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Qualitative Analysis of Sustainability Certification Systems Based on ISO 21929-1

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Abstract

Sustainability certification systems are parameters used to measure the extent to which the building meets the necessary sustainable requirements. Currently, there are several types of sustainability certificates, in addition to regulatory standards. Therefore, this work sought to analyze the most influential sustainability certificate systems in the market, using the qualitative analysis of content created by Bardin and based on ISO 21929-1, with fourteen aspects, as a parameter for comparison, the focus of the study was adapted to this method to have a better understanding of the behavior of these systems. Some conditions were imposed to narrow down the number of certification systems, four systems were selected to be analyzed. After the qualitative analysis, it was possible to identify that DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) is the only one that addressed all the fourteen aspects brought by ISO 21929-1, HQE (Haute Qualité Environnementale) and LEED (Leadership in Energy and Environmental Design) addressed fewer aspects, HQE highly addresses them. However, LEED has a more detailed and clear approach to the aspect related to the Internal conditions and air quality. Lastly, BREEAM addresses thirteen of the fourteen aspects of ISO 21929-1, and most of its content addressed is from the environmental area.

Author Keywords. Green Rating Systems, BREEAM, DGNB, HQE, LEED, Sustainability systems, Qualitative Research, Content Analysis.

Type: Research Article

1. Introduction

Sustainability certification systems are parameters used to measure the extent to which the listed building meets the requirements of a sustainable building. In this way, the categories, criteria, and indicators of these systems should better represent the "way to make the construction sustainable", and should be in accordance with environmental, social, and economic aspects (Illankoon et al. 2017). It is clear that the content of these certificate systems is derived from the environmental, social, and economic aspects of sustainable buildings, with great emphasis on the environmental aspect. While, other aspects like social and economic, are in many cases neglected (Illankoon et al. 2017; Zuo and Zhao 2014).

Sustainability certification systems have four generations according to their structure, assessment method, and certification process, which are: I) First Generation: uses a certification system with a pass or fail; Nominal type: II) Second Generation: uses simple additive systems; III) Third Generation: uses weighted additive systems and; lastly the IV) Fourth Generation:

works based on advanced concepts, such as the efficiency of the construction environment or the impact and cost of the life cycle. In general, most certification systems covered in this study belong to second or third generations (Varma and Palaniappan 2019).

In addition to sustainability certification systems, other regulatory and standards (such as ISO 21929-1, which is based on ISO 15392) guide the construction of sustainability-related indicators, providing that there is a general principle for construction sustainability. ISO 21929-1 framework establishes seven "Central Protected Areas" (CPA) originated from the three pillars of sustainability and are considered essential for construction sustainability. Also, arises from the CPA the main and not main criteria, influencing it with different forces. For example, the criterion "waste generation" (being the amount of waste production by its type) is considered a direct indicator of natural resources (environmental dimension). However, its characteristics have an indirect influence on the ecosystems areas (environmental dimension), health, and well-being (social dimension) (ISO 2011; Liang et al. 2021).

Due to documents variability in this type of certificate system that portrays buildings' sustainability, this paper aims to analyze them in detail, using the key sustainability criteria obtained from ISO 21929-1 as a basis. Among the methods already executed to assess the effectiveness of sustainability certification systems, stands out the "environmental performance assessment" and "comparative analysis," being the latter considered the most appropriate (Li et al. 2017). Furthermore, the main objective of this paper is to perform a qualitative analysis of the content of sustainability certification systems guides using a neutral reference - ISO 21929-1, and not to examine the certification system based on score or classification. Aiming to contribute to a better understanding of these systems together with other comparative analysis works.

2. Materials and Methods

In this part of the study, it is intended to analyze if the criteria established in ISO 21929-1 are present in the structure of the selected sustainability certification systems. Assuming that currently there are different sustainability certifications on the market, some conditions were imposed to narrow down, to identify and select only the most relevant systems for further analysis. As a result, the following criteria were carefully chosen to perform the certificate system selection. In this manner, the systems need to:

1. Address the construction of commercial buildings.
2. Have a number of certifications or pre-certifications above 1000 projects.
3. Scientific interest, with publications.
4. Availability of their guides for analysis.

This selection model is similar to the one used by the Bernardi et al. (2017) study. The results obtained from previous selection are presented in Table 1. As mentioned before, some conditions were imposed to constrain the number of certification systems. Since SBtool is not considered a certification system but rather a framework, it was excluded from this investigation. CASBEE (Comprehensive Assessment System for Built Environment Efficiency) guide was not available for access, and it was not included. Likewise, Green Mark and Green Star systems were removed from this study for not having a certification number higher than 1000 projects.

Eventually, the systems chosen were BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen), and HQE (Haute Qualité Environnementale), as they have greater widespread adoption in project certification, Including commercial buildings. In addition, they are tools that arouse scientific interest and, finally, their guides are available for analysis.

Systems	Keywords	Citations on Scopus	Nº Certification/Pre-Certification
BREEAM	(KEY (*breeam*) AND KEY (*building*))	101	>594.000
LEED	(KEY (*leed*) AND KEY (*building*))	614	>131.000
DGNB	(KEY (*dgnb*) AND KEY (*building*))	21	1889
HQE	(KEY (*hqe*) AND KEY (*building*))	7	380.000
Green Mark	(KEY (*green* AND *mark*)AND KEY (*building*))	33	N/A
Green Star	(KEY (*green* AND *star*) AND KEY (*building*))	89	828
CASBEE	(KEY (*casbee*) AND KEY (*building*))	34	530

Table 1: Selection process for more representative sustainability certification systems (BREEAM 2018b; USGBC, n.d.; GBCA, n.d.; DGNB, n.d.; Bernardi et al. 2017; IBEC, n.d.)

For the next step, the methodology for qualitative content analysis developed by Bardin (2000) was chosen, but it was necessary to adapt it for this study following the steps below:

- Pre-analysis: Content organization phase: Floating reading of the system guide, to understand how writing is structured and facilitate the collection of the content of interest; Establishment of the documents' order for analysis, a priori, considering that these certification systems have different types of guides and papers; build the corpus of research and develop study-based objectives.
- Material exploration: Coding and categorization of the material, in this stage the Atlas.ti, a software for qualitative data analysis was used to facilitate and optimize the document analysis task, which is divided into two parts. Firstly, it was required to create the registration unit, a given term to indicate what will be analyzed. In this case, the 14 criteria established by ISO 21929-1 were used, as exemplified in the red frame in Figure 1. Secondly, it was necessary to identify the context unit, a given term to show where the recording unit is in the document, which allows identifying the interconnection between the criteria - mentioned previously - with the structure of the system guides, indicated with a green frame in Figure 1.
- Results final treatment: Process of understanding the results obtained through interpretation and inference, which is summed up in capturing the content included in the document (Silva and Fossá 2015).
- This step consists of: A general reading of the selected content through the reports delivered by Atlas.ti; Group organization, that is, a grouping of each code, which in this case represents ISO 21929-1 criteria; Creation of the final content, "the message," that is, pointing out how the certification systems treat each criterion; Afterwards, it will be possible to overview each certification system regarding ISO 21929-1 through the final Atlas.ti reports, permitting to verify how each criterion was treated and the correlations between them.

Atlas.ti software was developed to analyze large quantities of qualitative data and has been used in different knowledge areas. Lately, it has been applied in content analysis and it is possible to have six types of results arising from this software: 1) Hermeneutic Unit, allows gathering and managing all the data of a research project; 2) Primary documents coming from interview transcripts and field notes, but support pictures and audio; 3) Quotes/quotation, such as relevant excerpts from interviews or documents; 4) Codes, allows creating a priori or a posteriori analysis, similar to Bardin's methodology, for example; 5) Memos, allows the description of the research history and records the researcher's interpretations; 6) Network view, helps to visualize the results in the form of graphs (Klüber 2014).

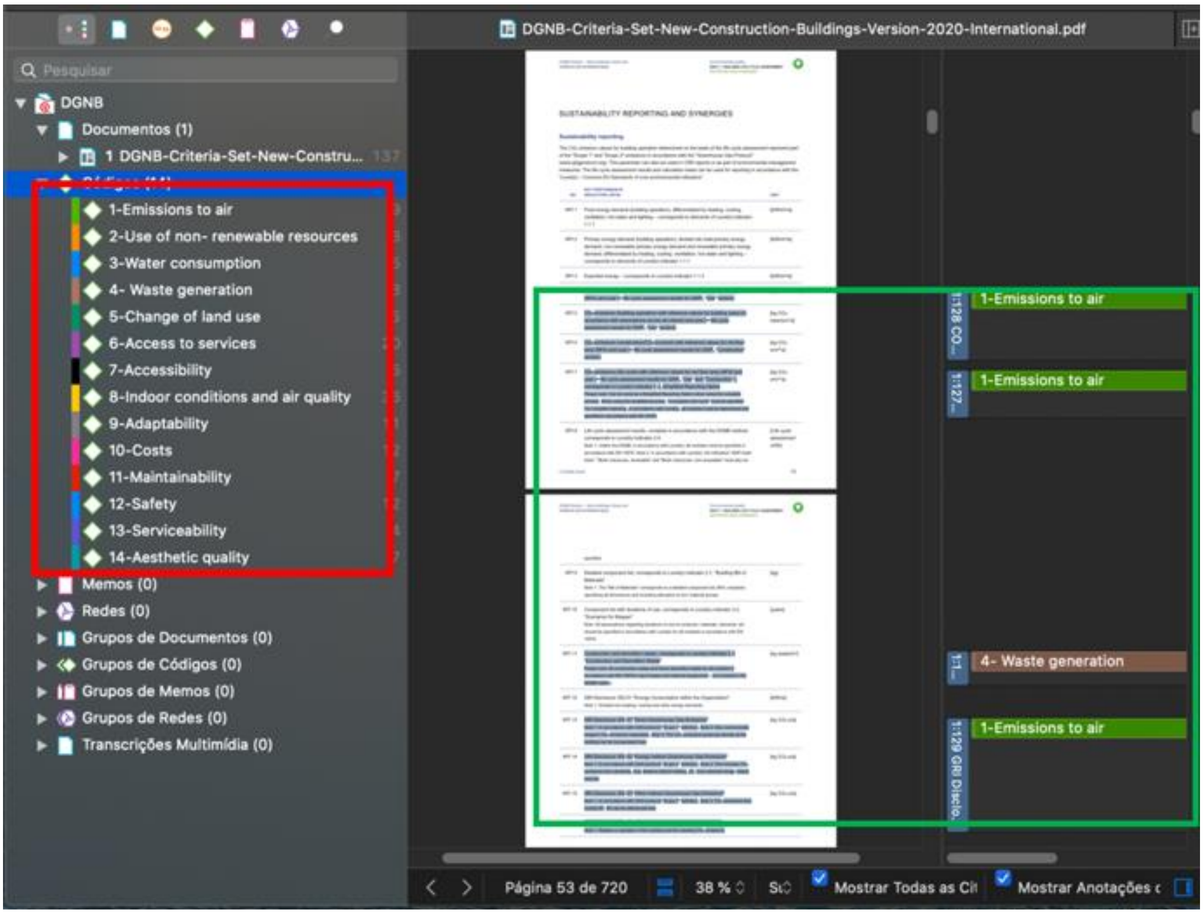

Figure 1: Atlas.ti software user interface, separated by command and functionality areas

2.1. Criteria comparison based on ISO 21929-1

ISO 21929-1 (Sustainability in building construction - Framework for the development of indicators and a core set of indicators for buildings) provides seven CPA in its structures - relating to the three known sustainability dimensions, which are: "Ecosystems" and "Natural Resources" referring to the environmental dimension; "Health and well-being", Social Equality" and "Cultural Heritage" referring to the social dimension and; "Economic Prosperity" and "Economic Capital" related with the economic dimension, which develops sustainability and the scope is the building life cycle. Furthermore, in its structure 14 groups are presented, being considered essential for the construction sustainability, as well as its indicators. These groups often influence directly or indirectly more than one protected area. Although ISO 21929-1 is based only on indicators, its structure gives us a first approach, setting limits and defining what a sustainability indicator means. According to this standard sustainability indicator is "a framework for the development of sustainability indicators for buildings based on the premise that sustainable building development brings about the required performance and functionality with minimal inverse environmental impact, while encouraging economic and social (and cultural) aspects improvements at the local, regional and global level" (ISO 2011).

Basically, this standard prescribes minimum acceptable performance standards with a certain number of criteria. However, it is possible to identify that the fourth pillar of sustainability, "institutions", is not presented in its structure (Liang et al. 2021).

Thus, ISO 21929-1 standard was used as a reference to compare the sustainability certification systems previously selected, providing the minimum criteria (aspects) for the improvement of the sustainable development in the construction industry. First, it was verified if the criteria presented by the standard were somehow related to the certification systems structure and after that a comparison to understand how each certification system interprets and assesses these aspects was conducted. This comparison helped to identify similarities, differences, strengths, and weaknesses of the sustainability certification systems selected, permitting us to determine which systems are more evolved in terms of aspects, serving as a basis to develop the monitoring tool for this study.

3. Discussion

In order to unify the terms, the use of group was adopted to mention the main sustainability topics, both by ISO 21929-1 and by the guides of the sustainability certification systems, the subgroups are more specific topics that derive from the groups and the indicators and/or criteria are the ways of measuring or classifying the subgroups and/or groups.

3.1. Air emissions

This group derives into two subgroups; the first one is the Global Warming Potential which has the function of measuring greenhouse gas (GHG) emissions derived from the production of products used in the construction industry such as in building construction and deconstruction phases. The second one is the Ozone Depletion Potential, which measures the release of gases with potential impact on the stratospheric ozone layer due to the resulting release in the fabrication process of construction products (ISO 2011).

During this evaluation, similarities between the standard and the guide texts were found. It was identified that in general the sustainability certification systems relate atmospheric emissions with energy consumption and not with the building construction phase, as can be verified in the following excerpts from the guides. In BREEAM, Ene 01 - Reduction of energy consumption and carbon emissions, which seeks to minimize operational energy demand, primary energy consumption, and CO2 emissions. LEED, EA - Minimum energy performance, which aims to reduce environmental and economic damage related to excessive energy consumption. HQE, 4.3. - The reduction of pollutant emissions into the atmosphere, it states that the pollution problems linked to the energy consumption of the building are very different so that a global indicator is defined for all emitted pollution. Last one, the DGNB - no direct indicator of atmospheric emissions identified in its guide. Still, the DGNB addresses other factors in the ENV1.1 category - Assessment of the construction life cycle that seeks through the the Life cycle analysis (LCA) and efficient planning of building to reduce impacts related to emissions and consumption of non-renewable resources at all stages of a building's life (DGNB 2020; BREEAM 2018a; USGBC 2020; CERTIVEA 2015). On the other hand, the ozone depletion potential is present in BREEAM, LEED, and HQE associated with air emissions, which is due to a significant volume of refrigerants in cold rooms and the risk of gas leakage, also it is not easy to evaluate (DGNB 2020; BREEAM 2018a; USGBC 2020; CERTIVEA 2015).

3.2. Use of non-renewable resources

The use of non-renewable resources derives from two subgroups, the first one measures the consumption of non-renewable raw materials and the second measures the consumption of non-renewable energy (ISO 2011). Concerning the consumption of non-renewable raw materials, some systems also associate this consumption with the use of materials from renewable sources, that is, it addresses the same subject, but with a renewable focus, such as in LEED, MR: Declarations of environmental product, which encourage the use of products and materials for which life cycle information is available, in a way that does not address non-renewable consumption. In HQE 2.3.3. The use of materials and products that provide to the site a minimum of CO2 pollution drives the choice of materials, focusing on the emissions that these materials can release (USGBC 2021; CERTIVEA 2015). For BREEAM and DGNB systems, the consumption of non-renewable raw materials is focused on the "whole life cycle" approach, referring to the impacts of construction products. This issue is intertwined with more factors and it is not measured alone (BREEAM 2018a; DGNB 2020).

3.3. Water consumption

The amount of water consumption derived from construction materials, work stages, use phase and subsequent deconstruction. All these items derive from this indicator, which has the function of observing the estimated consumption of freshwater throughout the life cycle in relation to the construction user (ISO 2011). In the context of ISO 21929-1, initially, only the BREEAM system addresses water consumption in the construction phase in chapter “Man 03 - Responsible construction practices”, there is an approach on this matter, which seeks better design efficiency and performance of the construction. However, all other systems have a chapter dedicated to water consumption. Like in LEED, “reducing the use of external water”, and “reducing the use of indoor water”, which aims to reduce total water consumption by 20% from baseline. While the measurement and optimization of water consumption, with the function of monitoring for additional savings, is similar to BREEAM (BREEAM 2018a; USGBC 2021). For DGNB, freshwater management is referenced by the category “ENV2.2- Drinking water demand and wastewater volume”, which aims to reduce the demand for drinking water through wastewater recycling and the use of local resources (DGNB 2020). The HQE system, like the others, addresses the conscientious consumption of water. In addition, it addresses the Sanitary Quality of Water with a focus on water intended for human consumption, which meets the criteria of potability and hygiene (CERTIVEA 2015).

3.4. Waste generation

This group is related to the total volume of non-hazardous and hazardous waste that impacts waste generation and disposal (ISO 2011). The BREEAM has a specific chapter (Wst 01 Construction waste management) in its guide associated with this subject, which intends to reduce construction waste throughout the lifecycle of the building. On the other hand, LEED does not directly address questions about the total volume of waste, just the criteria associated with the collection, storage, and recycling, targeting the reduction of waste generated by the building occupants, that is transported and disposed in landfills. Similarly, it occurs in the search for reduction of construction and demolition waste through the prevention of waste generation, reuse, recovery and recycling of materials (USGBC 2021; BREEAM 2018a). In the HQE certificate, the approach aims to limit the production of final waste, since waste management is essential for adverse effects. Therefore, it has two indicators for this subject: I) Optimization of activity waste recovery and; II) Quality of the waste management system of the activity. While DGNB system has two categories that address waste issues: the first one is the “PRO2.1 Work/construction process” which seeks to minimize negative impacts on the local environment during the construction phase through 4 indicators, the second one is the “4- Work with low residues”. However, “TEC1.6 - Ease of recovery and recycling category”, is where the waste management is treated more continuously, focusing on ensuring highly economical and efficient use of natural resources, through the creative strategy to raise the material efficiency and thus the materials are recycled effectively. What is highlighted is that the

DGNB has a greater focus on the material, not on waste generation, as it addresses in ISO 21929-1 (CERTIVEA 2015; DGNB 2020).

3.4.1. Land-use change

This group is associated with the reuse of abandoned areas, renovation, landfills, and existing networks aiming to contribute to the prevention of the consumption of existing green areas, which leads this group with the measurement of the use of existing infrastructure and networks. Concerning the design phase and the use phase, this measurement is done by checking the actual process, e.g., the development of the greenfield against the existing built environment and the brownfield (ISO 2011).

The first results found that the HQE system does not address this issue in its guide, on the other hand, the DGNB system presents a chapter "ENV2.3- Land use", this group address the reduction of excessive land use for: I) External urbanized area, II) Internal development area and III) Brownfield: For construction purposes, within an existing settlement structure. In the BREEAM system through Land Use and Ecology category, it is encouraged the sustainable use of land, the protection, and creation of habitats, the reuse of sites such as Brownfield or place of low ecological value. Moreover, encourages the impact mitigation, management and improvement of the ecologic system (DGNB 2020; CERTIVEA 2015; BREEAM 2018a). Lastly, the LEED system addresses in the chapter "SS: Site assessment", the parameters to assess site conditions before the design phase to assess sustainable options related to the site. Additionally, it brings a control form for soil erosion, river sedimentation, and airborne dust from construction activities. In the last one, there is the SS criterion "Prevention of pollution from the construction activity", which will prevent pollution by preserving 40% of the green area of the site or restoring a part of the construction site (USGBC 2021).

3.4.2. Access to services

The ISO 21929-1 access to the service is divided into four subgroups; the first is linked to public transportation, which measures the quality, proximity and access to the public transport around the assessed building. Secondly, transport modes measure access to the general traffic network. The third "Green and open areas", has the function of ensuring the quality and proximity to green and open areas, accessible to the public and, finally, the essential services relevant to the user, related to their presence (availability) and quality (number and type and proximity to services (ISO 2011).

During the content analysis of the certification systems, were identified different characteristics among them, the subject of public transport is addressed by almost all of them. Like in BREEAM, this category seeks to assess transport and travel plan to identify improvements and maximize the potential of public, private, and active local transport. While in LEED, the subject is addressed in the subgroup "LT: Traffic Access Quality", which aims to provide a framework to encourage the development of multimodal transport options or otherwise reduce the use of motor vehicles, as well as the subcategory "LT: Bicycle facilities". The DGNB, deals with this matter in the chapter "SITE1.3 Transport access", which promotes sustainable mobility in a variety of ways for building occupants and ensures the creation of sustainable traffic infrastructure (BREEAM 2018a; USGBC 2021).

In contrast, the "access to green and open areas" was only identified in the HQE system in the group "1.3. Quality of the environment of outdoor spaces for users" and healthy outdoor spaces through subgroup "1.3.4. Ensuring healthy outdoor spaces", which intends to pursue, and ensure that the project creates healthy outdoor spaces relating to air and soil quality. In the DGNB system, through the category "SOC1.6- Quality of indoor and outdoor spaces", which has the function to provide for building occupants' indoor and outdoor spaces with quality, also with recreational and functional variety. LEED system has a similar subgroup, focusing only on buildings linked to health centers and not on projects in general (CERTIVEA 2015; DGNB 2020; USGBC 2021).

The access to essential services is addressed only by the DGNB, in the group "SITE 1.4 category Access to amenities", which seeks to meet the daily needs of building occupants through social infrastructure and easy accessibility to commerce. With these three categories, the DGNB system addresses through its subgroups, the themes covered by the aspects of Access to services of ISO 21929-1 (DGNB 2020).

3.4.3.Accessibility

Conforming to the ISO, the accessibility aims to provide access to buildings for users and workers, from the construction to the operational phase through the two subgroups: a) Accessibility of the construction site and b) Accessibility of the building (ISO 2011).

Overall only BREEAM, specifically in the category "Man 03 Responsible Construction Practices", addresses the indirectly related accessibility issues, which are addressed by ISO 21929-1, through an objective of managing construction sites in an environmentally and socially responsible manner. Furthermore, only DGNB has the category "SOC2.1 Design for all" which aims to contribute to the accessibility of the construction environment without restrictions on its use (CERTIVEA 2015; BREEAM 2018a). The HQE system addressed in the group "2.2 Construction options for ease of access during the conservation and maintenance of the structure", in its subgroup "2.2.1. Ensuring Ease of Access for Building Maintenance" describes items but focus on maintenance, in terms of ease access rather than the accessibility of the construction site and/or the building, not precisely like ISO 21929-1. While, in The LEED guide was found no evidence about this subject (CERTIVEA 2015; USGBC 2021).

3.4.4.Internal conditions and air quality

This group is divided into four items, the first, indoor thermal conditions, seeks to measure the quality of indoor thermal conditions that reflect the thermal comfort of users. Second, indoor visual conditions measure the quality of indoor visual conditions that reflect users' visual comfort. The third, is the internal acoustic conditions, which has the function of controlling the quality of the acoustic conditions that can have a potential impact on the acoustic comfort of users and, finally, the fourth, internal air quality, responsible for measuring the quality of the internal air with potential implications for human health, referring to olfactory comfort and perceived comfort of users (ISO 2011).

All four systems address this group in their guides. BREEAM initially linked its criteria with this group mainly through the Health and well-being chapter, seeking to increase the health, well-being, and safety of building users, which are derived from the subgroups "Hea 01 Visual comfort", that incentives practices for better visual performance and comfort; "Hea 02 Indoor air quality", that is used to encourage and support healthy indoor environments with good indoor air quality for users, "Hea 04 Thermal comfort", has the main objective of ensuring that the building is able to provide an adequate level of thermal comfort and to reduce the impact on costs, environment and the risk of comfort, last one "Hea 05 Acoustic performance", its function is to provide a good acoustic environment and generate comfort for users (BREEAM 2018a). The LEED system brings the chapter the "(EQ) Indoor environment quality" group, which in its subgroups address, "(EQ): Minimum indoor air quality performance for the comfort and well-being of building occupants"; "(EQ): Tobacco smoke control, which seeks to reduce the exposure of building occupants to tobacco smoke"; "(EQ): Indoor air quality improvement strategies, which promote the comfort and well-being of occupants, improving indoor air quality"; "(EQ): Indoor construction air quality management to minimize indoor air quality issues associated with construction and renovation" and finally, "(EQ): Indoor air quality assessment, to establish better indoor air quality in the building after construction and during occupancy". The other subjects in this group are addressed by the subgroup "(EQ): Thermal Comfort", which has the function of stimulating users' productivity, comfort, and well-being, followed by "(EQ): Interior lighting" to provide high-quality lighting. Another subgroup, (EQ): Daylight", seeks to reduce the use of electric lighting through daylight in spaces and finally, "(EQ): Acoustic performance", which seeks an effective acoustic design in order to provide spaces that promote well-being, productivity, and communications (USGBC 2021).

The HQE system fully addresses this theme, having more criteria about this subject in addition to the ones covered by ISO 21929-1. Starting with the group for Hygrothermal Comfort, approaching the need for the human body to dissipate metabolic energy, through sensitive and latent heat exchange, this category is subdivided into the following subcategories: 8.1 Architectural arrangements, that aim to optimize hygrothermal comfort, in winter as in summer; 8.2. Creation of hygrothermal comfort conditions in winter; 8.3 Creation of hygrothermal summer comfort conditions in facilities that do not have a refrigeration system and; 8.4. Creating hygrothermal summer comfort conditions in facilities using a refrigeration system (CERTIVEA 2015). Regarding acoustic issues, the Acoustic Comfort group in HQE aims for the quality in terms of the local acoustic environment for occupants in order to influence the quality of work, sleep, and occupant relations. Visual Comfort is related to the user's ability to see certain objects and under certain light sources (natural and artificial) but being dazzled, in addition to having a light and satisfying atmosphere in terms of lighting and colors. Also, it is divided into two subgroups that portray natural and artificial lighting. The first, 10.1. Optimization of natural lighting" and the second is the "10.2. Optimization of artificial lighting". Last, the olfactory comfort subgroup content is related to indoor air quality, which seeks to control certain atmospheric pollutants (odors, Volatile organic compounds, formaldehyde, etc) (CERTIVEA 2015).

The DGNB system's sociocultural and functional quality chapter establishes eight subgroups for this subject. Four of them are related to air quality conditions, in order to assess the buildings, regarding health, comfort, and user satisfaction. Initially, the SOC1.1 Thermal comfort subgroup presents issues of thermal comfort appropriate to the intended use of the building throughout the year, covering the seasons through eight indicators based on different aspects. Then, subgroup SOC1.2 Indoor air quality aims to provide sufficient quality for the health and well-being of users, being an exclusion criterion in the DGNB certification system. The third subgroup, SOC1.3 Acoustic comfort, seeks to obtain acoustic conditions corresponding to the intended use and adequate user comfort, being evaluated according to the use of the rooms during the reverberation time, and finally, the subgroup SOC1.4 Visual comfort searches for a sufficient supply of natural and artificial light for interior areas, considering that visual comfort is an important basis for general well-being and is reflected in work productivity and efficiency, and natural light has a positive effect on mental health and human beings and has an impact on energy savings (DGNB 2020).

3.4.5.Adaptability

Adaptability is seen in two ways, the first related to the user's need and the second to climate change; although both are from the same area, they have different consequences, which are: I) Change in use or user needs and II) Adaptability to climate change (ISO 2011).

In general, adaptability is addressed in the analyzed systems, such as in BREEAM, specifically in the Wst 05 Adaptation to climate change subgroup, which seeks to reduce the future need to carry out adaptation works to meet climate change. The second subgroup Wst 06 Design for disassembly and adaptability, seeks to avoid unnecessary use of materials, costs, and interruptions resulting from the need for future adaptation works through optimized decommissioning. Within this theme, the LEED Guide only presents the subgroup MR-DESIGN FOR FLEXIBILITY, in order to conserve resources associated with the construction and management of buildings, designing for flexibility and ease of future adaptation and the useful life of components and assemblies, being discussed in parts what is described in the adaptability aspect of ISO 21929-1. In the case of HQE, adaptability is treated by subgroup 2.1. Constructive choices for the durability and adaptability of the structure that understand that products, systems, and construction processes influence the adaptability of the structure. So, it has criteria that contribute to the optimization of future renovations and remodeling and reduce the sources of waste, pollution, and other annoyances. And finally, the DGNB system, in the group ECO2.1Flexibility and Adaptability, aims to make the construction project as flexible as possible through a high proportion of usable area in relation to the total area of the building, which allows conversion to other uses (DGNB 2020; USGBC 2021; BREEAM 2018a; CERTIVEA 2015).

3.4.6. Cost

Cost-related issues have a potential impact on the accessibility and value of the building, it has the functionality of measuring all costs involved in buildings, such as start-up, operating, maintenance, and end-of-life costs (ISO 2011). This issue is not addressed equally by the analyzed certification systems. In the HQE, it did not find any evidence regarding the costs criterion. In LEED this subject is approached through the subgroup “Integrative Process”, which seeks to encourage the development of high-performance and cost-effective projects by addressing other aspects, such as water management and maintenance capacity, impacting the cost and the “Planning and Integrative Project Design”, which seeks for the integration and cost-effective adoption of green design and construction strategies. Proposing the integration of a life cycle cost analyst into the project team, in order to estimate the construction cost. Similarly, in BREEAM through “Man 02- Life cycle cost and service life planning”, seeks to promote business cases, focusing on sustainable buildings, by encouraging the use of life cycle cost to improve the project. This system also approaches lifetime maintenance and operation issues (CERTIVEA 2015; USGBC 2021; BREEAM 2018a). Last, the DGNB system addresses it in the subgroup “ECO1.1 - Life cycle cost”, which searches for a more conscious use of economic resources throughout the life cycle of a building. In addition, there are two more variant subgroups for this subject, the first one is “ECO2.1 Objective flexibility and adaptability”, despite having a focus on maintenance capacity issues, has correlated themes that aim to reduce the costs incurred throughout its life cycle. The subgroup “ECO2.2 Commercial viability”, seeks to create buildings with maximum user acceptance and long-term market potential (DGNB 2020).

3.4.7. Maintenance capacity

In order to measure the quality of the project, the construction and its structures and surfaces, and the quality of the maintenance plan, this area allows this control to contribute to the comfort of users and to the building's operating capacity (ISO 2011). The systems approach on this subject is not entirely similar to ISO 21929-1. In particular, BREEAM in the subgroup “Man 04 - Commissioning and delivery”, aims at encouraging properly planned delivery and commissioning, which can reduce operation and maintenance costs through efficient maintenance schedules, thus extending the life of systems and effective operational and maintenance personnel. Similarly, LEED in the subgroup "(EA) Fundamental Commissioning and Verification" addresses programmatic and operational parameters, which are indirectly associated with serviceability (BREEAM 2018a; USGBC 2021). The HQE system, on the other hand, attributes more direct criteria about building in the group maintenance process, within the subgroup "2.2 Constructive options for ease of access during the conservation and maintenance of the structure, pursuing a way to ensure that the structure maintenance process is conducted take into consideration the subgroup "2.2.1. Ensure ease of access for building maintenance", seeking to guarantee that the building maintenance can be carried out in good access conditions. The DGNB system, which has "the Maintenance Capacity criterion", which is correlated with another subgroup called the Ease of Maintenance, that appears in the subgroup "PRO1.5 - Documentation for sustainable management", focusing to ensure that the expected performance of the building is achieved in fact. Besides, through the "6.2 Maintenance care" subgroup, aims to accomplish it, ensuring that the caring for the outdoor area and environmental quality, remains operational (DGNB 2020; CERTIVEA 2015).

3.4.8. Safety

Safety is addressed in three parts by ISO 21929-1, being the first one the Structural Stability, which has the function of measuring stability against loading and expressing the building's ability to provide safe and resistant shelter. Followed by the fire safety, which is the ability to provide safe and resistant shelter with possible impact on the safety of users and occupants of the building and safety in use, reflecting on the safety of users and occupants, while limiting the potential risk of tripping, falling, and other types of accidents (ISO 2011). In this topic, only the DGNB system addresses it in its subgroup "TEC1.1 Fire safety as an integral part of the certification procedures", considering that fire events not only endanger the lives and safety of humans and animals, but also damage the structure of the building. In addition there is a subgroup "SOC1.7 Protection and safety criterion", linked to safety in use, that has a different focus when compared to TEC.1.1, which establishes a design concept in order to avoid dangerous situations in the buildings and surroundings (DGNB 2020).

3.4.9. Maintenance

According to the standard, from the point of view of functionality, ease of maintenance reflects the building's suitability to meet the user's requirements in terms of space design, building information and communication technology services concerning the proposed use and conditions of the user (ISO 2011). According to what was found during this research, the certification systems analyzed approach this issue slightly differently than ISO 21929-1. For example, the BREEAM framework addresses this issue by the "Wst 05 Adaptation to climate change criterion". Furthermore, this is associated with climate issues and is not a direct indicator of ease of maintenance. A similar situation occurs with LEED, in the subcategory "(EA): Commissioning and fundamental verification". Where It has a criterion linked to the preparation and maintenance of the current requirements for the facilities and also has an operations and maintenance plan with the necessary information to operate the building efficiently (BREEAM 2018a; USGBC 2021). On the other hand, the HQE system content is directly associated with the maintainability criteria established by ISO 21929-1. Such as the criterion "2.2.1. Ensure easy access for building maintenance", a subgroup of"2.2. Constructive options for ease of access during maintenance and maintenance of the structure", aims to ensure that the maintenance is in good access conditions, and it intends to obtain data from customers about the frequency according to the uses, needs, materials, and so on. The same occurs with the DGNB system, the group symbolically linked through Ease of Maintenance and Maintenance Capacity, by the subgroup "RO1.5- Documentation for sustainable management", ensuring that the planned performance of the building is achieved, with the smallest possible plans deviations, providing this information to the owner, tenant and manager of the management facility (CERTIVEA 2015; DGNB 2020).

3.4.10. Aesthetic quality

This group measures the aesthetic quality of the building in a qualitatively way through criteria such as "the integration and harmony of the building with its surroundings", "the impact of a new construction" or "renovation of an existing building on the cultural value of a site, neighborhood, local heritage and environment" (ISO 2011). Only HQE and DGNB systems sort of approach this issue. Initially, it is possible to identify that it in the HQE on the groups "1.3. Quality of the environment of outdoor spaces for users", through subgroup "1.3.6. Visual disturbance", which concerns the architectural quality of the project. On the DGNB guide, specifically "SITE 1.2 - Influence on the District's Objective", from the Site Quality dimension, establishes criteria for the building to exert a positive influence on the neighborhood (DGNB 2020; CERTIVEA 2015).

4. ISO 21929-1 criteria verification *versus* certification

In the last step of Bardin's method, called the final treatment of results, important text fragments collection for content analysis were summarized (content capture), since in this case study we want to verify if the certification systems also cover the issues raised by ISO 21929-1. The first group - air emissions, was identified in the four systems. However, it was observed a different approach when compared to ISO 21929-1. The systems associate emission directly with energy consumption, which is addressed more significantly. The ozone depletion potential is related to refrigerants in heating systems. The DGNB addresses air emissions issues differently through the life cycle chapter, interweaving with other factors. The use of non-renewable resources is related to the consumption of non-renewable raw materials and energy, and they are referred to in the certification systems guides. However, they are presented in a different way than it is presented in ISO 21929-1. Still, we cannot assume that this is an aspect neglected by systems. The water consumption group has a specific chapter for this issue in each system. However, each system follows a different approach, with only the BREEAM system presenting similar criteria when compared to ISO 21929-1. The same happens with the waste management aspect, there is a particular chapter for this issue in each system. The group of land-use change is approached in almost all systems, which present all the essential criteria. Nevertheless, it was not possible to identify any structure in the HQE related to land use. Access to services is dived into four subgroups, public transport, modes of transportation, access to green areas, and basic services. In general, almost all systems present criteria for public transport and transport modes, having their own structures. The exception was the HQE system, which did not have this item. Access to green areas is discussed in a vague way in LEED and HQE, and the DGNB covers in details the four themes. Accessibility is fully addressed by the DGNB, unlike LEED where it was not identified this subject in its structure and the others approach the topic in a vague way. In contrast, indoor conditions and air quality are present in the four systems. Paying special attention to the HQE, which has numerous subcategories about this matter. The adaptability group is divided into two subgroups: 1)User needs and 2) Adaptability to climate change. In BREEAM was identified only a criterion linked to this issue, while the others partially address it. The group cost-related issues were not identified in HQE. In contrast, the DGBN system has a specific chapter just for this aspect. The

BREEAM system has similar criteria to those covered by ISO 21929-1, whereas LEED has few criteria about costs. Serviceability is treated in almost all systems. Only the LEED system addresses this issue moderately, since it does not have all the criteria discussed in ISO 21929-1. Safety issues, including structural stability, fire safety, and safety in use, were only identified in the DGNB system. Similarly happens with the group of aesthetic quality, which is fully addressed by the DGNB, also it only detected some vague criteria about it in the HQE system. Ease of maintenance is referred to in all systems, with BREEAM and HQE covering all the criteria given by ISO 21929-1, followed by LEED and finally the DGNB, which vaguely addresses it. In general, only the DGNB system presents the 14 aspects discussed by ISO 21929-1, with a total or partial approach. The other systems lack at least one of the aspects, as can be seen in Figure 2.

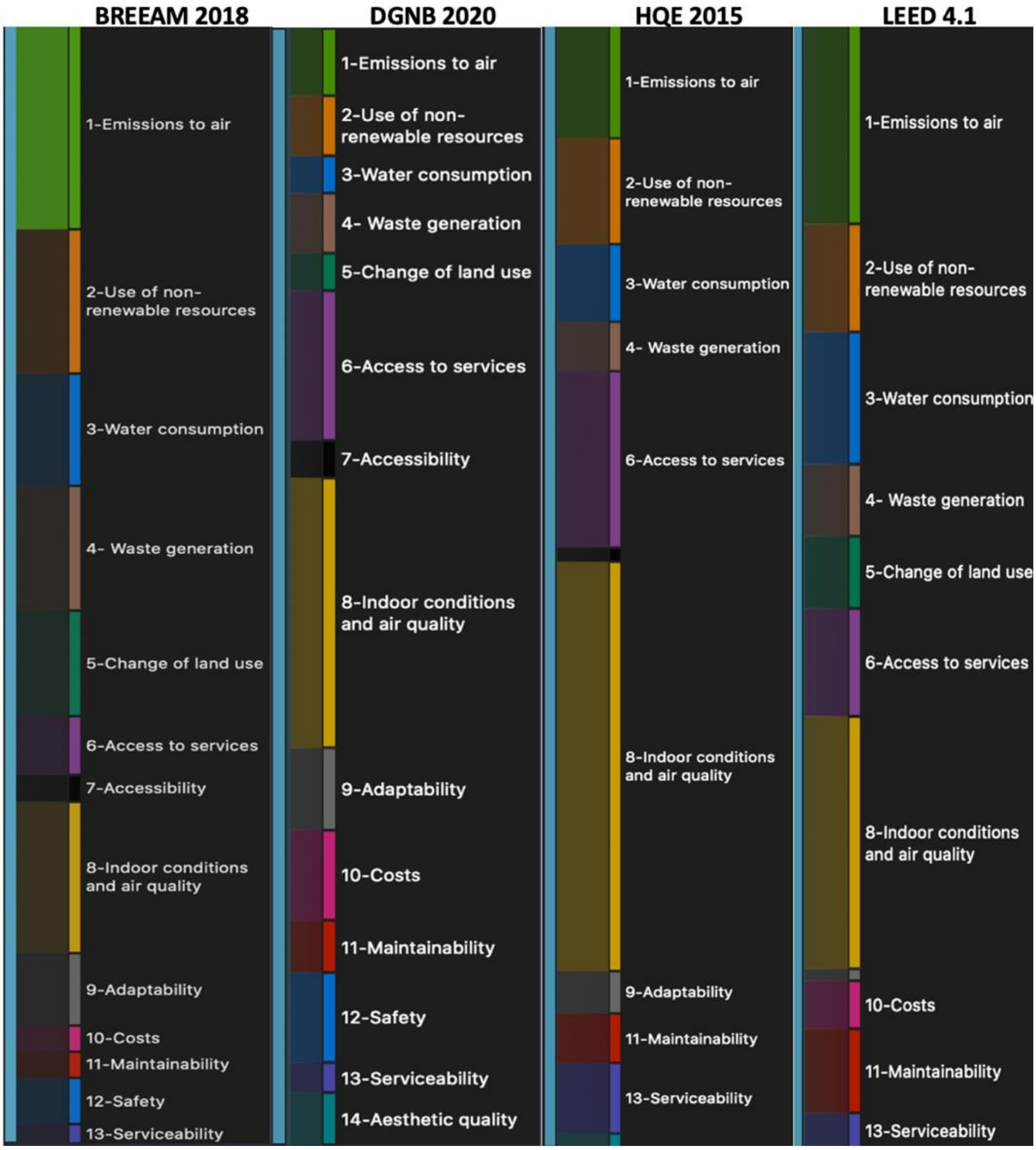

Figure 2: Sustainability groups based on ISO 21929-1, the size of each bar is based on the amount of content addressed by each sustainability certification system

4.1. Correlation between aspects

Another possible scenario to be observed regarding the results of the content analysis carried out on Atlas.ti, refers to the correlations among the aspects that the sustainability certification systems bring. Basically, it is possible to see how the groups are treated more individually or together with other groups. The BREEAM and LEED systems are the ones that have the most correlations between their aspects. Like LEED Emissions group, that is also presented in the maintainability and maintenance capacity groups. A similar situation occurs with the BREEAM waste generation aspect, at the same time that it is covered in its own chapter, it is also covered in the Adaptability, Safety and Serviceability chapters. On the contrary, the DGNB system is the one with the lowest correlation among groups. Meaning that this system closely matches the aspects of ISO 21929-1, a factor that can contribute to the isolated understanding of the aspects, when necessary. Finally, the HQE system has an intermediate position among the systems, presenting only two correlations with the groups, unlike LEED and BREEM, which have three correlations in most aspects. In the DGNB case, it has a correlation among most of the groups. Figure 3 and Figure 4 present these total correlations in a general way.

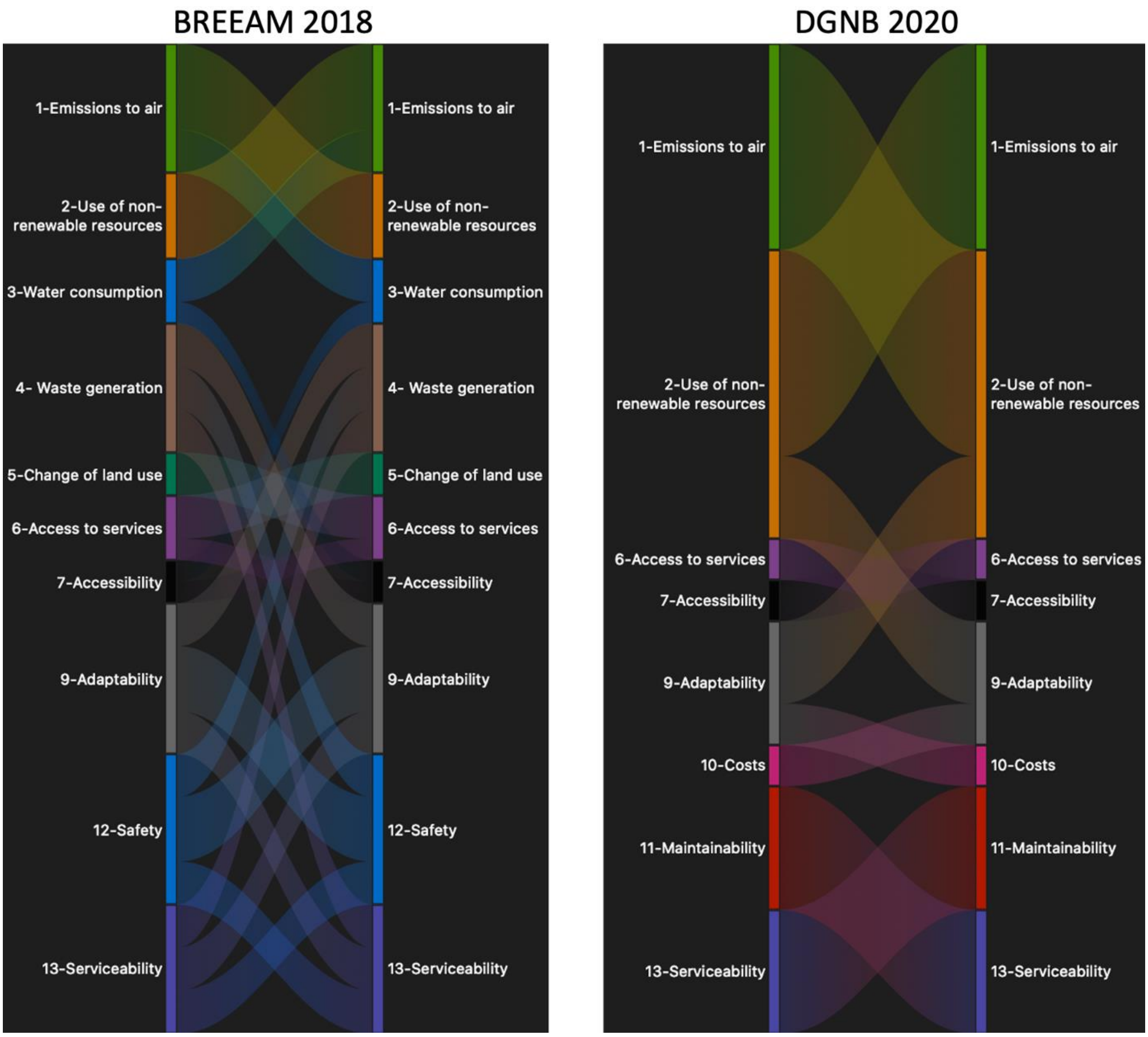

Figure 3: Connections of the sustainability groups (BREEAM and DGNB) based on ISO 21929-1 addressed in the certification systems, this shows when one group is addressed jointly with another group

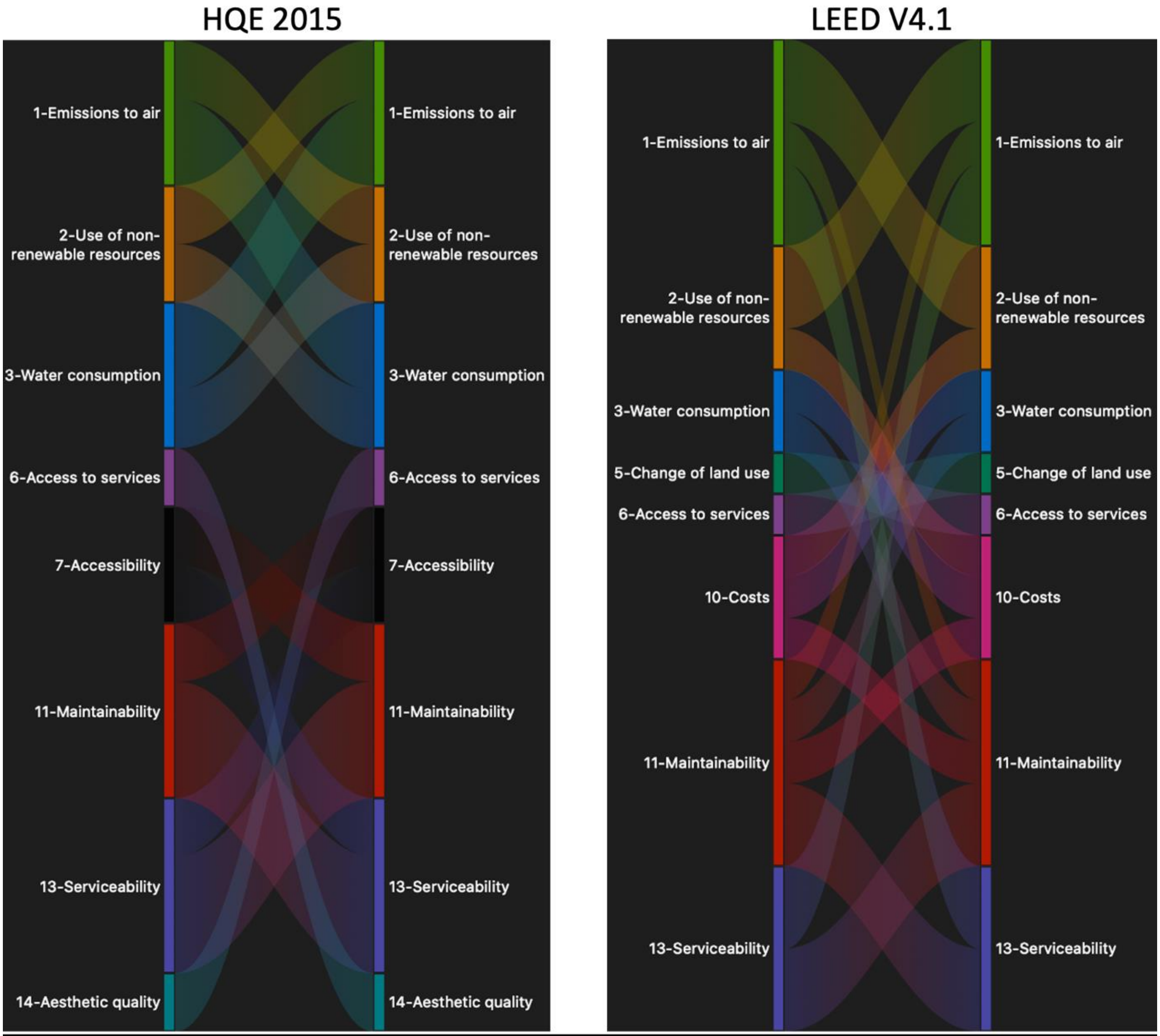

Figure 4: Connections of the sustainability groups (HQE and LEED) based on ISO 21929-1 addressed in the certification systems, this shows when one group is addressed jointly with another group

5. Conclusions

One of the objectives of this study is to contribute toward a distinguished view regarding the comparison among the sustainability certification systems. Principally when the main purpose of this work was to use an international standard as a reference for comparison, in this case, the ISO 21929-1, in other words, it is not just a comparison among systems as was previously done in other studies. In addition, the adopted methodology in this research, the qualitative content analysis created by Bardin, pursues to understand the content examined, in other words, this method focuses on how the subject is described and not on questions about subjects' weights, punctuation, and classification. Therefore, this study can indirectly contribute to other studies about systems comparison. Beyond that, it can help to a better understanding of the sustainability certification systems behavior. Besides, the four certification systems (BREEAM, DGNB, HQE, and LEED) chosen in this study have significant worldwide representations. In addition, it was possible to identify that the DGNB was the only one that addressed in fully the fourteen aspects brought by ISO 21929-1. A factor that may have influenced it is that its structure refers to the Environmental Product Declaration. This declaration was developed in accordance with ISO 14025 and EN 15804 standards, being considered a system that fulfills the definition of sustainability of the European Union. Additionally to other comparisons, was found that the sustainability certification system showed that the triple baseline components of sustainability are well balanced, and equally distributed (Varma and Palaniappan 2019; Zimmermann et al. 2019; Polli 2020).

However, HQE and LEED systems were the ones that had the minor aspects of ISO 21929-1 mentioned in their guides, with eleven of the fourteen aspects, this does not mean that they are less efficient though. It is worth mentioning that despite their differences, they have unique strengths. For instance, the aspect related to Internal conditions and air quality - with four features about this subject, naturally had more content addressed by all systems, as exhibited in Figure 2 (the size of the aspect color bar refers to the amount of content identified)and among the four systems, HQE was the one that addressed this aspect the most. In terms of weight of importance in the evaluation calculation, a similar result was noticed by other authors, that HQE focuses mainly on the aspects of Health and Quality, which corresponds to 50% of all significance (Mattinzioli et al. 2020).

Something similar happens with LEED, it does not have such a deep focus on internal conditions and air quality as HQE, but its content showed to be very detailed during the guide analysis. Analogous results were found by other authors who claim that health and well-being, together with the ability to modify the built environment has an essential factor that can influence behaviors and quality of health outcomes. Therefore, it was observed that LEED has a higher potential for health promotion, due to the language used to describe the potential benefits of a health credit present in its structure (Worden et al. 2020).

Finally, the BREEAM system, in this one it was noticed that it brought thirteen of the fourteen aspects of ISO 21929-1. However, it is possible to see that the initial aspects about: Air Emissions; Use of non-renewable resources; Water Consumption, Waste Generation, and Land Use correspond to half of the content identified when compared with ISO 21929-1. Meaning that most of the content covered in this system is from the environmental area, this goes hand in hand with the own system analysis score. Meaning that the environmental aspect corresponds to almost 3/4 of participation in the total score of the BREEAM system, suggesting that it can be considered a green evaluation system rather than a sustainable evaluation system (Doan et al. 2017; Sharifi and Murayama 2013).

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