# Development of a Sustainability Assessment Tool for office buildings

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ABSTRACT:

The few available sustainability assessment tools applicable in Portugal are oriented for residential buildings. Nevertheless, the impacts of office buildings have been rising mainly due to an increase in the energy consumption for cooling and heating. This way, due to the growing environmental impact of office buildings, the development of Building Sustainability Assessment (BSA) tools to assess the sustainability of this type of buildings is necessary and important to guide and to boost the construction sector towards sustainable development.

The main objective of this work was to develop a sustainability assessment tool aimed at office buildings based in SBTool$^{PT}$-H and was performed using the experience acquired in Master in Sustainable Construction and Rehabilitation (MCRS), in University of Minho.

The work includes the definition of the tool's framework and assessment method, as well as Portuguese benchmarks and weighting system used in the aggregation. In order to promote the practical use of this tool, an evaluation guide was also developed in which there are detailed information about calculation methods and aggregation models. The methodology presented in this paper is based on a list of indicators that are assessed by comparison with Portuguese reference practices (benchmarks).

## 1 INTRODUCTION

Our planet has been suffering profound changes in the last 60 years. The stable conditions that were verified for millions of years ended mainly due to human activities. Mankind, that is estimated to exist for 200.000 years, managed to live in harmony with the planet throughout history, but in the very short time of two generations, is causing impacts on the planet that can lead our specie to ruin, as well as most biodiversity. These problems result essentially by the interaction of tree main factors: increase in world population, resources consumption and pollutant emissions (to air, soil and water).

One of the sectors that most affects the planet is the buildings sector because during their life-cycle, buildings are responsible for the consumption of a huge amount of resources and energy, as well by the production of waste. At the same time, they are associated to great social and economic impacts (Mateus, 2009). For this reason there were several approaches in the last 2 decades to minimize buildings impact. One way to minimize buildings impact is to adopt the concept of sustainable construction (Kibert, 1994). In the last decade some sustainability assessment tools emerged allowing the assessment and rating of the building's sustainability across the three dimensions of Sustainable Development: environment, society and economy. The Portuguese chapter of the International Initiative for a Sustainable Built Environment (iiSBE Portugal) developed a methodology adapted to the Portuguese context based on the international SBTool to assess sustainability performance of residential buildings called SBTool$^{PT}$-H, Nevertheless, to increase the sustainability of construction sector there is the need to develop appropriate methodologies for other types of buildings to increase the sector's sustainability, such as office, retail, educational, hospitals and industrial buildings.

The use of sustainability assessment tools in office buildings can work as a positive impulse for these methodologies. Reasoning for this is that often the contractors and owners of residential buildings have some reluctance in applying sustainability features or in assessing the sustainability of their buildings, since they do not expect direct economic benefits. In that case, those who benefit from lower monthly expenses and higher comfort levels are the future end-users (occupants) of the buildings. At the level of environmental performance the situation is even worst because building stakeholders are not prepared to understand the environmental consequences and/or benefits of sustainable buildings. In the case of many office buildings, both private and public, in addition to the fact that the lower operation costs are cost savings or profits for the companies, there is also an indirect gain in improving their image of corporate social responsibility (Social Investment Forum, 2010). Consequently, the emergence of sustainability assessment tools applicable to office buildings will have certainly good acceptance by these companies/entities as they will intend to assess their buildings with high scores and thus to build/retrofit in a more sustainable way. In the future, the stakeholders' higher awareness in this field will boost and expand the use of these tools, even for other types of buildings, including residential, as they become more and more common.

## 2 STATE OF THE ART

### 2.1 *Sustainability in today's society*

The world population has been increasing exponentially in the last decades. To better understand the rapid population growth, world population reached one billion people by the year 1804, increased to 2 billion in 1927, three billion in 1960, 4 billion in 1974, 5 billion in 1987 and finally reached 6 billion in 1999. The world population in 2010 has reached 6.850 billion people and is expected to reach the 8 billion in 2028 (UN, 2010). This major increase in world population combined with the lifestyle of developed countries that is now beginning to be adopted by developing countries, is causing a great demand for the natural resources, being a major cause of the global crisis that mankind is experiencing nowadays. If the entire world's population lived under the European lifestyle, it would be necessary two and a half planets to supply resources for the entire population (EU, 2009).

Global warming results from the increase on emissions of greenhouse gases to the atmosphere and is a major cause of the environmental problems that humanity is currently experiencing. The main greenhouse gases are derived mainly from burning fossil fuels to produce energy. This phenomenon has caused severe consequences for the world's population, as increasing the average level of the sea, climate changes, biodiversity loss, and desertification, among others. For example, 12 of the 13 warmest years ever have occurred since 1995. In 2005, the average global temperature was 0.76 degrees Celsius above the average temperature of the pre-industrial era and it is expected that by the end of this century the temperature will increase 1.8 to 4 ºC. To understand the importance of preventing such a steady increase in temperature, there are considerable scientific evidences showing that there is a risk of irreversible climate change and possibly catastrophic consequences, such as melting ice at the poles and corresponding rise in water level of the sea, if the temperature rises 2 degrees Celsius above the temperature of the pre-industrial era, i.e. about 1.2 °C above the current temperature (EU, 2009).

Energy is consequently one of the most important factors in the quest for sustainable development. That is because the increase in energy consumption is a major factor leading to global warming. Energy consumption is the main responsible for emissions of greenhouse gases in the European Union (EC, 2006). Thus, the efficient use of energy is certainly one of the most important ways to minimize the environmental problems; however, the demand for energy is increasing worldwide. The International Energy Agency predicts that the global energy demand will increase by more than 50% by 2030 if policies remain unchanged and more than 60% of this increase respects to developing countries. This will cause a 52% increase in emissions of carbon dioxide (CO2) (Nelson, 2010).

Protecting biodiversity is also seen as an important factor enabling the fight against the greenhouse effect, since only with a rich biodiversity is possible through the photosynthesis of plants to provide an important natural mechanism for storing huge amounts of carbon. If the rhythm of species extinction continues, factors such as the pollination of plants and other complex factors are severely compromised threatening the future of the major consumer of atmospheric carbon (EC, 2005).

According to the European Environment Agency, in 2005 Europe produced 1300 million tons of waste, equivalent to 3.5 tons of waste per capita from which 518 kg of municipal solid waste (MSW) per capita. According to data from the Portuguese Environmental Agency the same year, Portugal produced 4.5 million tons of MSW, the equivalent of 450 kg of MSW per capita (Lipor, 2009).

Water is also one of the essential elements for life on the planet. It is an invaluable resource for the continuity of human life, not only for drinking, but it is also essential for the production of other food resources. In fact, it takes a lot more water to produce food than for direct consumption. The needs of drinking water per person per day are 2 to 4 litres, but it is needed 2000 to 5000 litres of water daily to produce the food needed for one person (UN-Water, 2010).

## 2.2 *Sustainability in construction*

The construction sector is responsible for worldwide consumption of about 40% of materials and 55% of the wood extracted (Gaspar, 2009). Represents 40% of final energy consumption in Europe (Directive 31/2001/EU) and about 35% of emissions of greenhouse gases (Nelson, 2010). When it comes to waste, construction activities generate about 22% of all waste generated in Europe (APA, 2010). These values are decreasing resulting from the nowadays economic crisis, but are still a major importance sector concerning to environment protection.

According to the Portuguese Energy Balance of 2005, the buildings were responsible for the consumption of 5.8 Mtoe (million tons oil equivalent), representing about 30%

of total primary energy consumption in the country and 62% of electricity consumption (Isolani, 2008). However, over 50% of this consumption can be reduced through energy efficiency measures (ADENE, 2009). For this reason, over the last decades a number of directives and laws at European and national levels were emerged to promote both the reduction of energy consumption and the increase in share of renewable energies.

The economy and social impact of the sector is also enormous. The sector is equivalent to almost 10% of GDP at the European level, directly employs 12 million EU citizens and about 26 million workers are indirectly dependent on this sector (EP, 2010).

The building sector (residential & SME) produces also 17% of emissions of greenhouse gases. However, as mentioned above in the building sector accounts for 40% of energy consumption. Thus, 40% of emissions in the energy sector are also related to the buildings, resulting in a total emission corresponding to this sector of approximately 28% (EU, 2009).

In 2002, the office buildings sector accounted for about 15% of the final energy consumption in Europe and 12% of final energy consumption in Portugal (Pires, 2005). Nevertheless, this sector’s growth rate in energy consumption is nowadays about 12% (Decree Law 79/2006), which is much higher than the values predicted in 2002. This sector, along with the residential sector is among those who have the greatest potential for energy savings in Europe. The potential energy savings in office buildings is about 30% (EC, 2007).

### 2.3 *Building Sustainability Assessment tools*

Several tools exist all over the world that can be used to assess the sustainability of buildings. A sustainability assessment of a building must take into consideration the political, cultural, social and economic aspects of the site where it is applied. Hence, given the subjectivity inherent in assessing sustainability, none of these methods is widely accepted (Mateus, 2009).

The first environmental assessment method for buildings was BREEAM. It was developed by researchers in the UK's BRE and the private sector in 1988. It is estimated that over 30% of buildings in the UK are assessed by this method. LEED is an American rating system that was established in 1996 and is managed by U.S. Green Building Council. The expansion of this system to the outside of the United States is notorious as this system is being used in many countries around the world. HQE is a French association founded in 1996 that brings together professionals in the construction sector. The label replaces the HPE HQE - Haute Performance énergétique existed since early 1990. The SBTool is a rating system for sustainable construction developed through the participation of more than 20 countries since 1996. This tool was prepared for the first Green Building Challenge in 1998 and was organized by the International Initiative for a Sustainable Built Environment (iiSBE), aiming to create a system from which it was possible to assess the environmental performance of buildings internationally. CASBEE is a Japanese system of environmental assessment of buildings presented in 2002. DGNB is a German environmental assessment tool that was developed by the German Sustainable Building Council and released in 2009 to be used for planning and evaluation of buildings.

Such tools are increasingly emerging as an important solution to decrease the impacts of the construction sector, that so far only have substantial advances related to energy regulation. Sustainability assessment of buildings is based in several themes of larger importance than considering only energy consumption. A sustainable building is based also in other environmental categories such as global warming, climate change, biodiversity, water, materials and wastes, and well as in social and economic aspects.

## 3 DEVELOPMENT OF THE ASSESSMENT TOOL

### 3.1 *Main overall updates*

Parallel to the methodology SBTool$^{PT}$-H, the SBTool$^{PT}$-S uses the Diaz-Baltero equation (1) to normalize the valued of each indicator, by comparison between the building's performance with Portuguese benchmarks.

$$\overline{P_i}=\frac{P_i-P_{i*}}{P_i^*-P_{i*}} \qquad (1)$$

In this equation, $P_i$ is the value of $i^{th}$ parameter. $P_i^*$ and $P_{i*}$ are the best and worst values of the $i^{th}$ parameter. The best value of a parameter represents the best practice and the worst value represents the standard practice or the minimum legal requirement.

The normalized level of performance of the building at the level of each indicator allows the determination of the performance level of the building in several categories, dimensions, and finally the global performance, through the use of a weighting system. Since this methodology is actually a comparison between the building and the national reference practices, it can be said that it is a relative sustainability assessment sustained on the three sustainability dimensions: environment, society and economy. Each of these dimensions is subdivided into categories which in turn are subdivided into indicators. In the methodology SBTool$^{PT}$-H, there are nine categories that are subdivided into 24 indicators and 25 parameters (Table 1). Detailed information about the framework and methods of the SBTool$^{PT}$-H assessment module can be found in Mateus and Bragança (2011).

The development of SBTool$^{PT}$-S was divided in four phases. Initially, some considerations are listed and general updates that covers the entire evaluation methodology. In the next phase SBTool$^{PT}$-H was analysed, examining the assessment methods of the various parameters in order to verify the compatibility and applicability of these methods for office buildings, since they were prepared for residential buildings. In this stage it was also decided whether new indicators are needed to address specifications of office buildings that are not covered in the methodology SBTool$^{PT}$-H.

In a third phase the need of making adjustments to the weights of indicators, categories and dimensions were evaluated. This step had particularly importance because there were changes made in both the number of indicators and in the structure of the methodology. Finally, an assessment guide was developed, detailing the assessment methods, which allow a qualified expert to perform a building sustainability assessment more quickly and effectively.

There were also introduced some new features, such as a simplification in the structure based on the elimination of the previous level parameters, structuring the methodology only in dimensions, categories and indicators. This changes due to the fact that in the previous structure, parameters added relatively little information regarding the names of indicators and categories. The indicator names were also simplified, once they often contained too much information, resulting in names too detailed and extensive. Simpler and clearer names were chosen, which can facilitate the understanding and dissemination of the tool.

The applicability of the indicators had also suffered some changes. In SBTool$^{PT}$-H, applicability field in the assessment guide is repetitive mentioning that the methodology applies to new buildings and rehabilitation works or extension, differing only in some indicators. In the indicators that had specifications on the type of buildings, they were listed at the end of the calculation method. In order to do not create redundant information, it was defined for SBTool$^{PT}$-S a fixed applicability in terms of building type, type of construction and phases of work. Thus, all indicators apply to office buildings, new and rehabilitation or expansion operations and in the stage of preliminary design, design, construction and use phases. These types of works and the different stages are the same as those used in the global methodology SBTool (iiSBE, 2010).

Table. 1 List Structure of SBTool$^{PT}$-H

| Dimension | Category | Indicator | Parameter |
|---|---|---|---|
| Environmental | C1 Climate change and outdoor air quality | Environmental impact associated to buildings life cycle | P1 Aggregate value of environmental impacts throughout the life cycle per m2 of floor area of pavement |
|  | C2 Biodiversity and land use | Urban Density | P2 Used percentage of available net area index<br>P3 Waterproofing index |
|  |  | Reuse of pre-contaminated or pre-built soil | P4 Percentage of used land area previously contaminated or built |
|  |  | Use of native plants | P5 Percentage of green areas occupied by native plants |
|  |  | Heat island effect | P6 Percentage of horizontal area with reflectance equal or bigger than 60% |
|  | C3 Energy | Non renewable primary energy | P7 Non renewable primary energy consumption in operation phase |
|  |  | Locally produced energy from renewable sources | P8 Amount of energy that is produced in the building from renewable sources |
|  | C4 Materials and solid waste | Reuse of materials | P9 Percentage on cost of reused materials |
|  |  | Use of recycled materials | P10 Percentage by weight of building’s recycled content |
|  |  | Use of certified materials | P11 Percentage in cost of certified organic products |
|  |  | Use of cement substitutes on concrete | P12 Percentage in mass of cement replacement materials in concrete |
|  |  | Storage conditions of solid wastes during use phase | P13 Potential of building conditions for promote separation of solid waste |
|  | C5 Water | Water consumption | P14 Annual volume of water consumed per capita inside the building |
|  |  | Reuse of non potable water | P15 Percentage of reduction in the consumption of drinking water |
| Social | C6 comfort and health of users | Efficiency of natural ventilation in interior spaces | P16 Potential for natural ventilation |
|  |  | Toxicity of finishing materials | P17 Percentage by weight of finish materials with low VOC content |
|  |  | Thermal comfort | P18 Average annual thermal comfort level |
|  |  | Visual comfort | P19 Average daylight factor |
|  |  | Acoustic comfort | P20 Average level of sound insulation |
|  | C7 Accessibility | Accessibility to public transport | P21 Index of accessibility to public transport |
|  |  | Accessibility to amenities | P22 Index of accessibility to amenities |
|  | C8 awareness and education for sustainability | Formation of occupants | P23 Availability of the building's owners manual |
| Economic | C9 Life cycle costs | Initial costs | P24 Net Present value of initial investment costs per $m^2$ of net area |
|  |  | Operation costs | P25 Net Present value of operation costs per $m^2$ of net area |

### 3.2 *Updates in calculation methods of indicators*

This chapter presents the adjustments made to the calculation methods of indicators in order to adapt the assessment methodology for office buildings.

#### 3.2.1 *Indicator 1- Aggregate value of environmental impacts throughout the life cycle per m$^2$ of pavement floor area*

A deep analysis was performed on the LCA calculation method used in this indicator and there were verified some issues that could lead evaluators to some calculation errors. Thus, keeping the original base, some improvements were made to the calculation method to solve these problems and also to facilitate the application of this indicator, which was very complex. These changes reduced the number of variables and tables and its complexity and processing speed, above all enabling greater clarity in the final results.

#### 3.2.2 *Indicator 3 – Waterproofing index*

It was decided to move this indicator to Category 5: "Water.", since it was difficult to find a direct relationship between the waterproofing index and its influence on biodiversity. To adapt the assessment method of this indicator for office buildings, a study was made to the various Municipal Directorate Plans (PDM's) including all the districts of Portugal, to set new benchmarks for covering the characteristics of buildings. This has set a new standard practice of 70% for the Waterproofing Index and consequently set the value of best practice in 35%. The calculation method was also improved to consider areas from which rainwater runoff is collected in tanks for future use as 100% permeable areas.

#### 3.2.3 *Indicator 4 – Percentage of used land area previously contaminated or built*

In this indicator, the conventional practice value was changed from 0% to 30%. This value was obtained by taking into account the Portuguese publication "Construction and Housing Statistics 2008" which indicates for buildings concluded in 2008, except family buildings, a percentage of 30% for rehabilitation works. In the rehabilitation works there are always occupied pre-built or pre-contaminated lands. This change applies a more representative value of conventional practice and is more damaging to the new buildings that are built in greenfield sites, giving a clear incentive to reduce the occupation of areas with important ecological value.

#### 3.2.4 *Indicator 6 – Percentage of horizontal area with reflectance equal or bigger than 60%*

This indicator was moved to Category 1: Climate change and outside air quality since it is more related to global warming, tropospheric ozone and outdoor air quality than to biodiversity.

#### 3.2.5 *Indicator 7 – Non renewable primary energy consumption in operation phase*

To adapt the calculation method of this indicator for office buildings, it was necessary to define a new calculation method that enables assessment of office buildings that are covered by different energy building regulations. Another change was made to evaluate the performance of the building without accounting for in-situ energy produced through renewable sources. This is because if a building produced a considerable amount of energy from renewable sources, the calculations wrongly produced a low value for the global primary energy needs and could get a good score at this indicator without using energy efficient solutions. Additionally, these buildings were being doubly benefited by getting also a good grade in indicator 8 that refers to renewable energy produced in the building.

### 3.2.6 *Indicator 9 – Percentage on cost of reused materials*

This indicator suffered an improvement in the calculation process, accounting now the materials and products that are expected to be reused in the end cycle of the building. In order to these materials be accounted, the promoter must compromise that the building will be deconstructed in the end of its life cycle and there must be proof that the materials can be removed from the building without suffering damage.

### 3.2.7 *Indicator 10 – Percentage by weight of building's recycled content*

A new calculation method was developed that assesses the percentage in cost of materials and products with a recycled content higher than the conventional value. Since the indicator is evaluated using a different unit, it was necessary to establish new benchmarks. While the practice of selecting materials with high recycled content is not yet a common practice in Portugal, it was decided to consider as standard practice a value of 0%. For the best practice a value of 10% was defined. This value is presented in a study by WRAP (WRAP, 2010) as a requirement increasingly sought by owners. With these values, it is possible to reward designers and promoters who use a small percentage of materials with recycled content, which turns out to be an encouragement to this practice.

### 3.2.8 *Indicator 11 – Percentage in cost of certified organic products*

Taking into account that the influence of this indicator focuses on the protection of biodiversity by promoting the reduction of deforestation and illegal logging, it was decided to move this indicator to a Category 2: "Biodiversity and Land Use."

### 3.2.9 *Indicator 12 – Percentage in mass of cement replacement materials in concrete*

This indicator has major influence on global warming, climate change and outside air quality. Thus, although this indicator is related to materials selection, it was decided to change this indicator to Category 1: "Climate change and air quality outside". Regarding the benchmarks, it was decided to lower the value of best practice from 60% to 40%. This change resulted from the fact that the practice of replacing cement by other binders in Portugal is not a common practice and having a best practice value too high may never encourage prosecutors to use this practice because even if they did they would not be properly valued. This value is also indicated as an optimal dosage for replacement of cement (Camões, 2005).

### 3.2.10 *Indicator 14 – Annual volume of water consumed per capita inside the building*

This indicator was updated defining a new calculation method, since office buildings can have various types of uses and therefore considerable variation in water consumption. The new calculation method is now comparing the building's water consumption to benchmarks that represent the use of standard solutions and high efficient solutions in the same building. That process considers the building's function and water use, instead of comparing it to fixed Portuguese average consumption values.

### 3.2.11 *Indicators 16 and 17 – Natural ventilation and finish materials with low VOC content*

These two indicators were merged into one in order to evaluate the building in terms of air quality. The new indicator is called "Indoor air quality". To adapt this indicator to office buildings some changes were introduced to the calculation method because it merged two indicators. For this purpose, it was taken into account that in office buildings mechanical ventilation is generally used. The change made in the calculations is also due to the fact that in office buildings covered by regulation RSECE it is necessary to perform air quality audits by measuring the concentration of various pollutants. This is the best method for assessing the quality of air, thus the method of evaluation of this indicator was separated according to the design of the building and the regulation applicable (RCCTE or RSECE).

For buildings that are under RSECE and in operation phase, air quality is assessed by physically measuring the concentrations of pollutants in the building. For buildings under the building regulation RCCTE or under RSECE, in the phases of preliminary design, design or construction, the assessment is made taking into account the predicted air quality as a function of two factors: the ventilation rate of the building and the selection of finishing materials with low levels of VOC emissions.

### 3.2.12 *Indicator 18 – Average annual thermal comfort level*

To adapt this indicator to office buildings there were made some adjustments to the calculation process to take into account that is common in Portuguese office buildings to use cooling systems in summer. Thus, it was maintained the calculation method for the heating season and changed the calculating method for the cooling season. To define the new benchmarks, the values in standard EN15251 were used for each type of space, indicating the values of conventional practice relating to a class III comfort and the values of best practice were obtained using values of class I.

### 3.2.13 *Indicator 19 – Average daylight factor*

The assessment method of this indicator changed from measuring daylight factors to illuminance levels. This change had not only in mind the need for the adaptation to office buildings, but was also an improvement in order to measure more correctly the comfort of users regarding the lighting. Thus, the performance of a building in this indicator is obtained through the level of annual weighted average daily lighting for the building. This value is obtained by determining the annual daily average levels of illumination in different compartments of the buildings, considering the relation between natural and artificial light, depending on the operating hours of building and average daily number of annual hours of sunlight. Since major changes were made in the calculation method, new benchmarks were adopted using the recommended values for each type of space and usage in standard EN12464-1.

### 3.2.14 *Indicator 20 – Average level of sound insulation*

To adapt this indicator to office buildings, significant changes were made in the calculation process to take into account the different regulations that apply to Portuguese office buildings. The benchmarks were also updated in conformity.

### 3.2.15 *Indicators 24 and 25 – Initial investment costs and Operation costs*

The adaptation of the methodology for evaluating these indicators for office buildings was carried out simultaneously, since both indicators were merged into a single indicator that evaluates the economic performance of the building throughout its life cycle. This change considers that in office buildings the owner is often the same entity that uses the building, making more sense to carry out a joint assessment. Previously in methodology SBTool$^{PT}$-H, the weight of each of the economy indicators was 50%, but this distribution hardly reflects the relationship between the initial investment costs and operating costs. It is believed that this new assessment method best reflects the economic performance of a building, considering the life-cycle values.

### 3.3 *SBTool$^{PT}$-S final structure*

Considering the changes described in previous chapters, the structure for SBTool$^{PT}$-S is presented in Table 2. The weights of the indicators that have been moved were kept, while the indicators that were merged had their weights combined. It was also proposed to change the weight for indicators of the category "accessibilities" for office buildings, reducing the impact of the amenities and increasing importance of public transport. The aggregation models and global sustainability level calculation were maintained from SBTool$^{PT}$-H.

Table 2: Structure of SBTool$^{PT}$-S

| Dimension | Category | Indicator |
|---|---|---|
| Environmental | C1 Climate change and outdoor air quality | I1 Life cycle environmental impacts<br>I2 Replacement of cement in concrete<br>I3 Heat island effect |
| | C2 Biodiversity and land use | I4 Net area index<br>I5 Previously contaminated or built areas<br>I6 Native plants<br>I7 Certifies organic products |
| | C3 Energy | I8 Energy consumption<br>I9 Renewable energy |
| | C4 Materials and solid waste | I10 Reuse of materials<br>I11 Materials with recycled content<br>I12 Solid waste separation |
| | C5 Water | I13 Water consumption<br>I14 Drinking water consumption reduction<br>I15 Waterproofing index |
| Social | C6 comfort and health of users | I16 Indoor air quality<br>I17 Thermal comfort<br>I18 Visual comfort<br>I19 Acoustic comfort |
| | C7 Accessibility | I20 Accessibility to public transportation<br>I21 Accessibility to amenities |
| | C8 awareness and education for sustainability | I22 Building sustainable management |
| Economic | C9 Life cycle costs | I23 Life cycle costs |

## 4 DISCUSSION AND CONCLUSIONS

This work successfully achieved its main objectives. The developed module of the SBTool$^{PT}$ system to assess the sustainability of office buildings (SBTool$^{PT}$-S) introduced several improvements in the system when compared with the existing methodology SBTool$^{PT}$-H. The development of the methodology improved the applicability field of the indicators, considering the different phases of building design and its scope in terms of regulations and type of buildings, providing an important contribution for the calculation methods to make evaluations more comprehensive and objective. It also took into account the diversity of uses that office buildings may have, adapting the calculation method of some indicators by increasing their flexibility. However the objectivity remained and, whenever possible, the calculation processes were improved in order to facilitate their application. There were also some changes in some indicators, changing its position to other categories that represent in a more realistic way their real impact on the sustainability of buildings. Important updates were also made in the benchmarks of most indicators.

Furthermore, it is remarkable that this work was done probably at the stage of human history in which man is more willing to move towards sustainability. The awareness of previous generations was based on the willingness to prevent future generations from suffering serious problems. In current society, the problems had already begun and the effects of non sustainability are already felt by the citizens. Thus, the motivation for sustainability in today's society is a crucial driver for the use of sustainability assessment tools and the application of good practices in the construction sector.

## 5 FUTURE DEVELOPMENTS

The improvement of sustainability assessment tools is a never ending process. Next steps on the improvement of SBTool PT are to adapt the tool for touristic buildings, which have great importance in Portugal. After the development of SBTool$^{PT}$-S, an effort will be done to make all the tools compatible and updated, in terms of structure and calculation methods. At the same time, there are advances for the development of an online tool that will allow easy application of these tools by qualified experts.

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