Green buildings: a worldwide overview on leed, breeam and green star certifications

Green buildings: uma análise do panorama mundial das certificações leed, breeam e green star

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ABSTRACT
Sustainable development is an increasingly relevant theme. Civil Construction is responsible for much of greenhouse gas emissions and energy consumption. Within this context, the design, construction, and operation of the well-known green buildings has allowed the application of sustainability concepts to achieve environmental, social and economic benefits in civil construction. Since 1990, certifications have emerged as a way for the market to attest the performance of buildings through specific criteria. Although there are many certifications, the purpose of this research is to perform a comparative analysis between three of them; LEED, Green Star and BREEAM. The methodology used in this research was the investigation of bibliographical references on the subject through analysis of websites, theses, scientific papers and historical series of open databases. Thus, this article seeks to provide objective data and criteria for comparison between the three certifications considering a worldwide scenario and to address the existing knowledge gap in the Brazilian market regarding international environmental certifications.

Keywords: Sustainability, Green Building, Sustainability Certifications.

RESUMO
O desenvolvimento sustentável é um tema cada vez mais relevante. A construção civil é responsável por grande parte das emissões de gases do efeito estufa e no consumo de energia. Dentro deste contexto, a concepção, a construção e a operação dos conhecidos green buildings (edifícios verdes) têm permitido aplicação dos conceitos de sustentabilidade com intuito de alcançar benefícios ambientais, sociais e econômicos. A partir de 1990, as certificações surgiram como uma maneira encontrada pelo mercado de atestar o desempenho do empreendimento por meio de critérios específicos. Embora existam muitas certificações, o objetivo deste artigo é realizar uma análise comparativa

entre três delas: LEED, Green Star e BREEAM. Utilizou-se como metodologia a investigação das referências bibliográficas sobre o assunto por meio da análise de informações em sites, teses, artigos especializados e séries históricas de bancos de dados abertos. Desta forma, este artigo busca fornecer dados e critérios objetivos de comparação entre as três certificações considerando cenário mundial e abordar a lacuna de conhecimento existente no mercado brasileiro referente às certificações ambientais internacionais.

Palavras-Chave: Sustentabilidade, Edifícios Verdes, Certificações de Sustentabilidade.

1 INTRODUCTION

Sustainable development is an increasingly relevant topic for the political, social, and economic world according to Bauer, Mösle and Schwarz (2010). It ceased to be a concern only for environmentalists to become a prominent topic in all human endeavors with impacts on the environment according to Kubba (2017). According to de Brundtland (1987, p.47), the concept of sustainable development consists of “meeting the needs of the present, without compromising the ability of future generations to meet their own needs”.

Among the main concerns raised by environmentalists as shown in Tiossi and Simon (2021), the emission of greenhouse gases has a main highlight, since the correlation with increases in global average temperatures, increase in ocean levels and the disappearance of species (UN-HABITAT, 2011). At the 2015 United Nations Conference on Climate Change, also called COP-21, the Paris Agreement was drawn up, signed by 155 countries, including Brazil (MINISTÉRIO DO MEIO AMBIENTE, 2017).

As stated by Harari (2018, p.122), the impact of global warming is not restricted to just a few nations, but to the entire globe. Therefore, "[...] for actions to be effective, they must be taken on a global level". For this reason, there is a growing interest from scientific, political and business leaders in this topic.

Civil construction, directly and indirectly, is responsible for 40% of greenhouse gases emissions according to a study by Jalali and Torgal (2010) and for about 40% of consumption of energy (BAUER, MÖSLE AND SCHWARZ, 2010),

Numerous studies have shown that "[...] buildings are primarily responsible for the impact on the environment - either during its construction or during its operation" (KUBBA, 2017, p.36).

Faced with this reality, the concept of green building emerged. According to USGBC (2018), green building consists of the practice of creating and using models of

construction, renovation, operation, maintenance, and demolition that are efficient in the use of resources. Given the participation of civil construction in greenhouse gas emissions, green buildings are fundamental to sustainable development and to achieve the goals proposed in the Paris Agreement.

A fundamental change brought about by the energy crisis was the fact that architects, engineers and investors take Life Cycle Assessment into account as show in Silva, Ludolf and Meiriño (2019).

For this, in Brazil, the NBR ISO 14040 – Environmental Management - Life Cycle Assessment was created with the objective of establishing the criteria for assessing environmental aspects and potential impacts associated with a product through:

> [...] - a compilation of an inventory of inputs and determinants of a product system;
> - an assessment of the potential impacts associated with these inputs and requirements;
> - an interpretation of the results of the phases of inventory analysis and impact assessment in relation to the objectives of the studies.
> (ABNT ISO 14040, 2001, p.2, our translation)

This standard applied to buildings, certifies how sustainable a building is from a perspective where the process of conception, planning, execution, and final operation is taken into account.

This analysis in a defined time frame helps to eliminate one of the main barriers of green buildings, which consists of the initial cost for its implementation. Although, according to Kubba (2017), green buildings are 1% to 4% more expensive than conventional buildings, the savings achieved with maintenance and operation throughout the life of the building make the investment attractive.

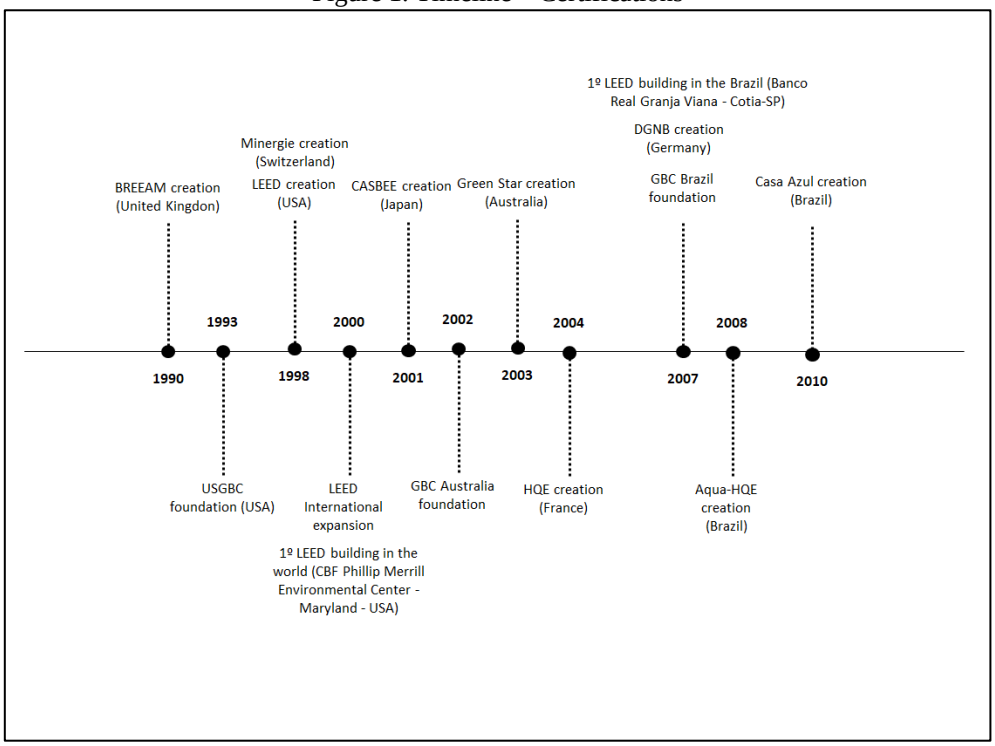
According to USGBC (2018), green buildings certified by LEED (Leadership in Energy and Environmental Design) reduce the consumption of water and carbon dioxide by about 50%, costing around 25% less in their operation. Buildings certified by BREEAM have a reduced operational cost and, typically, the investments made do not exceed 1% of the overall value of the project if it was not a certified building (BREEAM, 2019). Green Star buildings produce approximately 62% less greenhouse gases and use around 66% less energy than conventional buildings (GBCA, 2018).

Certifications provide an objective criterion for measuring the environmental performance of a building. Since the creation of BREEAM in 1990 and LEED in 1998, the search of the real estate market has encouraged the creation and adaptation of

certification systems according to the socioeconomic reality of the geographic region where they operate (KUBBA, 2017).

The creation of the main existing certifications is represented in a timeline below:

Figure 1. Timeline – Certifications



Source: OWN ELABORATION, 2019.

This article proposes to do a comparative analysis between the criteria required in green building in LEED (Leadership in Energy and Environmental Design) Green Star and BREEAM (Building Research Establishment Environmental Assessment Method) certifications under the aspect of proportional weights of each criterion and buildings typologies predominant in each of them, as well as the probable reasons for the observed pattern. As they are among the pioneers, these certifications serve as a basis for the preparation of other certifications, such as the German DGNB (2007), the Japanese CASBEE (2004) and the Swiss MINERGIE (1998) (KUBBA, 2017). In addition, "the most representative and widely used certifications are the Leadership in Energy and Environmental Design - LEED (1998), the Building Research Establishment Environmental Assessment Method - BREEAM (1990) and Green Star (2003) (RODERICK et al., 2009, p.1169).

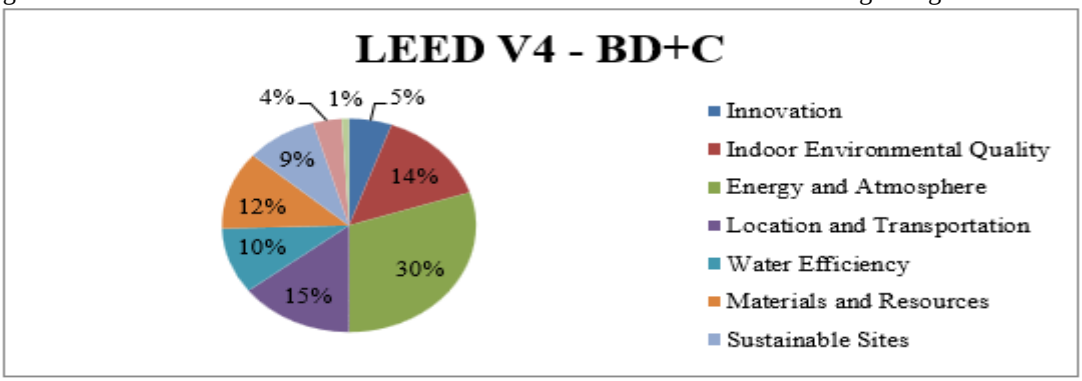
For this analysis, it was considered information on projects built around the world certified by LEED, BREEAM and Green Star.

Given the growing interest in the theme, this article addresses the existing knowledge gap on the scenario of sustainable construction and its daily practice in projects in the Brazilian market regarding international certifications (GRUNBERG; MEDEIROS; TAVARES, 2014). With the increase in the number of environmental certifications for buildings, we seek to offer data and criteria for comparison and decision-making considering a worldwide scenario and aspects, "since even in the advanced centers of Brazilian civil construction, the market is not yet prepared for international green seals" (SILVA; PARDINI, 2010, p.93; our translation). BREEAM and Green Star certifications will be addressed, since their expressive numbers worldwide (GBCA, 2019; BREEAM, 2019) are not shown in Brazilian publications, given the low number of scientific papers that address these two certifications.

1.1 LEED - LEADERSHIP IN ENERGY AND ENVIROMENTAL DESIGN

In 1993, Rick Fedrizzi, David Gottfried and Mike Italiano founded the U.S. Green Building Council (USGBC) with the mission of promoting sustainable practices in the design, construction, and operation of buildings in the construction industry (USGBC, 2019). The USGBC is a non-governmental organization (NGO). The Leadership in Energy and Environmental Design (LEED) certification emerged in 1998 as an initiative by the USGBC to create an objective assessment system for green buildings. LEED is the best known of green building certifications, used in more than 160 countries. LEED has prerequisites and recommendations in 8 areas, namely Location and Transport, Sustainable Land, Water Efficiency, Energy and Atmosphere, Materials and Resources, Internal Environmental Quality, Innovation and Processes, Regional Priority Credits and Integrated Process. LEED certification criteria and prerequisites are distributed as follows:

Figure 2. Data with the relative distribution of the score of the LEED V4 - Building Design+Construction



Source: Elaborated by the author based on USGBC, 2019.

LEED has typologies that meet the different types of buildings and different types of interventions, as shown below:

- LEED BD + C - Building Design and Construction: This typology applies to new buildings or that will undergo significant renovations (renovated area is greater than 50% of the total built area). It applies to new constructions, Core & Shell, Schools, Retail, Hotels, Data Centers, Health, Warehouses and distribution centers.
- LEED ID + C - Interior Design and Construction: This typology is aimed at complete renovations of the interior of the building. Applies to Commercial Buildings, Retail and Hotels.
- LEED O + M - Building Operations and Maintenance: This typology applies to buildings that are undergoing renovations and retrofits. Applies to existing buildings, Schools, Retail, Hotels, Data Centers, Warehouses and distribution centers.
- LEED ND - Neighborhood Development: This typology applies to new or existing planned neighborhoods whose use can be residential, non-residential or both. Projects can be at any stage of development, from conception to construction.
- LEED for Homes: This category applies to single-family or multi-family residential homes up to six floors.
- LEED for Cities and Communities: This typology applies to entire cities or subsections of a city. Through the Arc performance platform, LEED for Cities can measure and manage the city's water consumption, energy consumption, waste disposal, transportation and the user experience (USGBC, 2019).

According to GBCB (2019), there are different categories of certification, as shown in table 1. The score is determined according to the level of adherence to the criteria and prerequisites.

Table 1. LEED levels

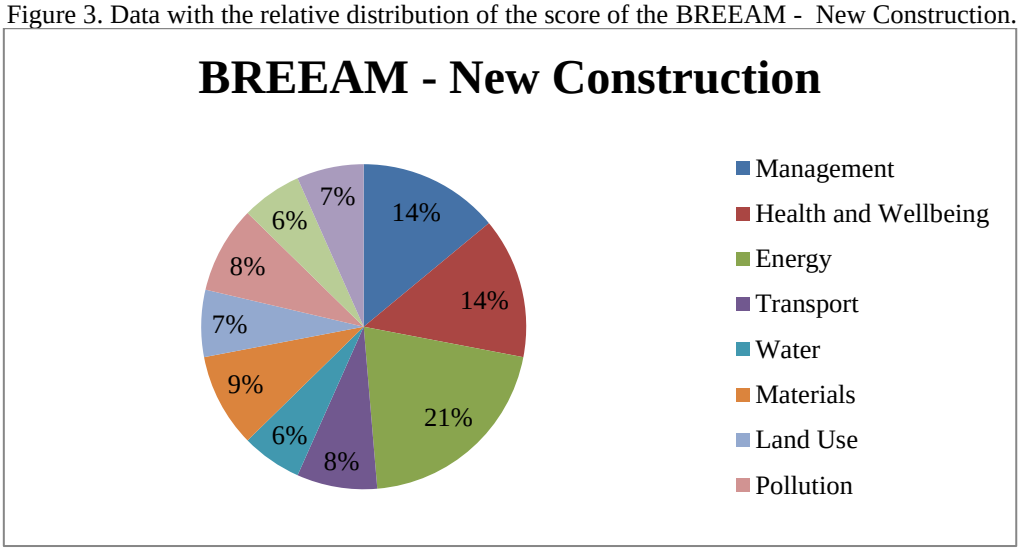
LEED Level	Score
Certified	40-49
Silver	50-59
Gold	60-79
Platinum	≥80

Source: Elaborated by the author based on USGBC, 2019

1.2 BREEAM - BUILDING RESEARCH ESTABLISHMENT ENVIRONMENTAL ASSESSMENT METHOD

The BREEAM (Building Research Establishment Environmental Assessment Method) was the pioneer method of building certification, being established in 1990 by the Building Research Estabilishment (BRE), in the United Kingdom. BRE was founded in 1921, as a British national laboratory with the aim of studying, improving, and developing housing in England. In 1997, it was privatized, the current owner being the BRE Trust, the UK's largest independent charity. BREEAM emerged as a response to the search for a method for assessing, classifying, and certifying the sustainability of buildings. The evaluated items are divided into: Energy, Health and Wellness, Innovation, Land Use, Materials, Management, Pollution, Transport, Waste and Water (BREEAM, 2019). The BREEAM certification criteria are distributed in the following proportion:

Figure 3. Data with the relative distribution of the score of the BREEAM - New Construction.



Source: Elaborated by the author based on BREEAM, 2019.

BREEAM has 5 assessment standards (typologies) that encompass the different types of interventions carried out in the construction industry:

- BREEAM New Construction: Typology used to analyze, evaluate, and classify according to BREEAM standards new constructions, including buildings, houses and increase in the built-up area of existing buildings.
- BREEAM Communities: This typology aims to measure and certify the sustainability of large-scale development plans, such as planned neighborhoods and communities. It can be used to evaluate and certify the performance of medium to large-sized projects, including new communities and revitalization projects.

- BREEAM Infrastructure (CEEQUAL): Acquired by the Building Research Establishment in 2015, CEEQUAL is the evidence-based sustainability assessment, analysis and certification system for civil engineering, infrastructure, and public projects such as bridges, roads, ports, railways, and railway stations. water and sewage treatment (BREEAM, 2018). This typology is in a pilot project at the time of this research (September 2018).
- BREEAM In-use: Typology aimed at providing a methodology for performance certification in the operation of buildings.
- BREEAM Refurbishment & Fit-out: Typology that establishes the process of evaluating and certifying reforms carried out in a building. It encompasses improvements in the facade, structure, main services, local services, or interior design of a building (BREEAM, 2019).

There is a credit system for each item that confer the certification category. The categories are assessed as a percentage of compliance with the BREEAM benchmarks, the minimum standards, the weights adopted in the environmental section and the credits given to each of the items assessed. Through the combination of these elements, the certification levels are divided into Pass, Good, Very Good and Outstanding (BREEAM, 2019), as shown in table 2. The BREEAM certification has its scoring matrix with more than 50% of the items as criteria in the areas of Energy, Health and Wellness and Management. Like the LEED Platinum certification level, buildings with Outstanding certification levels tend to be pioneers in the use and implementation of innovations that improve performance and become references for other buildings (KUBBA, 2017).

Table 2. BREEAM Levels

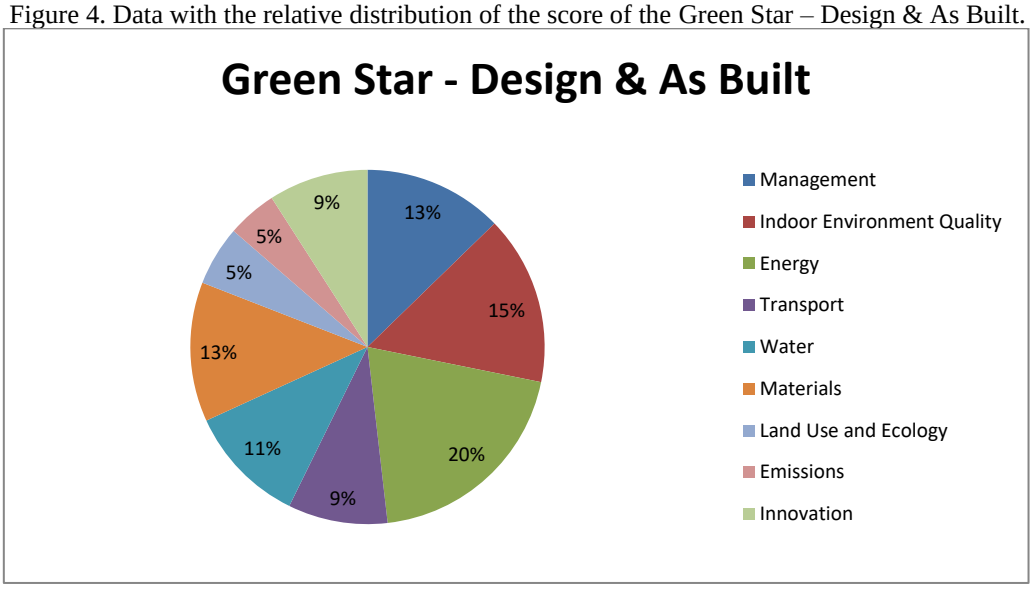
BREEAM Level	Score
Pass	≥ 30%
Good	≥ 45%
Very Good	≥ 55%
Excellent	≥ 70%
Outstanding	≥ 85%

Source: Elaborated by the author based on BREEAM, 2019

1.3 GREEN STAR

Green Star is the most popular building certification system in Australia. It was designed by the Green Building Council of Australia (GBCA) in 2003. Its development was based on hot climates, where there is a great need for cooling systems and high solar incidence (BAUER, MÖSLE, SCHWARZ, 2010). The evaluated categories are Management, Internal Environmental Quality, Energy, Transport, Water, Materials, Land Use and Ecology, Emissions and Innovation (GBCA, 2018).The Green Star certification criteria and prerequisites are presented as follows:

Figure 4. Data with the relative distribution of the score of the Green Star – Design & As Built.



Source: Elaborated by the author based on GBCA, 2019.

Like LEED, Green Star has typologies that meets the different interventions carried out in civil construction, as shown below:

- Green Star - Communities: This typology aims to serve neighborhoods, communities, and districts through 5 categories of impact; Governance, Habitability, Economic Prosperity, Environment and Innovation.
- Green Star - Design & As Built: Typology that meets new constructions and major renovations through the categories Management, Internal Environmental Quality, Energy, Transport, Water, Materials, Land Use and Ecology, Emissions, and Innovation
- Green Star - Interiors: This type caters to interior renovations of buildings and retrofits of equipment. The categories are the same as the Design & As Built typology.
- Green Star - Performance: This typology aims to verify the operational performance of buildings in the categories.

The Green star bases its classification on a scoring system that gives stars according to table 3. The stars measure the compliance of the building with the criteria and requirements of the certification. According to GBCA (2019), buildings with the 6 star level have many of the best practices during construction and operation that ensures a superior performance compared to conventional Australian buildings.

Table 3. Green Star levels

Green Star Level	Score
1 Star (minimum practice)	10-19
2 Star (average practice)	20-29
3 Star (good practice)	30-44
4 Star (best practice)	45-59
5 Star (australian excellence)	60-74
6 Star (world leadership)	≥75

Source: Elaborated by the author based on GBCA, 2019.

2 DEVELOPMENT

2.1 METHODOLOGY

The methodology used was to consult bibliographic references such as books, scientific papers, theses on the subject.

Historical series of open databases maintained by organizations on their respective websites (BREEAM, 2019; GBCA, 2018; GBCB, 2018) on the internet were used to verify the registration fees made in recent years and the building categories. The building categories were divided into offices, schools and colleges, retail, multi-residential, Industry, health and others, where buildings such as shopping centers, hotels, convention centers, data centers, airports and others are located. For comparison purposes, the buildings analyzed refer to new buildings represented by the categories Building Design + Construction, New Construction and Design & Construction for LEED, BREEAM and Green Star respectively.

To list the building categories, typologies and criteria of each certification, the authors based themselves on the official description of each item present in the official documents made available on the web platform maintained by each certification studied.

For LEED, data were extracted from the open database maintained by the USGBC on all certified buildings up to the first half of 2019 worldwide. The data extracted in the

form of a spreadsheet were treated considering the gradual change in the descriptions of the typologies and the previous versions of LEED used by the USGBC. Thus, the absolute numbers were transformed into percentages to make the comparison clear.

For BREEAM, the data extracted were from the publication The Digest of BREEAM Assessment Statistics (2014), where data from all certified buildings since its creation are presented. Unlike LEED and Green Star, BREEAM does not keep the database open and updated in real time, so the data from this publication was used, whose deadline is the end of 2014.

For data referring to the Green Star certification, data used was from the open and updated real-time database maintained by the Green Building Council of Australia. Like LEED data, the information was extracted in the form of a spreadsheet, treated in such a way as to represent building categories according to the criteria above and transformed into percentages. The deadline used for data extraction was the end of the first half of 2019.

To compare the costs involved in the process of each of the certifications, a new commercial building with a total built area of 40,000 m² was used as a standard building, with 5,000 m² of parking with a construction cost of USD 94,000,000.00 in a company associated with the responsible entities.

2.2 DATA ANALYSIS OF LEED CERTIFIED BUILDING

Analyzing the data publicly available on the USGBC websites, it is possible to notice a predominance of commercial buildings according to table 4, mainly offices, representing 40% of all new certified buildings.

Second, there is the category Schools and Colleges. As already demonstrated in (KATS, 2003), certified educational buildings improve student performance.

Third, there is the category of others, which include buildings such as shopping centers, hotels, convention centers, data centers and airports for example.

Table 4. Building Design + Construction categories certified by LEED between 2000 and 2019.

LEED - BD+C 2000-2019

Category	Quantity
Offices	40%
School and Universities	17%
Others (Shoppings, hotels, data centers, airports)	14%
Retail	13%
Multi-residential	6%
Industry	6%
Health	4%

Source: Elaborated by the author based on USGBC, 2019

2.3 DATA ANALYSIS OF BREEAM CERTIFIED BUILDINGS

The most recent data for BREEAM certified buildings can be found in the publication The Digest of BREEAM Assessment Statistics (2014), in which statistics on certified buildings are presented from their creation in 1990 to 2014.

Firstly, there are Offices, like LEED, representing 34% of the total, as shown in table 5. Next, there is Others category, which includes buildings such as shopping centers, hotels, convention centers, data centers and airports. Third, the Schools and Colleges category stands out, with 16% of the total certified buildings.

It is important to note that the same LEED categories were repeated with an exchange of positions between the Schools and Faculty and Others categories.

Table 5. New Construction certified by BREEAM between 1990 and 2012.

BREEAM New Construction (1990-2012)

Category	Quantity
Offices	34%
Others (Shoppings, hotels, data centers, airports)	21%
School and Universities	16%
Industry	13%
Retail	7%
Multi-residential	6%
Health	3%

Source: Elaborated by the author based on BREEAM, 2014.

2.4 DATA ANALYSIS OF GREEN STAR CERTIFIED BUILDINGS

Green Star data is available from the Green Building Council of Australia (GBCA) on its website.

Repeating the LEED and BREEAM standard, commercial buildings composed of offices represent most of the certified buildings, with 64% of the total as shown in table 6. Schools and Colleges are the second category with the most certified buildings.

In contrast to the other certifications, in third place are multi-residential buildings, with 12%. In Green Star, residential buildings are in greater relative number than in the other certifications object of study in this research.

Table 6. Design & Construction certified by Green Star between 2004 and 2019.

Green Star Design & Construction (2004-2019)

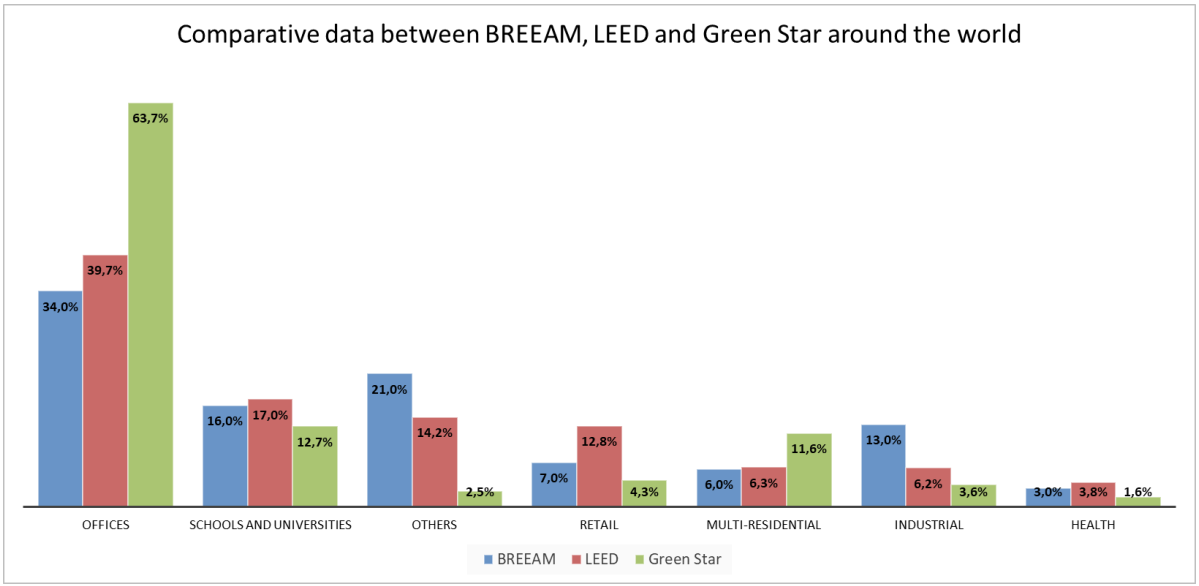
Category	Quantity
Offices	64%
School and Universities	13%
Multi-residential	12%
Retail	4%
Industry	4%
Others (Shoppings, hotels, data centers, airports)	2%
Health	2%

Source: Elaborated by the author based on GBCA, 2019.

2.5 COMPARISON BETWEEN LEED, BREEAM AND GREEN STAR

From the data, commercial buildings turned to offices represent the largest relative number of certified buildings in all three certifications analyzed, shown in figure 5. One of the reasons for this, according to Oliveira (2013), is the higher market value of certified commercial buildings in relation to conventional buildings and lower vacancy rate in rented properties. Certification, in this case, has the function of attesting, through an independent body, the superior performance and less environmental impact in relation to conventional buildings (KUBBA, 2017).

Figure 5. Comparative data between new building categories from the certifications BREEAM, LEED and Green Star.



Source: Elaborated by the author based on GBCA, 2019; USGBC, 2019 e BREEAM, 2014.

2.6 COMPARATIVE TABLE

Table 7 was prepared with the objective of seeking a better understanding of the certifications analyzed throughout this article. The criteria used were the country of origin, full name, date of creation, responsible entity, criteria used for the credits, the existing typologies, the categories of certification and the cost. For the purpose of comparing the cost of each certification, a new commercial building with a total constructed area of 40,000 m² will be used as a model, with 5,000 m² of parking with a construction cost of USD 94,000,000.00 in a company associated with the responsible entities.

Table 7. Comparative table between certifications reviewed

Certification	LEED	BREEAM	Green Star
Origin	United States of America	United Kingdon	Australia
Name	Leadership in Energy and Enviromental Design	Building Research Estabilishment Environmental Assessment Method	Green Star
Creation	1998	1990	2003
Responsible Entity	U.S. Green Building Council (USGBC)	Building Research Estabilishment (BRE)	Green Building Council Australia (GBCA)

Criteria	Location and Transportation Sustainable Sites Water Efficiency Energy and Atmosphere Materials and Resources Indoor Environmental Quality Innovation Regional Priority Integrated Process	Energy Health and Wellbeing Innovation Land Use Materials Management Pollution Transport Waste Water	Energy Indoor environment Quality Inovation Land use and ecology Transport Materials Management Emissions Water
Typology	LEED BD+C - Building Design and Construction LEED ID+C - Interior Design and Construction LEED O+M - Building Operations and Maintenance LEED ND - Neighborhood Development LEED for Homes LEED for Cities and Communities	BREEAM New Construction BREEAM Communities BREEAM Infrastructure (CEEQUAL) BREEAM In-use BREEAM Refurbishment & Fit-out	Green Star – Communities Green Star – Design & As Built Green Star – Interiors Green Star – Performance
Levels	Certified (40-49 pontos) Silver (50-59 pontos) Gold (60-79 pontos) Platinum (mais de 80 pontos)	Pass (≥ 30%) Good (≥ 45%) Very Good (≥55%) Excellent (≥ 70%) Outstanding (≥ 85%)	1 Star 10-19 pontos 2 Star 20-29 pontos 3 Star 30-44 pontos 4 Star 45-59 pontos 5 Star 60-74 pontos 6 Star ≥75 pontos
Cost for certification of the model building	USD 26.512,00	USD 4.997,00	USD 21.045,00

Source: Adapted from USGBC, 2019; BREEAM, 2019; GBCA, 2019

3 FINAL CONSIDERATIONS

The construction industry has a huge impact on the environment (JALALI; TORGAL, 2010) and, therefore, green buildings provide an alternative to reduce the environmental impacts of civil construction and help to build a future environmentally appropriate, socially beneficial, and economically viable.

This article seeks to highlight the importance of certifications and green buildings as an alternative to civil construction in terms of the goals stipulated in the Paris Agreement (2014). However, in the Brazilian market, green buildings and their certifications are not a substantial part of the professional routine (SILVA; PARDINI, 2010). Thus, this work sought to fill this knowledge gap with the provision of data from buildings all around the world certified by LEED, BREEAM and Green Star for comparison and decision making, involving types of buildings and costs.

Certifications are a way found by the market to attest the performance of the buildings within a series of criteria and requirements. Among the various benefits associated with green buildings, we can highlight its higher market value in relation to buildings that do not have certification (OLIVEIRA, 2013) and the improvement in the quality of life of the occupants, as well as the performance of students in educational units. (KATS, 2003). The commercial buildings constitute the largest proportion of certified buildings. This result can be correlated to the economic and social benefits involved described by Kats (2003) and Oliveira (2013). The certifications also favor innovation in environmental design, as they all offer extra credits for innovative initiatives whose performance must be corroborated by robust evidence.

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