmental effectiveness), to the detriment of other actions with greater environmental efficiency, and presumably more economical.

Let's take an example. Let us imagine that a high specific weight is given to the *indicators* responsible for assessing the technological equipment of a building (heating, air conditioning, ventilation, photovoltaic energy generators, geothermal heat pumps, aerothermal energy, etc.), and instead, gives a disproportionately low specific weight to the *indicators* responsible for assessing its bioclimatic and thermodynamic design. In this case, the resulting GBRS will value those buildings that contain machines (energy consumers) much more than the well designed buildings that have few machines and are capable of providing the same thermal comfort to their occupants. The paradox is that if a correct bioclimatic and thermodynamic design of a given building is carried out, many fewer heating, air conditioning and ventilation machines would be necessary¸ and the building would also be more economical and would consume much less energy. As a result, the idea that the machines are more effective than a correct design would spread in society, since it has been legitimized by the previously designed GBRS. In a complementary way, certain users, even if they are aware of the poor design of these GBRS, would learn to take advantage of them, as a “green-washing” tool, investing in technological equipment (justifying their ecological goodness by the result of the GBRS used) attracting uninformed customers, also obtaining tax advantages or even subsidies from the political and administrative establishments fueled by the profits of the companies that manufacture those overrated machines. Few users will want to invest in a correct bioclimatic and thermodynamic design of their building since the GBRS would give it a low value and it would not have the indicated advantages.

A rigorous process was followed to design the CEDES system, free from any type of bias with the aim of assigning the appropriate weights to both the *categories* and the *indicators*. However, this is the most complex issue in the design of a GBRS, so the relative assessment of categories and indicators must be continually reviewed according to comparative studies.

**6. Determining the weights of CEDES categories and indicators**

6.1. *Categories*. Once the 8 *categories* have been identified, a specific weight must be given to each with respect to the others. This is a big problem, since it is very difficult to compare different *categories* with each other and establish their relative value. What is more valuable from an environmental point of view, optimizing resources or reducing energy consumption? Of course, both *categories* are indirectly related to each other, but there are no common units of measurement, nor a meeting point in which to compare both. How can they compare then? Because of the economic value? Because of the difficulty? For environmental improvement? The different existing GBRS have absolute secrecy in this regard, and everything is ambiguous and redirections to external entities, expert committees, altruistic contributors, etc., which are not specified or described.

In the case of CEDES, the specific weight of each *category* was achieved by evaluating the *indicators* of the rest of the *categories*.

An example could be given that illustrates this strategy. Let's say for example that 12 judges meet and each one has a vote with a different value. How would the specific weight of each judge be determined? The best way is for each judge to be evaluated by the rest of the judges.

In CEDES, the same strategy was followed, and the specific weight of each category was obtained by evaluating each category using all the indicators of the remaining categories (Table 9).

|  |  |  |
| --- | --- | --- |
| *1. Optimization of resources* | *18 %* | *0.18* |
| *2. Reduction of energy consumption* | *34 %* | *0.34* |
| *3. Use of natural energy sources* | *13 %* | *0.13* |
| *4. Reduction of waste and emissions* | *12 %* | *0.12* |
| *5. Increase in the quality of life of the occupants* | *8 %* | *0.08* |
| *6. Reduction in economic cost* | *10 %* | *0.1* |
| *7. Social adequacy* | *3 %* | *0.03* |
| *8. Others* | *2%* | *0.02* |

**Table 9.** Relative weight of each *category* in CEDES

Further research should be carried out in this regard, since a substantial change in the percentage of each *category* can generate a substantial variation in the total score.

However, an independent assessment can also be carried out, evaluating a specific building according to each *category*.

6.2. *Subcategories*. Each *category* is broken down into *sub-categories*, and these in turn into new *sub-categories* that are also decomposed into *indicators*, forming 4 levels of abstraction, creating a staggered hierarchy of *indicators*.

To give a relative value to the different *sub-categories* of the 8 initial *categories*, a complete analysis of the life cycle of each of the possible activities and stages in the construction of a building is carried out. For this purpose, an enormous number of comparative studies were collected on the *sub-categories* of each of the *categories*, especially on energy consumption, resource consumption, waste generation and the use of renewable energy sources [41, 60, 61, 62, 63, 69, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86]. A simplification of the AHP method was then used by 10 experts (analytical hierarchy process) [87].

Thus, in the “*resource optimization*” *category*, a general sweep was carried out and all the aspects and stages in which a maximum optimization of resources can be made were identified. The first stage is to use natural resources. However, since few natural resources can be used in the construction of buildings, they must be produced incrementally. At the same time, to optimize the manufactured resources, their durability must be enhanced (to minimize their environmental impact per unit of time), the capacity of reuse materials, the disassembly capacity of the components, the waste utilization capacity, the repair capacity, the reusability capacity, the recycling capacity, the disassembly capacity, and the optimized and industrialized design to take full advantage of the optimization of resources. Therefore, what was done was to subdivide the “*resource optimization*” *category* into other *sub-categories* in such a way that they are complete (the entire spectrum of possibilities is covered) and do not overlap. To establish the specific weight of each *sub-category*, a multitude of comparative studies were taken into account between the different *sub-categories* of each *category*.

Let us analyze, for example, the *category*, “*reduction of energy consumption*”, in which 7 *sub-categories* were identified, trying to represent all the stages of the life cycle of all possible aspects of the construction process: “*energy consumption in obtaining of materials*”, “*energy consumption in the transportation of materials*”, “*energy consumption in the transportation of labor*”, “*energy consumption in the building construction process*”, “*energy consumption by the building throughout its useful life*”, “*bioclimatic architectural design*”, “*energy consumption in the process of demolition or disassembly of the building*” (Table 10).

The specific weight of each *sub-category* can now be determined with comparative studies, since they can all be measured in energy units. In this regard, a multitude of comparative studies on the energy consumption of each *category* have been carefully analyzed by a group of 10 ANAS experts, with more than 30 years of experience and finally rounding out by orders of magnitude (Tables 1, 2, 3, 4, 5, 6, 7 and 8).

To refine the relative value of the different *sub-categories* further comparative studies should be carried out on energy consumption in each of them in various types of buildings. *Big-Data* algorithms will undoubtedly be useful in this regard in the near future when sufficient data are available, since by analyzing large databases, adequate coefficients can be achieved for each *sub-category*.

As a result, the coefficients assigned to each *sub-category* in CEDES are:

|  |  |
| --- | --- |
| *Energy consumed in obtaining materials* | *0.037* |
| *Energy consumed in the transportation of materials* | *0.022* |
| *Energy consumed in transporting labor* | *0.019* |
| *Energy consumed in the building construction process* | *0.115* |
| *Energy consumed by the building* | *0.325* |
| *Bioclimatic / thermodynamic architectural design*  | *0.458* |
| *Energy consumed in the process of demolishing/disassembling the building* | *0.024* |

**Table 10.** Weight of *sub-category*ies included in *”reduction of energy consumption” category*

6.3. Sub-*Subcategories*. Each *subcategory* can be divided, in turn, into several *sub-subcategories* (second level). For example, the *sub-category* “*energy consumption throughout the useful life of the building*” is made up of three other *sub-subcategories*: “*energy consumption in building accessibility*”, “*energy consumption by building devices*”, and “*energy consumption in building maintenance*”.

In turn, the sub*category* "*energy consumption by building devices*" is divided into seven *indicators*: "*energy consumption in heating*", "*energy consumption in air conditioning*", "*human technological adequacy*", “*energy consumption in ventilation systems*”, “*energy consumption in lighting*”, “*energy consumption in home* *appliances*” and “*energy consumption in* *telecommunication systems*”. The specific weight of each *sub-subcategory* at each level is calculated by considering the comparative analyzes carried out on the energy consumption of various types of buildings.

It is important to be exhaustive in the definition of *subcategories* and *sub-subcategories*, without forgetting any one since, otherwise, the resulting GBRS would provide erroneous results. Especially harmful would be the deliberate elimination of certain *categories*, or simply undervaluing them.

- Let's take an example. Let us imagine that a certain company has invested $300,000 in changing the air conditioning system of a building in order to save energy. Let's also imagine that you have purchased the most effective system that provides the greatest savings on the market. In this case, the corresponding *indicator* (“*air conditioning*” would provide a value of 5 (the highest rating), but this score must be multiplied by the total specific weight of “*air conditioning*” within the *category* “*reduction of energy consumption*” (Table 12). This weight is the result of multiplying its specific weight within the *sub-category* “*energy consumption by technological equipment of building*” (0.325), by its relative specific weight within the *sub-category* “*energy consumption by building throughout its lifecycle*" (0.9), and by the relative specific weight of this within the *category* "*reduction in energy consumption*" (0.35). The total specific weight of "*air conditioning*" would, therefore, be 0.102375 (0.35 \* 0.9 \* 0.325) (Table 12). In other words, an investment of 300,000 dollars would have a score (within the *category* “*reduction of energy consumption*”) of 0.511875 (5 \* 0.102375) out of 5.

Let's imagine that, on the other hand, another company had invested $100,000, choosing good architects, and purchasing some additional construction materials (sun protections, cooling galleries, ducts, ec.) and ingenious and more advanced construction solutions. In this case, the set of “*bioclimatic architectural design*” *indicators* would provide a score of 5. This score must be multiplied by its total specific weight within the *category* “*reduction of energy consumption*”, which is 0.458 (Table 2).

In other words, an investment of $100,000 would have a score (within the *category* “*reduction of energy consumption*”) of 2.29 (5 \* 0.458) out of 5. These data coincide, in order of magnitude, with the experience of having designed and analyzed about 200 projects, including about 2,000 houses [35, 36, 37, 38, 39, 40].

Therefore, investing in good design has an economic cost three times lower than investing only in the replacement of air conditioning equipment, but you can obtain an energy improvement 4.47 times higher (2.29 / 0.511875 = 4.47).

Evidently, if a different set of *categories* and *indicators* had been designed, and a different specific relative weight had been given to each *indicator*, the results would have been completely different, even contrary. In this way, the resulting GBRS would stop evaluating conveniently and would become a tool to legitimize certain political interests.

6.4. *Indicators*. The CEDES hierarchical structure makes it easier to determine the relative importance of each indicator in relation to the total set, making it easier to assign an appropriate weight. As seen, categories are divided into subcategories. When subcategories cannot be divided, they become indicators, and when they can be divided, they are divided into sub-subcategories. In turn, when sub-subcategories cannot be divided, they become indicators, and when they can be divided, they are divided into indicators.

The result is a set of categories and indicators structured in 4 levels of abstraction and with a perfectly balanced weight (Tables 11, 12, 13, 14, 15, 16, 17, 18). The last column on the right shows the weight of each indicator in relation to the total set of indicators.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* | *Percentage* | *Category**weight* | *Subcat1**weight* | *Subcat2**weight* | *Indicator**weight* |
| ***1. 1. Optimization of resources*** ***18%***  |  | 0.18 |  |  |  |
| *1. 1.1. Use of natural resources*  | 0.1 |  | 0.018 |  |  |
|  *1.1.1. Water*  | 0.4 \* 0.1 |  |  | 0.0072 |  |
|  *1.1.1.1. Rain water* | 0.6 \* 0.4 \* 0.1 |  |  |  | 0.00432 |
|  *1.1.1.2. Groundwater* | 0.4 \* 0.4 \* 0.1 |  |  |  | 0.00288 |
|  *1.1.2. Vegetation* | 0.25 \* 0.1 |  |  | 0.0045 |  |
|  *1.1.2.1. Wild vegetation* | 0.3 \* 0.25 \* 0.1 |  |  |  | 0.00135 |
|  *1.1.2.2. Unprocessed wood* | 0.4 \* 0.25 \* 0.1 |  |  |  | 0.0018 |
|  *1.1.2.3. Vegetable waste* | 0.3 \* 0.25 \* 0.1 |  |  |  | 0.00135 |
|  *1.1.3. Soil* | 0.25 \* 0.1 |  |  | 0.0045 |  |
|  *1.1.3.1. Not elaborated stones* | 0.5 \* 0.25 \* 0.1 |  |  |  | 0.00225 |
|  *1.1.3.2. Soil* | 0.5 \* 0.25 \* 0.1 |  |  |  | 0.00225 |
|  *1.1.4. Choice of site* | 0.1 \* 0.1 |  |  | 0.0018 |  |
|  *1.1.4.1. Use of not arable land* | 0.3 \* 0.1 \* 0.1 |  |  |  | 0.00054 |
|  *1.1.4.2. Accessibility* | 0.3 \* 0.1 \* 0.1 |  |  |  | 0.00054 |
|  *1.1.4.3. Positive impact on the place* | 0.4 \* 0.1 \* 0.1 |  |  |  | 0.00072 |
| *1. 1.2. Resource optimization* | 0.9 |  | 0.162 |  |  |
|  *1.2.1. Amount of resources needed* | 0.08 \* 0.9 |  |  | 0.01296 |  |
|  *1.2.1.1. Resources needed in construction* | 0.3 \* 0.08 \* 0.9 |  |  |  | 0.00388 |
|  *1.2.1.2. Resources needed throughout the lifecycle of building* | 0.2 \* 0.08 \* 0.9  |  |  |  | 0.00259 |
|  *1.2.1.3. Resources needed for building maintenance* | 0.1 \* 0.08 \* 0.9  |  |  |  | 0.00129 |
|  *1.2.1.4. Abundance of resources for component manufacturing*  | 0.4 \* 0.08 \* 0.9 |  |  |  | 0.00518 |
|  *1.2.2. Durability level of components and materials*  | 0.18 \* 0.9 |  |  | 0.02916 | 0.02916 |
|  *1.2.3. Waste utilization level* | 0.01 \* 0.9 |  |  | 0.01620 | 0.01620 |
|  *1.2.4. Reusability of components* | 0.34 \* 0.9 |  |  | 0.05508 |  |
|  *1.2.4.1. Use of previously used components* | 0.1 \* 0.34 \* 0.9  |  |  |  | 0.00550 |
|  *1.2.4.2. Component reparability level* | 0.2 \* 0.34 \* 0.9 |  |  |  | 0.01101 |
|  *1.2.4.3. Component reusability level*  | 0.2 \* 0.34 \* 0.9 |  |  |  | 0.01101 |
|  *1.2.4.4. Disassembly level. Reconfigurability and expandability* | 0.5 \* 0.34 \* 0.9 |  |  |  | 0.02754 |
|  *1.2.5. Component recycling* | 0.04 \* 0.9 |  |  | 0.00648 |  |
|  *1.2.5.1. Use of recycled components* | 0.25 \* 0.04 \* 0.9 |  |  |  | 0.00162 |
|  *1.2.5.2. Use of recycled grey water* | 0.25 \* 0.04 \* 0.9 |  |  |  | 0.00162 |
|  *1.2.5.3. Component recycling level* | 0.5 \* 0.04 \* 0.9 |  |  |  | 0.00324 |
|  *1.2.6. Level of exploitation of resources* | 0.25 |  |  | 0.045 |  |
|  *1.2.6.1. Refined design* | 0.6 \* 0.25 |  |  |  | 0.02700 |
|  *1.2.6.2. Industrialization level* | 0.4 \* 0.25 |  |  |  | 0.01800 |
|  *1.2.7. Functional durability of components* | 0.06 |  |  | 0.01080 | 0.01080 |
|  *1.2.8. Functional adaptation of components* | 0.04 |  |  | 0.00720 | 0.00720 |

**Table 11.** Weight of *sub-categories* and *indicators*, within the *“optimization of resources” category*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* | *Percentage* | *Category**weight* | *Subcat1**weight* | *Subcat2**weight* | *Indicator**weight* |
| ***1. 2. Reduction in energy consumption 34%***   |  | 0.34 |  |  |  |
| *1. 2.1. Energy consumption in obtaining materials*  | 0.043 |  | 0.01462 |  | 0.01462 |
| *2.2.2. Energy consumption in transportation of materials/components* | 0.022 |  | 0.00748 |  | 0.00748 |
| *2.2.3. Energy consumption in transportation of labor* | 0.013 |  | 0.00442 |  | 0.00442 |
| *2.2.4. Energy consumption in building construction process* | 0.115 |  | 0.03910 |  | 0.03910 |
| *2.2.5. Energy consumption by building throughout its lifecycle* | 0.325 |  | 0.1105 |  |  |
|  *2.5.1. Energy consumption in building accessibility* | 0.05 \* 0.325 |  |  | 0.00552 |  |
|  *2.5.1.1. Accessibility to the area* | 0.5 \* 0.05 \* 0.325 |  |  |  | 0.00276 |
|  *2.5.1.2. Accessibility to the rooms of the building* | 0.5 \* 0.05 \* 0.325 |  |  |  | 0.00276 |
|  *2.5.2. Energy consumption by building devices* | 0.9 \* 0.325 |  |  | 0.09945 |  |
|  *2.5.2.1. Heating* | 0.35 \* 0.9 \* 0.325 |  |  |  | 0.03480 |
|  *2.5.2.2. Air-conditioning* | 0.35 \* 0.9 \* 0.325 |  |  |  | 0.03480 |
|  *2.5.2.3. Human technological adequacy* | 0.05 \* 0.9 \* 0.325 |  |  |  | 0.00497 |
|  *2.5.2.4. Ventilation systems* | 0.05 \* 0.9 \* 0.325 |  |  |  | 0.00497 |
|  *2.5.2.5. Lighting* | 0.05 \* 0.9 \* 0.325 |  |  |  | 0.00497 |
|  *2.5.2.6. Home appliances* | 0.1 \* 0.9 \* 0.325 |  |  |  | 0.00994 |
|  *2.5.2.7. Telecommunication systems* | 0.05 \* 0.9 \* 0.325 |  |  |  | 0.00497 |
|  *2.5.3. Energy consumption in building maintenance* | 0.05 \* 0.325 |  |  | 0.00552 |  |
|  *2.5.3.1. Cleaning* | 0.3 \* 0.05 \* 0.325 |  |  |  | 0.00165 |
|  *2.5.3.2. Repairs* | 0.4 \* 0.05 \* 0.325 |  |  |  | 0.00221 |
|  *2.5.3.3. Improvements* | 0.3 \* 0.05 \* 0.325 |  |  |  | 0.00165 |
| *1. 2.6. Bioclimatic architectural design* | 0.458 |  | 0.15572 |  |  |
|  *2.6.1. Location* | 0.025 \* 0.458 |  |  |  | 0.00389 |
|  *2.6.2. Correct N-S orientation* | 0.1 \* 0.458 |  |  |  | 0.01557 |
|  *2.6.3. Appropriate architectural typology*  | 0.3 \* 0.458 |  |  |  | 0.04671 |
|  *2.6.4. Efficacy of sun protections* | 0.1 \* 0.458 |  |  |  | 0.01557 |
|  *2.6.5. Architectural heating systems* | 0.1 \* 0.458 |  |  |  | 0.01557 |
|  *2.6.6. Architectural cooling systems* | 0.1 \* 0.458 |  |  |  | 0.01557 |
|  *2.6.7. Proper thermal inertia of building* | 0.1 \* 0.458 |  |  |  | 0.01557 |
|  *2.6.8. Proper building insulation* | 0.1 \* 0.458 |  |  |  | 0.01557 |
|  *2.6.9. Natural ventilation* | 0.025 \* 0.458 |  |  |  | 0.00389 |
|  *2.6.10. Thermal bridges* | 0.05 \* 0.458 |  |  |  | 0.00778 |
| *1. 2.7. Energy consumption in demolishing/disassembling* | 0.024 |  | 0.00816 |  | 0.00816 |

**Table 12.** Weight of *sub-categories* and *indicators*, within the *“reduction in energy consumption”* category

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* | *Percentage* | *Category**weight* | *Subcat1**weight* | *Subcat2**weight* | *Indicator**weight* |
| ***1. 3. Use of natural energy sources 13%***   |  | 0.13 |  |  |  |
| *2.3.1. Solar energy* | 0.6 |  | 0.078 |  |  |
|  *3.1.1. Thermal solar energy* | 0.7 \* 0.6 |  |  |  | 0.0546 |
|  *3.1.2. Photovoltaic solar energy* | 0.3 \* 0.6 |  |  |  | 0.0234 |
| *1. 3.2. Geothermal energy* | 0.3 |  | 0.039 |  |  |
|  *3.2.1. Geothermal energy without heat pump* | 0.8 \* 0.3 |  |  |  | 0.0312 |
|  *3.2.2. Geothermal energy with heat pump* | 0.2 \* 0.3 |  |  |  | 0.0078 |
| *1. 3.3. Renewable energies for the natural ecosystem* | 0.1 |  | 0.013 |  |  |
|  *3.3.1. Wind power* | 0.3 \* 0.1 |  |  |  | 0.0039 |
|  *3.3.1. River and sea energy* | 0.4 \* 0.1 |  |  |  | 0.0052 |
|  *3.3.1. Energy from underground sources* | 0.3 \* 0.1 |  |  |  | 0.0039 |

**Table 13.** Weight of *sub-categories* and *indicators*, within the *“use of natural energy sources”* category

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* | *Percentage* | *Category**weight* | *Subcat1**weight* | *Subcat2**weight* | *Indicator**weight* |
| ***1. 4. Reduction of waste and emissions 12%***   |  | 0.12 |  |  |  |
| *2.4.1. Waste and emissions generated in obtaining materials* | 0.2 |  | 0.024 |  |  |
|  *4.1.1. Waste* | 0.3 \* 0.2 |  |  |  | 0.0072 |
|  *4.1.2. Emissions* | 0.7 \* 0.2 |  |  |  | 0.0168 |
| *1. 4.2. Waste and emissions generated in manufacturing*  | 0.15 |  | 0.018 |  |  |
|  *4.2.1. Waste* | 0.2 \* 0.15 |  |  |  | 0.0036 |
|  *4.2.2. Emissions* | 0.8 \* 0.15 |  |  |  | 0.0144 |
| *1. 4.3. Waste and emissions generated in transport* | 0.05 |  | 0.006 |  |  |
|  *4.3.1. Waste* | 0.1 \* 0.05 |  |  |  | 0.0006 |
|  *4.3.1. Emissions* | 0.9 \* 0.05 |  |  |  | 0.0054 |
| *1. 4.4. Waste and emissions generated in construction process* | 0.2 |  | 0.024 |  |  |
|  *4.4.1. Waste* | 0.5 \* 0.2 |  |  |  | 0.0120 |
|  *4.3.1. Emissions* | 0.5 \* 0.2 |  |  |  | 0.0120 |
| *1. 4.5. Waste and emissions generated in building maintenance* | 0.2 |  | 0.024 |  |  |
|  *4.4.1. Waste* | 0.3 \* 0.2 |  |  |  | 0.0072 |
|  *4.3.1. Emissions* | 0.7 \* 0.2 |  |  |  | 0.0168 |
| *1. 4.6. Waste and emissions generated in demolition of building* | 0.2 |  | 0.024 |  |  |
|  *4.4.1. Waste* | 0.9 \* 0.2 |  |  |  | 0.0216 |
|  *4.3.1. Emissions* | 0.1 \* 0.2 |  |  |  | 0.0024 |

**Table 14.** Weight of *sub-categories* and *indicators*, within the *“reduction of waste and emissions”* category

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* | *Percentage* | *Category**weight* | *Subcat1**weight* | *Subcat2**weight* | *Indicator**weight* |
| ***1. 5. Health and quality of life of building occupants 8%***   |  | 0.08 |  |  |  |
| *1. 5.1. Harmful emissions to natural ecosystem* | 0.2 |  | 0.0160 |  | 0.0160 |
| *1. 5.2. Harmful emissions to human health* | 0.3 |  | 0.0240 |  | 0.0240 |
| *1. 5.3. Number of illnesses of building occupants* | 0.3 |  | 0.0240 |  | 0.0240 |
| *1. 5.4. Degree of well-being of building occupants* | 0.2 |  | 0.0160 |  | 0.0160 |

**Table 15.** Weight of *sub-categories* and *indicators*, within the *“health and quality of life of building occupants”* category

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* | *Percentage* | *Category**weight* | *Subcat1**weight* | *Subcat2**weight* | *Indicator**weight* |
| ***1. 6. Economic cost 10%***   |  | 0.10 |  |  |  |
| *2.6.1. Direct economic cost in building construction* | 0.4 |  | 0.040 |  | 0.040 |
| *1. 6.2. Indirect economic cost in building construction* | 0.05 |  | 0.005 |  | 0.005 |
| *1. 6.3. Economic cost in maintenance* | 0.2 |  | 0.020 |  |  |
|  *6.3.1. Materials* | 0.1 \* 0.2 |  |  |  | 0.002 |
|  *6.3.1. Labor* | 0.3 \* 0.2 |  |  |  | 0.006 |
|  *6.3.1. Technological devices* | 0.3 \* 0.2 |  |  |  | 0.006 |
|  *6.3.1. Cleaning* | 0.3 \* 0.2 |  |  |  | 0.006 |
| *1. 6.4. Cost of emissions and waste management* | 0.1 |  | 0.010 |  | 0.010 |
| *1. 6.5. Cost of treating diseases and illnesses* | 0.05 |  | 0.005 |  | 0.005 |
| *1. 6.6. Economic revaluation of the building* | 0.05 |  | 0.005 |  | 0.005 |
| *1. 6.7. Economic revaluation of the environment* | 0.05 |  | 0.005 |  | 0.005 |
| *1. 6.8. Construction speed* | 0.05 |  | 0.005 |  | 0.005 |
| *1. 6.9. Cost of demolishing/disassembling* | 0.05 |  | 0.005 |  | 0.005 |

**Table 16.** Weight of *sub-categories* and *indicators*, within the *“economic cost”* category

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* | *Percentage* | *Category**weight* | *Subcat1**weight* | *Subcat2**weight* | *Indicator**weight* |
| ***1. 7. Social adequacy 3%***   |  | 0.03 |  |  |  |
| *2.7.1. Local level of economic development* | 0.2 |  | 0.006 |  | 0.006 |
| *1. 7.2. Local technological level* | 0.2 |  | 0.006 |  | 0.006 |
| *1. 7.3. Local quality preferences* | 0.1 |  | 0.003 |  | 0.003 |
| *1. 7.4. Local design preferences* | 0.2 |  | 0.006 |  | 0.006 |
| *1. 7.5. Local preferences in construction systems* | 0.2 |  | 0.006 |  | 0.006 |
| *1. 7.6. Local type of family unit* | 0.1 |  | 0.003 |  | 0.003 |

**Table 17.** Weight of *sub-categories* and *indicators*, within the *“social adequacy”* category

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* | *Percentage* | *Category**weight* | *Subcat1**weight* | *Subcat2**weight* | *Indicator**weight* |
| ***1. 8. Complementary sustainable aspects 2%***   |  | 0.02 |  |  |  |
| *2.8.1. Adaptability to change and flexibility of the building* | 0.3 |  | 0.006 |  | 0.006 |
| *1. 8.2. Social aesthetic appeal of building* | 0.3 |  | 0.006 |  | 0.006 |
| *1. 8.3. Ecological regeneration of environment* | 0.4 |  | 0.008 |  | 0.008 |

**Table 17.** Weight of *sub-categories* and *indicators*, within the *“complementary sustainable aspects”* category

**6. Description of the CEDES operation process**

To illustrate the CEDES evaluation process a house, the *Casa Mariposa*, which was built in 2010 in Cali (Colombia) was evaluated (Fig. 5). The house is bioclimatic and provides a comfortable internal temperature without the need for heating, air conditioning or ventilation, so that its energy consumption is very low. The house is self-sufficient in water and energy at a very low price due to its low energy requirement. The house was been built by a normal construction company and hardly any waste was generated in its construction so that a final score will be very high. However, this fact is secondary since this house was chosen solely to illustrate the CEDES evaluation process.

****

**Figure 5.** Mariposa Eco-House

Eight tables were created to carry out the evaluation (Tables 19, 20, 21, 22, 23, 24, 25, 26) corresponding to the 8 CEDES categories. Each table contains a column with the name of the category, subcategories 1, subcategories 2, and indicators; a column with the score that can be given to each indicator (from 0 to 5), a column with the general weight of each indicator, and a column with the partial score of the indicators. At the end of each table, the total score provided by each category is shown.

By adding the scores provided by each of the 8 categories, the final score of the dwelling is obtained, on a scale of 0 to 5. Multiplying by 2, the final score of the dwelling is obtained, on a scale of 0 to 10 (Table 27).

The total score obtained, 8.04918, is very high, since it is extremely difficult to achieve a score higher than 8. By looking at the scores in each table, it is easy to deduce the actions needed to further increase the score of the Mariposa house: use more natural materials, design the house so that it can be dismantled, and thus allow for future reuse of components, use waste and materials previously used in construction, and increase the flexibility of uses and spaces in the house. The usefulness of CEDES as a guide in the design process can now be clearly appreciated.

|  |  |  |  |
| --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* |  *Score* *0 - 5* | *Indicator**weight* |  *Final Score* |
| ***1. 1. Optimization of resources*** ***18%***  |  |  |  |
| *1. 1.1. Use of natural resources*  |  |  |  |
|  *1.1.1. Water*  |  |  |  |
|  *1.1.1.1. Rain water* | 5 | 0.00432 | 0.02160 |
|  *1.1.1.2. Groundwater* | 5 | 0.00288 | 0.01440 |
|  *1.1.2. Vegetation* |  |  |  |
|  *1.1.2.1. Wild vegetation* | 5 | 0.00135 | 0.00675 |
|  *1.1.2.2. Unprocessed wood* | 1 | 0.00180 | 0.00180 |
|  *1.1.2.3. Vegetable waste* | 5 | 0.00135 | 0.00675 |
|  *1.1.3. Soil* |  |  |  |
|  *1.1.3.1. Not elaborated stones* | 2 | 0.00225 | 0.00450 |
|  *1.1.3.2. Soil* | 5 | 0.00225 | 0.01125 |
|  *1.1.4. Choice of site* |  |  |  |
|  *1.1.4.1. Use of not arable land* | 5 | 0.00054 | 0.00270 |
|  *1.1.4.2. Accessibility* | 4 | 0.00054 | 0.00216 |
|  *1.1.4.3. Positive impact on the place* | 5 | 0.00072 | 0.00360 |
| *1. 1.2. Resource optimization* |  |  |  |
|  *1.2.1. Amount of resources needed* |  |  |  |
|  *1.2.1.1. Resources needed in construction* | 5 | 0.00388 | 0.01940 |
|  *1.2.1.2. Resources needed throughout the lifecycle of building* | 5 | 0.00259 | 0.01295 |
|  *1.2.1.3. Resources needed for building maintenance* | 5 | 0.00129 | 0.00645 |
|  *1.2.1.4. Abundance of resources for component manufacturing*  | 5 | 0.00518 | 0.02590 |
|  *1.2.2. Durability level of components and materials*  | 5 | 0.02916 | 0.14580 |
|  *1.2.3. Waste utilization level* | 1 | 0.01620 | 0.01620 |
|  *1.2.4. Reusability of components* |  |  |  |
|  *1.2.4.1. Use of previously used components* | 1 | 0.00550 | 0.00550 |
|  *1.2.4.2. Component reparability level* | 4 | 0.01101 | 0.04404 |
|  *1.2.4.3. Component reusability level*  | 2 | 0.01101 | 0.02202 |
|  *1.2.4.4. Disassembly level. Reconfigurability and expandability* | 1 | 0.02754 | 0.02754 |
|  *1.2.5. Component recycling* |  |  |  |
|  *1.2.5.1. Use of recycled components* | 2 | 0.00162 | 0.00324 |
|  *1.2.5.2. Use of recycled grey water* | 5 | 0.00162 | 0.00810 |
|  *1.2.5.3. Component recycling level* | 3 | 0.00324 | 0.00972 |
|  *1.2.6. Level of exploitation of resources* |  |  |  |
|  *1.2.6.1. Refined design* | 4 | 0.02700 | 0.10800 |
|  *1.2.6.2. Industrialization level* | 4 | 0.01800 | 0.07200 |
|  *1.2.7. Functional durability of components* | 5 | 0.01080 | 0.05400 |
|  *1.2.8. Functional adaptation of components* | 5 | 0.00720 | 0.03600 |
| Total | 0.67131 |

**Table 19.** Scoring process using indicators of *“optimization of resources” category*

|  |  |  |  |
| --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* |  *Score* *0 - 5* | *Indicator**weight* |  *Final Score* |
| ***1. 2. Reduction in energy consumption 34%***   |  |  |  |
| *1. 2.1. Energy consumption in obtaining materials*  | 5 | 0.01462 | 0.07310 |
| *2.2.2. Energy consumption in transportation of materials/components* | 5 | 0.00748 | 0.03740 |
| *2.2.3. Energy consumption in transportation of labor* | 5 | 0.00442 | 0.02210 |
| *2.2.4. Energy consumption in building construction process* | 5 | 0.03910 | 0.19550 |
| *2.2.5. Energy consumption by building throughout its lifecycle* |  |  |  |
|  *2.5.1. Energy consumption in building accessibility* |  |  |  |
|  *2.5.1.1. Accessibility to the area* | 4 | 0.00276 | 0.01104 |
|  *2.5.1.2. Accessibility to the rooms of the building* | 5 | 0.00276 | 0.01380 |
|  *2.5.2. Energy consumption by building devices* |  |  |  |
|  *2.5.2.1. Heating* | 5 | 0.03480 | 0.17400 |
|  *2.5.2.2. Air-conditioning* | 5 | 0.03480 | 0.17400 |
|  *2.5.2.3. Human technological adequacy* | 5 | 0.00497 | 0.02485 |
|  *2.5.2.4. Ventilation systems* | 5 | 0.00497 | 0.02485 |
|  *2.5.2.5. Lighting* | 5 | 0.00497 | 0.02485 |
|  *2.5.2.6. Home appliances* | 5 | 0.00994 | 0.04970 |
|  *2.5.2.7. Telecommunication systems* | 5 | 0.00497 | 0.02485 |
|  *2.5.3. Energy consumption in building maintenance* |  |  |  |
|  *2.5.3.1. Cleaning* | 5 | 0.00165 | 0.00825 |
|  *2.5.3.2. Repairs* | 5 | 0.00221 | 0.01105 |
|  *2.5.3.3. Improvements* | 5 | 0.00165 | 0.00825 |
| *1. 2.6. Bioclimatic architectural design*  |  |  |  |
|  *2.6.1. Location* | 4 | 0.00389 | 0.01556 |
|  *2.6.2. Correct N-S orientation* | 5 | 0.01557 | 0.07785 |
|  *2.6.3. Appropriate architectural typology*  | 5 | 0.04671 | 0.23355 |
|  *2.6.4. Efficacy of sun protections* | 5 | 0.01557 | 0.07785 |
|  *2.6.5. Architectural heating systems* | 5 | 0.01557 | 0.07785 |
|  *2.6.6. Architectural cooling systems* | 5 | 0.01557 | 0.07785 |
|  *2.6.7. Proper thermal inertia of building* | 5 | 0.01557 | 0.07785 |
|  *2.6.8. Proper building insulation* | 5 | 0.01557 | 0.07785 |
|  *2.6.9. Natural ventilation* | 5 | 0.00389 | 0.01945 |
|  *2.6.10. Thermal bridges* | 5 | 0.00778 | 0.03890 |
| *1. 2.7. Energy consumption in demolishing/disassembling* | 3 | 0.00816 | 0.02448 |
| Total | 1.27068 |

**Table 20.** Scoring process using indicators of *“reduction in energy consumption”* category

|  |  |  |  |
| --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* |  *Score* *0 - 5* | *Indicator**weight* |  *Final Score* |
| ***1. 3. Use of natural energy sources 13%***   |  |  |  |
| *2.3.1. Solar energy* |  |  |  |
|  *3.1.1. Thermal solar energy* | 5 | 0.0546 | 0.32700 |
|  *3.1.2. Photovoltaic solar energy* | 3 | 0.0234 | 0.07020 |
| *1. 3.2. Geothermal energy* |  |  |  |
|  *3.2.1. Geothermal energy without heat pump* | 5 | 0.0312 | 0.15600 |
|  *3.2.2. Geothermal energy with heat pump* | 0 | 0.0078 | 0 |
| *1. 3.3. Renewable energies for the natural ecosystem* |  |  |  |
|  *3.3.1. Wind power* | 0 | 0.0039 | 0 |
|  *3.3.1. River and sea energy* | 0 | 0.0052 | 0 |
|  *3.3.1. Energy from underground sources* | 0 | 0.0039 | 0 |
| Total | 0.55320 |

**Table 21.** Scoring process using indicators of *“use of natural energy sources”* category

|  |  |  |  |
| --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* |  *Score* *0 - 5* | *Indicator**weight* |  *Final Score* |
| ***1. 4. Reduction of waste and emissions 12%***   |  |  |  |
| *2.4.1. Waste and emissions generated in obtaining materials* |  |  |  |
|  *4.1.1. Waste* | 4 | 0.0072 | 0.02880 |
|  *4.1.2. Emissions* | 4 | 0.0168 | 0.06720 |
| *1. 4.2. Waste and emissions generated in manufacturing*  |  |  |  |
|  *4.2.1. Waste* | 5 | 0.0036 | 0.01800 |
|  *4.2.2. Emissions* | 5 | 0.0144 | 0.07400 |
| *1. 4.3. Waste and emissions generated in transport* |  |  |  |
|  *4.3.1. Waste* | 5 | 0.0006 | 0.00300 |
|  *4.3.1. Emissions* | 5 | 0.0054 | 0.02700 |
| *1. 4.4. Waste and emissions generated in construction process* |  |  |  |
|  *4.4.1. Waste* | 5 | 0.0120 | 0.06000 |
|  *4.3.1. Emissions* | 5 | 0.0120 | 0.06000 |
| *1. 4.5. Waste and emissions generated in building maintenance* |  |  |  |
|  *4.4.1. Waste* | 5 | 0.0072 | 0.03600 |
|  *4.3.1. Emissions* | 5 | 0.0168 | 0.08400 |
| *1. 4.6. Waste and emissions generated in demolition of building* |  |  |  |
|  *4.4.1. Waste* | 3 | 0.0216 | 0.06480 |
|  *4.3.1. Emissions* | 4 | 0.0024 | 0.00960 |
| Total | 0.53240 |

**Table 22.** Scoring process using indicators of *“reduction of waste and emissions”* category

|  |  |  |  |
| --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* |  *Score* *0 - 5* | *Indicator**weight* |  *Final Score* |
| ***1. 5. Health and quality of life of building occupants 8%***   |  |  |  |
| *1. 5.1. Harmful emissions to natural ecosystem* | 5 | 0.016 | 0.08000 |
| *1. 5.2. Harmful emissions to human health* | 5 | 0.024 | 0.12000 |
| *1. 5.3. Number of illnesses of building occupants* | 5 | 0.024 | 0.12000 |
| *1. 5.4. Degree of well-being of building occupants* | 5 | 0.016 | 0.08000 |
| Total | 0.40000 |

**Table 23.** Scoring process using indicators of *“health and quality of life of building occupants”* category

|  |  |  |  |
| --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* |  *Score* *0 - 5* | *Indicator**weight* |  *Final Score* |
| ***1. 6. Economic cost 10%***   |  |  |  |
| *2.6.1. Direct economic cost in building construction* | 4 | 0.040 | 0.16000 |
| *1. 6.2. Indirect economic cost in building construction* | 5 | 0.005 | 0.02000 |
| *1. 6.3. Economic cost in maintenance* |  |  |  |
|  *6.3.1. Materials* | 5 | 0.002 | 0.01000 |
|  *6.3.1. Labor* | 5 | 0.006 | 0.03000 |
|  *6.3.1. Technological devices* | 5 | 0.006 | 0.03000 |
|  *6.3.1. Cleaning* | 5 | 0.006 | 0.03000 |
| *1. 6.4. Cost of emissions and waste management* |  |  |  |
| *1. 6.5. Cost of treating diseases and illnesses* | 5 | 0.005 | 0.02500 |
| *1. 6.6. Economic revaluation of the building* | 5 | 0.005 | 0.02500 |
| *1. 6.7. Economic revaluation of the environment* | 5 | 0.005 | 0.02500 |
| *1. 6.8. Construction speed* | 4 | 0.005 | 0.02000 |
| *1. 6.9. Cost of demolishing/disassembling* | 4 | 0.005 | 0.02000 |
| Total | 0.39500 |

**Table 24.** Scoring process using indicators of *“economic cost”* category

|  |  |  |  |
| --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* |  *Score* *0 - 5* | *Indicator**weight* |  *Final Score* |
| ***1. 7. Social adequacy 3%***   |  |  |  |
| *2.7.1. Local level of economic development* | 5 | 0.0060 | 0.03000 |
| *1. 7.2. Local technological level* | 3 | 0.0060 | 0.01800 |
| *1. 7.3. Local quality preferences* | 4 | 0.0030 | 0.01200 |
| *1. 7.4. Local design preferences* | 5 | 0.0060 | 0.03000 |
| *1. 7.5. Local preferences in construction systems* | 3 | 0.0060 | 0.01800 |
| *1. 7.6. Local type of family unit* | 4 | 0.0030 | 0.01200 |
| Total | 0.12000 |

**Table 25.** Scoring process using indicators of *“social adequacy”* category

|  |  |  |  |
| --- | --- | --- | --- |
|  *Name of the Category, Subcategory 1, Subcategory 2 and Indicator* |  *Score* *0 - 5* | *Indicator**weight* |  *Final Score* |
| ***1. 8. Complementary sustainable aspects 2%***   |  |  |  |
| *2.8.1. Adaptability to change and flexibility of the building* | 2 | 0.006 | 0.01200 |
| *1. 8.2. Social aesthetic appeal of building* | 5 | 0.006 | 0.03000 |
| *1. 8.3. Ecological regeneration of environment* | 5 | 0.008 | 0.04000 |
| Total | 0.08200 |

**Table 26.** Scoring process using indicators of *“complementary sustainable aspects”* category

|  |  |
| --- | --- |
| *Category* | *score* |
| *1. Optimization of resources* | 0.67131 |
| *2. Reduction of energy consumption* | 1.27068 |
| *3. Use of natural energy sources* | 0.55320 |
| *4. Reduction of waste and emissions* | 0.53240 |
| *5. Increase in the quality of life of the occupants* | 0.40000 |
| *6. Reduction in economic cost* | 0.39500 |
| *7. Social adequacy* | 0.12000 |
| *8. Others* | 0.08200 |
| **Total (0 - 5)** | 4.02459 |
| **Total (0 - 10)** | 8.04918 |

**Table 27.** Overall score using CEDES

**7. Results**

*- Use of CEDES as evaluation tool*

The CEDES aevaluation tool is simple to operate. Each *indicator* must be scored with numbers from 0 to 5, then this value must be multiplied by its specific weight and finally the resulting values must be added.

In this way, a total value can be obtained that shows the building’s ecological and sustainable level. A partial value per *category* can be obtained, which shows the goodness of a building in that *category*. Finally, the values ​​of each *indicator* can also be obtained, which shows the possible environmental deficiencies of a building in the different environmental aspects.

With these results, the most effective and economical actions that can be taken to improve the ecological and sustainable level of a building can be determined.

*- Using CEDES as design tool*

CEDES serves especially as a tool for the building design process and can be used in each of the design stages. The CEDES *indicators* are well defined and structured without ambiguities and without overlaps, so that they can be associated with the most appropriate, economical and effective set of actions at each stage of the design process.

The different *indicators* must first be classified according to their specific weight, and then a specific list of possible actions associated with each *indicator* must be made. These actions must be classified according to their environmental effectiveness and economic cost (*inverted pyramid model*). When perfectly integrated into the general design process, the actions must be executed in order from the most effective and economical actions to the least effective and most expensive actions.

This strategy is valid for all stages of the design process, from the first sketches through the development of the general project to determine all the construction details.

**8. Discussion**

The current GBRS are under suspicion, and as indicated, they have many flaws and their usefulness is questioned. To make matters worse, the current GBRS are very different from each other, so that each one would give a different score to the same building. They all have a different internal structure and different assessment mechanisms. They all have different categories and a different number of indicators with a different specific weight. This raises the suspicion that sustainable assessment is subject to too many local interpretations based on economic and political interests and therefore it is possible that none of the current GBRS are adequate. The term "sustainable construction" should thus be defined in detail and given a common taxonomic structure to design more adequate, effective and legitimate GBRS, capable of rigorous evaluationa.

This paper describes the basic structure of the new CEDES GBRS, which solves these problems and also serves as a guide to the design process. Its internal structure is very clear, but of course it is subject to revisions and improvements, based on future studies. Studies should be carried out to determine the relative importance of each *category*, and especially the weight of the different *indicators*. Our idea is to compile many more studies that can be carried out in this regard and to improve the system gradually based on their results. However, we believe that CEDES is an important contribution, since it is a much more complete and seamless system, which resolves the current criticisms of the GBRS, is easy to use and, above all, is a simple tool capable of guiding the sustainable design process.

**9. Conclusions**

In this work, a new GBRS is described that we consider to be free of the defects and limitations of the current GBRS, which are widely different from each other, are incomplete, do not consider the importance of architectural design, have a complex operation and questionable specific weights of their *indicators*. It is therefore necessary to design a new framework that can serve as a common reference point to design new GBRS in the future.

For this reason, CEDES was designed based on a taxonomic structure of 8 *categories* and 106 *indicators*. It is an easy-to-use system which facilitates the complete initial evaluation and allows the execution of all types of innovative and varied actions with the aim of increasing the sustainable level of any building. And above all, CEDES is a system for designing buildings, from the initial idea to the execution of the final project in every detail.

With the proposed *categories* and *indicators* the total spectrum of the LCA of all the different parameters of the construction process of a building is swept, so that no aspect is left unevaluated. In addition, a specific weight relative to each *indicator* has been assigned based on the evaluation carried out by the rest of the *indicators*, and based on studies carried out on the environmental impact of all aspects of the construction process, and especially with respect to the comparative energy consumption of all aspects of the building construction process. The score that can be assigned to each *indicator* in the evaluation process of a given building is extraordinarily simple (an integer from 0 to 5) so that anyone can carry out the evaluation. Each *indicator* evaluates the sustainable level of a certain aspect of the building, and is associated with a set of actions that could be executed to increase the sustainable level in the said aspect. These actions must be adapted to a given building, in a given environment. Once identified, they must be classified in order of maximum environmental effectiveness and minimum economic cost.

Thus, CEDES serves especially as a perfect guide that can be easily integrated into the usual design process of engineers and architects with the aim of achieving buildings with the highest ecological and sustainable level possible. In this way, as it always should have been, the evaluation process would become a simple process of free administrative verification.

**Data Availability Statement (DAS)**

The data that support the findings of this study are available from the corresponding autor (De Garrido, Luis), upon reasonable request.

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**Highlights**

- Taxonomic framework for designing better GBRS

- ASGB, BEAM, BREEAM, CASBEE, DNGB, GBI, GG, GM, GS, HQE, IGBC, LEED, LEVEL's, Minergie, PassivHaus, SBTools

- New GBRS more complete, legitimate and adequate

- Desing of better Green Building Rating Systems

- Improving Green Building Rating Systems

- New GBRS as a guide to sustainable building design