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Abstract

The building industry has an enormous impact on the environment, economics, and society. Therefore, the promotion of green building concepts is essential for all countries nowadays. Started in the mid-1980s the sustainable sector has grown a number of diverse rating systems, which serve to evaluate green buildings according to certain standards. Some certification tools assist small groups within the building sector, accentuating the countries local demands, others have grown into big international certification systems used for different purposes by varied groups of people. The major focus of this paper is on the overview of the most widely recognized and used green building certification systems, such as BREEAM, LEED, and DGNB, with an emphasis on the evaluation measures used, similarities, and differences between these systems. The certification of sustainable real estate will become more and more important in the future. Not only the advantages in renting and selling excellent properties are important. Mankind also benefits from a balance between ecological, economic, and social aspects. It is believed that the national interests of the certification systems will be left out in the future and instead a uniform intention to protect our environment for prospective generations will be pursued, thus creating a homogeneous basis among the systems.

Keywords: Green Building Certification System; LEED; BREEAM; DGNB; sustainability; assessment tools

The building sector has extensive influence on the environment we live in, country economics, and society. During the erection phase, demolition, occupancy period, or renovation, buildings use energy, water, and materials and are substantial emitters of waste and CO_2. According to Global Status Report, 2019, published by United Nations Environment Program (UNEP) “the buildings and construction sector have accounted 36% of global energy use and 39% of process-related CO_2 emission, 11% of which resulted from manufacturing building materials and products such as steel, cement, and glass”. Buildings significantly contribute to climate change, which can be easily proven by looking at their large environmental footprint (Reed, et. al., 2008). This fact has incentivized the establishment of green building standards, certification, and rating systems, intending to mitigate the effect of the construction industry on the environment through a sustainable approach.

The push towards sustainability started in the mid-1980s in response to a series of catastrophic disasters such as The Bhopal disaster (1984), the Chernobyl nuclear explosion (1986), and the Exxon Valdez tanker spill (1989) (Baumann, Tillman, 2004). The term “sustainability” was first coined in the Brundtland Report in 1987 composed by several countries for the United Nations (Active Sustainability, 2019). This prompted the launch of the Building Research Establishment Environmental Assessment Method (BREEAM) in 1990, the first green building rating system in the world (Reed, et. al., 2009). Three years later U.S. Green Building Council (USGBC) issued a mission to promote sustainability-focused practices in the building and construction industry (World Green building Council, 2020). They were also responsible for the further establishment of the Leadership in Energy and Environmental Design (LEED) certification system in 1998 (U.S. Green Building Council, 2020). Since the first release, these certification systems have continued growing in significance and variety.

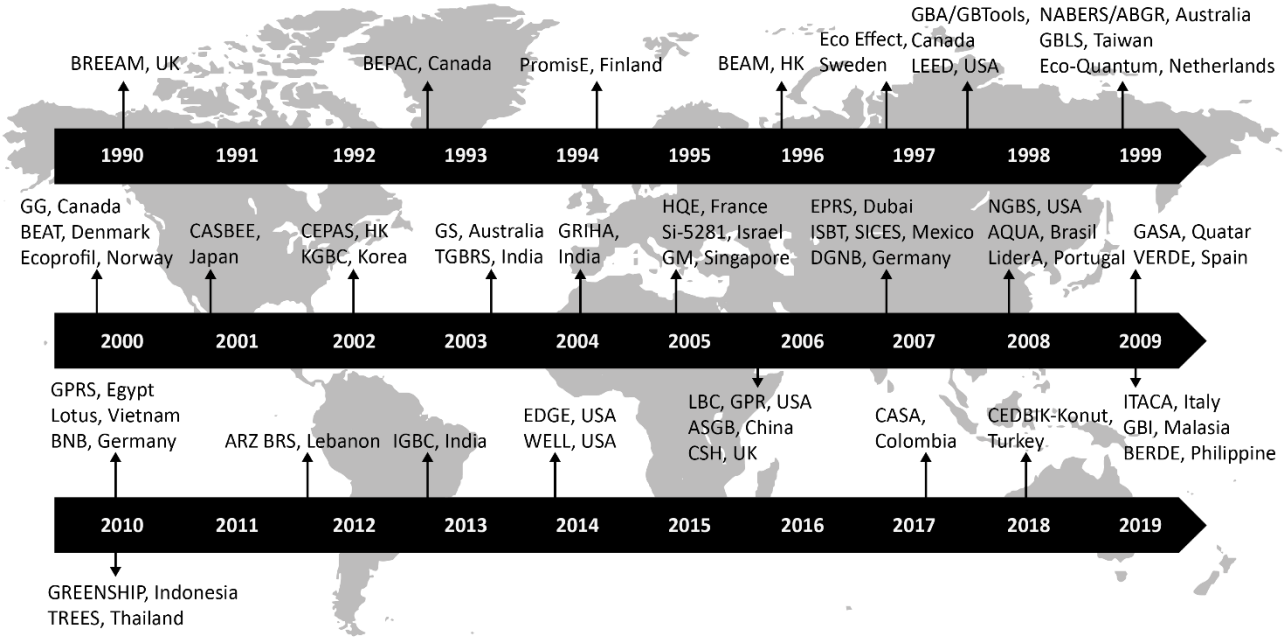

Figure 1. Timeline of green building rating system (GBRS) development
Source: Yinqi Z, et al., 2019, *A Survey of the Status and Challenges of Green Building Development in Various Countries*

Until now plenty of countries have developed their own rating tools for a sustainable design tailored to their national priorities and requirements (Fig. 1). Other rating systems strive to go beyond the current limits and follow specific aims, such as the ‘net-zero energy concept’ or ‘living and restoration building concept’. On the one hand, this variability creates complications for parties, which purchase buildings in different countries. However, based on individual characteristics of a specific country, i.e., the climate type and natural resources, evaluating the sustainability level of the buildings might be more objective and quite beneficial

(Dixon, et. al., 2008). For instance, Germany introduced its own certification system in 2007. DGNB (Deutsche Gesellschaft für nachhaltiges Bauen e.V., DGNB in German) is generally treated jointly with BREEAM and LEED as one of the most internationally spread systems today (Kosanovic, et. al., 2018).

This paper is focused on an overview of the most widely recognized and used green building certification systems, such as BREEAM, LEED, and DGNB, with an emphasis on their specifics and real-world implementation. Nevertheless, before going to the single system evaluation part, we will take a closer look at the common criteria necessary to obtain a green building certificate and who has the interest to receive one.

What is a green building?

To make a building green you need to follow an integrated design process for a project to be environmentally responsible and resource-efficient throughout a building lifecycle: from siting and design to construction, maintenance, renovation or refurbishment, and demolition. According to World Green Building Council (2021), some features can contribute to a green building:

- Efficient use of energy: reducing the carbon footprint on the environment with the use of renewable energy sources (such as solar, wind, or geothermal energy, etc.).
- Water use: preserving and optimizing utilization of existing water cycle; retaining and turning stormwater into potable water, through filtration on location; recycling wastewater for the second use, and therefore preserving the existing natural hydrological ecosystem.
- Construction materials: the building needs to use eco-friendly, efficient, and sustainable construction materials, which can be recycled at the end of its lifecycle.
- Pollution and waste reduction measures: building CO_2 emission is to strive to zero, especially over the erection phase.
- Indoor comfort: the building should provide optimal comfort indoors, through efficient maintenance of air quality, temperature, and ventilation, sufficient daylight to conserve electric energy.
- Consideration of the environment in design, construction, and operation: the building is created through sustainable development, without damaging the existing ecosystems.
- Location: the site and its surrounding conditions influence the comfort of the inhabitants.
- Consideration of the quality of life of occupants in design, construction, and operation.
- A design that enables adaptation to a changing environment.

Whereas philosophy, approach, and certification methods range across the systems, a common intention of any certified building is to reduce the overall impact of the built environment on human health and the natural environment.

There are rating systems available for new buildings, which focus on all construction phases, as well as for already existing buildings, which focus on functioning and maintenance through the building lifetime.

The systems also differ in the building type they are applied to, such as residential or commercial construction, or even districts or neighborhoods (Worldgbc, 2021).

Benefits of using green building certification systems

Willingness to obtain a green building certificate for the project can vary. Certification validates the green nature of the project and can be a precious educational and marketing tool for both owners and design and construction teams while they create a sustainable building. Rating systems also distinctly define the green standards needed to be followed and the kinds of sustainable products that might be used in the project. Beyond that, the certification process can also encourage society to develop and promote highly sustainable construction practices. However, not all truly sustainable buildings strive to acquire a corresponding certificate.

The significantly growing number of certified green buildings (Globenewswire, 2021), as well as system types, demonstrates to us the expanding popularity of the certification process all around the world. One of the reasons for this surge is the multiple benefits given to accredited buildings (Fig. 2).

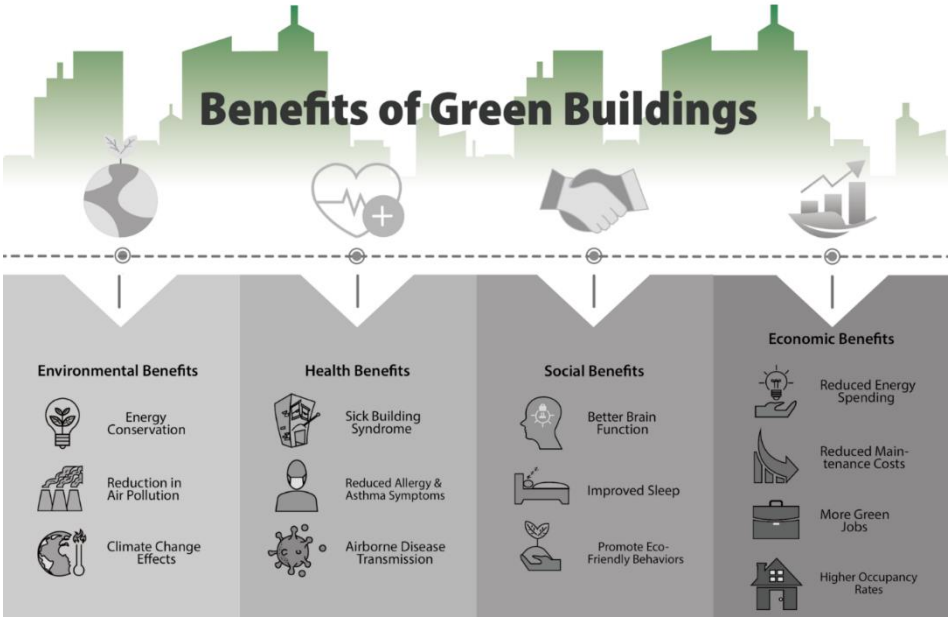

Figure 2. The most impactful green building benefits across a variety of areas.

Source: Miniwiz.com, October 14, 2020, *What are the Biggest Benefits of Green Buildings?*

Environmental

Probably the most important contribution of the green building sector is its low influence on the natural environment (Best, 2021). Firstly, green buildings reduce a negative impact on nature by using fewer resources and producing fewer pollutants. Besides that, they improve the current situation by, for instance, generating more energy and, therefore, supplying surrounding neighborhoods, or increasing the biodiversity of living beings.

- As one of the biggest consumers of global energy – 40% of the total energy usage (IEA, 2020) – the building sector has the largest potential to reduce greenhouse gas emissions (UNEP, 2009).
- The building sector is able to limit the global temperature increase to 1,5^{o}C, which corresponds to the Paris Agreement from 2021 by making new constructions and 20% of the existing building stock carbon zero till 2030 (IEA, 2021).
- According to a UNEP report from 2020, the building sector consumes 25% of global water, where 15% is potable water (15 trillion gallons per year). Water efficiency efforts in green buildings are expected to reduce water use by 15 percent and save more than 10 percent in operating costs (Geological Survey U.S., 2000; Hill, 2011), which could be the equivalent of removing 15,000 cars from the road for one year (EPA, 2011).
- The building sector operates 40% of all global resources (UNEP, 2020). Meanwhile, green buildings use fewer resources and minimize waste. Only LEED projects are responsible for diverting more than 80 million tons of waste from landfills, and by 2030 that number is expected to grow to 540 million tons.

Economic

Green buildings are capable to offer a number of economical benefits to individual people as well as to groups of people. These can constitute cost savings on utility bills for tenants or households (through energy and water efficiency); lower construction costs and higher property value for building developers; increased occupancy rates or operating costs for building owners; and job creation (Worldgbc, 2021).

- Green buildings reduce day-to-day costs. For instance, LEED reports maintenance costs reduced by 20% compared to typical commercial buildings (Fowler, et al., 2011).
- According to the report by European Commission in2015 total energy savings can be increased from €280 to €410 billion.
- The green buildings industry is outpacing overall construction growth and continues to rise (Schutters, 2015). It contributes to new full-time job creation: 1.1 million jobs and $75.6 billion in wages in the United States by 2018 (USGBC, 2018); and 300.000

jobs and $23.45 billion in GDP in Canada in 2014 (Canada Green Building Council, 2016).

Social

Above the environmental and economic benefits, the green building sector contributes to health and well-being.

- Workers in green, well-ventilated offices with lover levels of indoor pollutants have significantly higher cognitive functioning scores (Harvard, 2015).
- Green buildings positively affect overall public health by reducing risks of asthma, respiratory allergies, depression, and stress (Singht, et. al., 2010). Moreover, the studies from the Academy of Sleep Medicine, 2013, have shown that employees in offices with windows slept on average 46 minutes more per night.
- USGBC's research from October 2018 showed that employees feel happier, healthier, and more productive in green buildings.

BREEAM

The Building Research Establishment's Environmental Assessment Method (BREEAM) is the original version of all certification systems for sustainable building. BREEAM was developed by the Building Research Establishment (BRE) in Great Britain. It was the first certificate to assess sustainable building quality. Most other sustainability certificates are based on the content and assessment procedures of the original British system (Ebert, 2012). BREEAM evaluates the use of energy and resources, indoor air quality as well as the implementation and organization of construction activities (Makkie, 2010). Through a network of operators and experts, BREEAM is locally adapted as well as applied. The use of BREEAM helps to measure and reduce the environmental impact of buildings (BREEAM DE, 2018).

History

Under the name of Building Research Station, BRE was founded in 1921 as a governmental organization. It was concerned with the development of standards for materials and housing construction. Besides this existed organizations concerned with research on wood-based materials and fire protection. In 1972, all these organizations merged under the name Building Research Establishment. In the early 1980s, the development of the certification system took place. With the first system variant for an office building, it was launched in 1990. This assessment tool for new office buildings was the start of BREEAM. Initially focused on national application, over the years, BREEAM also developed on an international level. After the privatization in 1997, the focus was increasing on contract auditing and certification of buildings and construction products. BREEAM has been revised several times over the years and extended to different building types. Since 2008 the current system is valid. In addition to certification, the tasks of BRE Global today also include the testing and approval of fire protection and safety systems as well as quality inspections. It is also responsible for the training and examination of BREEAM assessors and acts as a founding member of the United Kingdom Green Building Council. Despite an internationalization of the system and application abroad, the focus is definitely on the UK. This is due to the government's requirements for newly constructed residential buildings, which is why there are a large number of BREEAM registrations and certifications (Ebert, 2012).

System variants

Within the UK as well as on an international level, BREEAM offers a wide range of system variants for different types of use. BRE Global Limited is the National System Provider of BREEAM in the UK. It develops and operates a range of BREEAM systems for the UK and internationally. In each case, the environmental performance of buildings is assessed at

different stages of the life cycle (BREEAM DE, 2018). In Great Britain, BREEAM UK offers a broad variety of distinct options. In the following a selection is listed:

System variant	**Contents**
BREEAM Office	Evaluation of new buildings or extensive renovations of office buildings in the planning phase or after completion in operation.
BREEAM Education	Evaluation of new buildings or extensive renovations of educational buildings, for example, schools, in the planning phase or after completion.
BREEAM Industrial	Evaluation of logistics buildings, factories, and workshops in the planning phase and after completion.
BREEAM HealthCare	Evaluation of clinics and health care buildings in different life cycle phases.
The Code for Sustainable Homes	Since April 2007, the code for sustainable homes has been applied for the certification of newly constructed residential buildings.
BREEAM Multi-Residential	Evaluation of student residences, retirement homes, and similar buildings in the planning phase and after completion.
BREEAM Communities	Evaluation and improvement of neighborhood developments under sustainability aspects.

(BREEAM UK, 2021)

All sustainability certification systems have emerged in local markets. No system can really fulfill the claim of being applicable in other countries. Outside the UK, mainly country-specific schemes are used. Through cooperation between BRE Global and a national organization in the respective country, a country representative, the so-called National Scheme Operator (NSO) is created. This operator develops the country-oriented approaches based on BREEAM and takes local requirements and standards as well as climatic conditions into account (Lakenbrink, 2012). The German licensee of BRE Global and thus promoter of BREEAM DE is the DIFNI (Deutsches Privates Institut für Nachhaltige Immobilienwirtschaft GmbH & Co. KG) launched the German version of BREEAM in March 2012. With BREEAM DE, all non-residential buildings can be assessed and awarded (DIFNI). There are several BREEAM systems for different building types and application areas. BREEAM can be applied to new buildings, office and commercial buildings, as well as to infrastructure facilities and entire urban districts (Schoof, 2018).

With BREEAM Europe, BRE has developed an international system, that have been adapted to the respective climatic and regional conditions. The European Union developed BREEAM Europe and thus responds individually to different national standards and regulations. Depending on the building use, the system alternatives of BREEAM Europe differ into, for example, BREEAM Europe Offices, BREEA; Europe Retail or BREEAM Europe Industrial, to name just a few (Draeger, 2010).

Certification process

The BREEAM certification process covers various planning and construction phases. At the beginning of the certification process, the project/object must register for a specific form of the system. An approved BREEAM assessor must be engaged after the fitting system version has been selected for the project. This assessor accompanies the complete certification process, carries out building inspections, and prepares documentation. In addition to this, a BREEAM Accredited Professional can be consulted. With this expert, a lot of knowledge in the field of sustainable building and certification process can be obtained to achieve the highest possible score in the evaluation. The level of certification to be achieved is then determined (Ebert, 2012). The documents are then sent to BREEAM or its national representatives for verification. If there are no discrepancies, the review takes about three weeks. The information is then sent to the assessor and the building owner (Hellerforth, 2014). After that, the assessor registers the project with BREEAM. The final valuation will be made after the completion of the object (Ebert, 2012).

Evaluation method and criteria

BREEAM's evaluation system is one of the most common and internationally recognized certification systems for sustainability in buildings and includes a variety of assessment criteria to evaluate the performance of a building. Depending on the type of project, BREEAM assesses the sustainability of buildings in up to ten categories (Schoof, 2018), which are mentioned in more detail below.

The BREEAM assessment is based on a scoring system for different criteria at the global and local levels. The three levels of evaluation apply to both the buildings themselves, as well as their design and management. The better the environmental performance of a building is rated, the more points are awarded for each area. The maximum score is 100, which is a parameter of the overall score. The further development of BREEAM is a valuation based on a full Life Cycle Assessment (LCA) of the building. The classification of a building depends on the weighted sum of the scores for all criteria (Makkie, 2010). BREEAM's scoring system is divided into ten rating categories, according to which there is a seal of approval in six gradations depending on the points achieved. During the evaluation, the categories are weighted differently, which depends on the respective system variant. The main evaluation criteria groups are:

- Management – 12,0%
- (Health &Well-being) – 15,0%
- Energy – 19,0%
- Transport – 8,0%
- Water – 6,0%
- Materials – 12,5%
- Waste – 7,5%
- (Land Use & Ecology – 10%
- Pollution – 10%
- Innovation – 10%

(Hellerforth, 2014)

A certain number of individual criteria are awarded for each main category. Each main criteria group contains a different number of individual criteria. The total number of points achieved for all evaluation categories results in the score (Draeger, 2010). The points of each category are added together and compared to the maximum achievable points in this category. The fulfillment percentage of category results from the ratio between the achievable and the achieved score. Based on the listed percentages of a category in the total score, the overall fulfillment level of a building is thus added up (Ebert, 2012).

BREEAM awards the six different certificates in descending order:

- **outstanding** >85%,
- **excellent** >70%,
- **very good** >55%,
- **good** >40%,
- **pass** >25%
- **acceptable** >10 %
- **unclassified** <10%

(Ebert, 2012).

Through its certifications, BREEAM aims to recognize the value of better performing buildings by rewarding sustainability over the entire life cycle of design projects. BREEAM is currently present in over 78 countries. Since its launch in 1990, 590,000 buildings have been certified with BREEAM to date (BREEAM UK, 2018).

LEED

LEED is a green building classification system that stands for “Leadership in Energy and Environmental Design”. It is a sustainability certification used worldwide, which defines a set of standards for environmentally friendly, resource-efficient, and sustainable construction. The LEED system was developed on the basis of the British BREEAM certification system by the U.S. Green Building Council in 1998. As with BREEAM, buildings are evaluated by awarding points for individual criteria. The resulting total score determines how the building is classified and rated. In the assessment, the system refers to all phases of the life cycle (Baunetzwissen, 2021). The reason for establishing such certification systems is that the building sector consumes an enormous number of resources and energy and also produces a great deal of waste. Sustainably designed buildings are primarily intended to curb the consumption of energy and resources so that CO_2 consumption is reduced (USGBC, 2021). In Germany, the term sustainability originates from forestry and was defined in 1713 by Hans Carl von Carlowitz, who was minister of mining in Saxony in Germany. The term was used to describe the practice of not harvesting wood faster than it grows back. Sustainable development is therefore development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). Sustainability and environmental protection are thus closely related. In the United States, the Green Building Council, an agency that promotes sustainability the best practices in construction and disseminates knowledge related to environmental protection, provides a means to measure the environmental impact of buildings. Since 1999, the year when the LEED Green Building Rating System for New Construction was first published, it has been an important aid for building professionals and, in general, for all stakeholders, as it allows them to increase the benefits of the sustainable approach. The program is a voluntary certification that aims to strengthen and promote the high performance of sustainable buildings. Through the building evaluation, the designer has the opportunity to immediately know the scope of his design decisions related to environmental impacts, which are divided into nine categories that concern and involve the health of people and the environment. The categories are in turn divided into requirements that are evaluated on a scientific basis. The following pages show the amounts of points that are given for each category (USGBC, 2021).

Certification Process

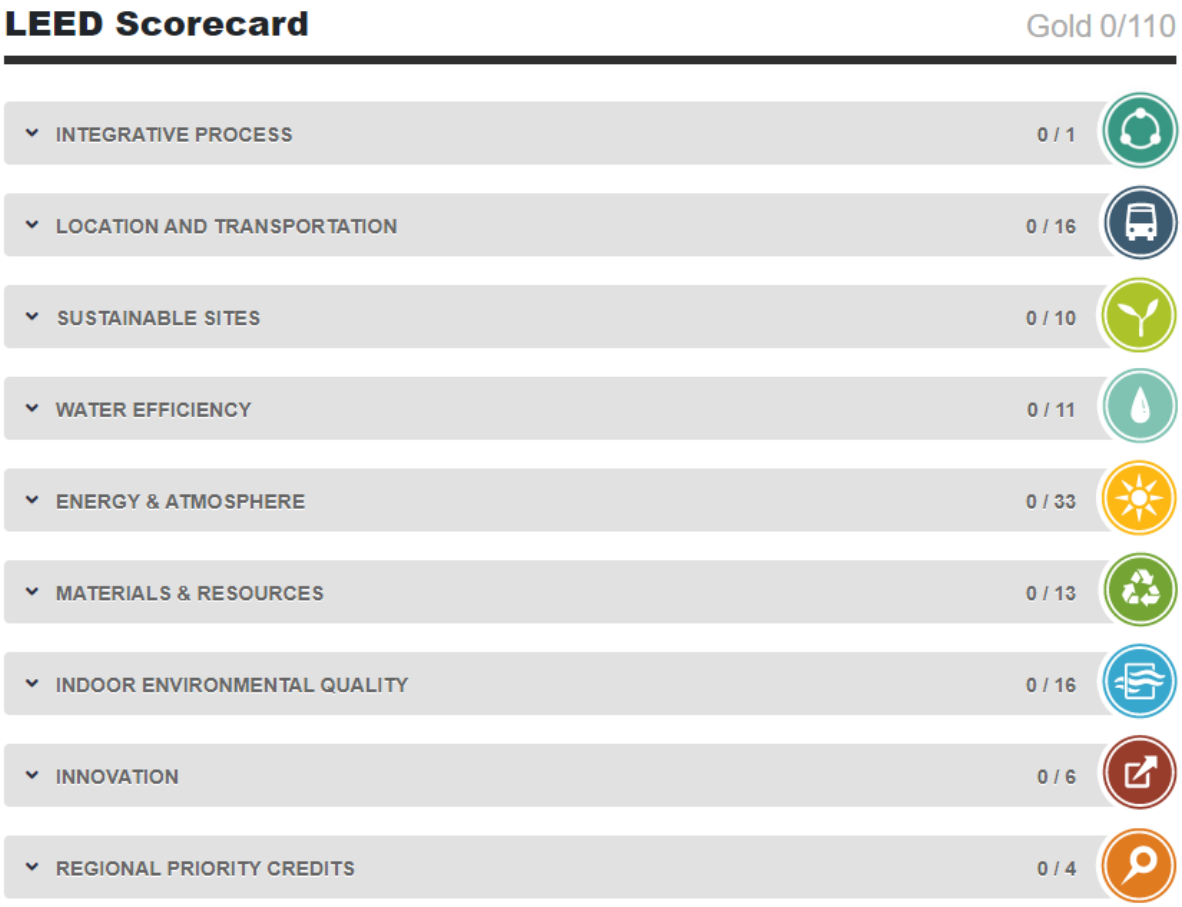

Figure 3. LEED Scorecard, U.S. Green Building Council, 2021

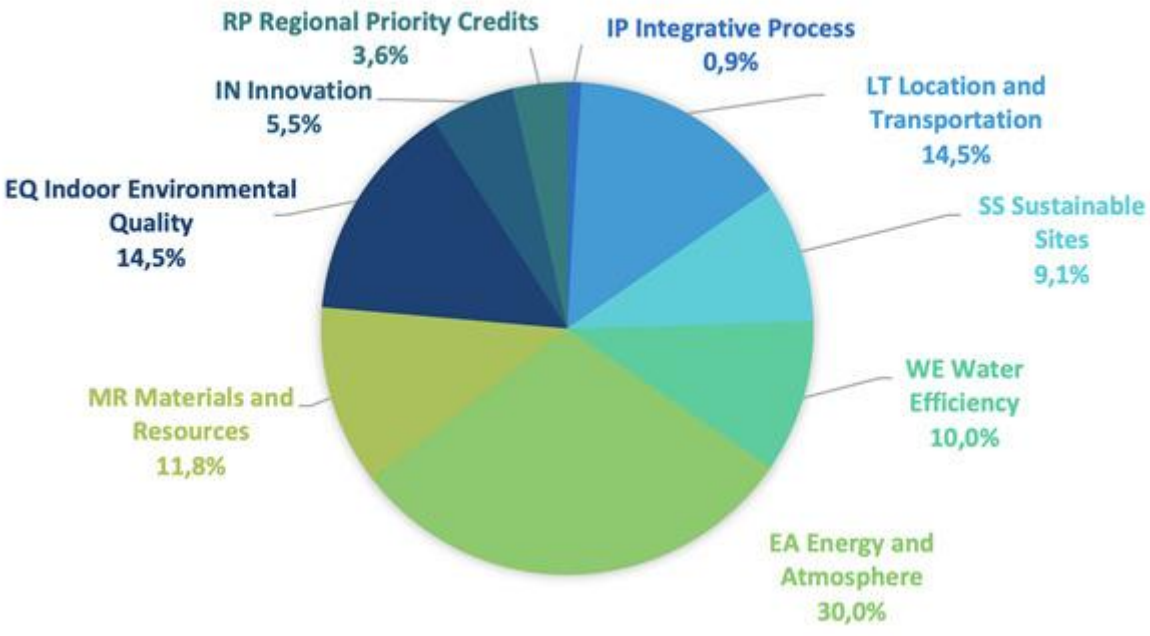

Figure 4. The share of the individual environmental categories in the overall rating HOINKA (2021)

1. Integrative Process

Integrative Process	**0-1**
Integrative Process	0-1

2. Location and Transportation

Location and Transportation	**0-16**
LEED for Neighborhood Development Location	0-16
Sensitive Land Protection	0-1
High Priority Site and Equitable Development	0-2
Surrounding Density and Diverse Uses	0-5
Access to Quality Transit	0-5
Bicycle Facilities	0-1
Reduced Parking Footprint	0-1
Electric Vehicles	0-1

3. Sustainable sites

Sustainable sites generally deal with the prevention of soil pollution and the prevention of construction site noise. The choice of the construction site location is rated with one point.

Neighborhoods should not only be disturbed by approaching trucks and construction site noise.

Sustainable sites	**0-10**
Construction activity pollution prevention	0-1
Site Assessment	0-1
Protect or Restore Habitat	0-2
Open Spaces	0-1
Rainwater Management	0-2
Heat Island Reduction	0-2
Light Pollution Reduction	0-1

4. Water efficiency

Water efficiency describes the procedure of keeping water consumption as low as possible. This includes, for example, water-saving faucets or the use of treated water for flushing toilets.

Water efficiency	**0-11**
Outdoor Water Use Reduction	prereq
Indoor Water Use Reduction	prereq
Building-Level Water Metering	prereq
Outdoor Water Use Reduction	0-2
Indoor Water Use Reduction	0-6
Optimize Process Water Use	0-2
Water Metering	0-1

5. Energy & atmosphere

The design of systems for energy monitoring of buildings, minimum energy standards, as well as the reduction of fluorocarbons in the ventilation and air conditioning systems are prerequisites to be considered in the study of Energy and Atmosphere. In this sub-item, the use of renewable energy sources plays a decisive role, as through them energy can be used cleanly. In order not to consume too much energy unnecessarily, it is important to measure and monitor it constantly. The goal is to keep greenhouse gases as low as possible.

Energy and atmosphere	**0-33**
Fundamental Commissioning and Verification	prereq
Minimum Energy Performance	prereq
Building-Level Energy Metering	prereq
Fundamental Refrigerant Management	prereq
Optimize Energy Performance	0-18
Enhanced Commissioning	0-1
Advanced Energy Metering	0-1
Renewable Energy	0-5
Enhanced Refrigerant Management	0-1
Grid Harmonization	0-2

6. Materials & resources

The topic of materials and resources is mainly concerned with recycling and the environmental compatibility of the materials used as well as sustainable mining methods in order to avoid as much waste as possible. Materials should be sourced as far as possible from regional sources, as this saves transport distances. Rapidly renewable raw materials and their recycling are awarded up to 2 points.

Materials and Resources	**0-13**
Storage and Collection of Recyclables	prereq
Building Life-Cycle Impact Reduction	0-5
Environmental Product Declarations	0-2
Sourcing of Raw Materials	0-2
Material Ingredients	0-2
Construction and Demolition Waste Management	0-2

7. Indoor environmental quality

The air quality in the building affects the comfort of the user. In order to provide the best possible air quality, the indoor air or the CO_2 content within a room must be constantly monitored. Control systems ensure that it does not get too cold or too warm in the building. The penetration of sufficient daylight is also checked during certification, as this also has a beneficial effect on the user and thus contributes significantly to comfort. The use and installation of materials that can release substances into the room air must be avoided as this can lead to headaches, dizziness, and nausea.

Indoor environmental quality	**0-16**
Minimum Indoor Air Quality performance	prereq
Environmental Tobacco Smoke Control	prereq
Enhanced Indoor Air Quality Strategies	0-1
Low-Emitting Materials	0-4
Construction Indoor Air Quality Management Plan	0-2
Indoor Air Quality Assessment	0-1
Thermal Comfort	0-1
Interior Lighting	0-2
Daylight	0-2
Quality Views	0-2

Acoustic Performance	0-1

8. Innovation and design process

A sixth category - innovation and design process - includes issues not included in the other categories, such as acoustics, community use, and other factors that may vary from time to time depending on the type of building.

Innovation	**0-6**
Innovation in design	0-5
LEED Accredited Professional	0-1

9. Regional priority credits

Regional priority credits	**0-4**
Regional Priority Specific Credits	0-4

Evaluation

The points are awarded for the criteria in the topic areas described above. Based on the number of points earned, a project can achieve one of four LEED rating levels.

The minimum value starts at 40 points and goes up to a maximum of 110 points. In this process, the buildings are subdivided in detail as follows:

- Basic Certification (Certified, 40-49 Points)
- Silver Certification (Silver / 50-59 points)
- Gold Certification (Gold / 60-79 points)
- Platinum certification (Platinum / 80 points and above

Areas of application

Certification systems such as LEED aim to make sustainability in architecture transparent and comparable. Architects, engineers, planners, and other companies can use the LEED system to support the good practice of sustainable design because these practices not only have a positive impact on human health and the planet but also help to mitigate the passive costs that the community has to pay every day (USGBC, 2021). Investors and builders thus want to showcase their commitment to the outside world with a certificate and also make economic sense of it. It is certainly an opportunity to stand out as a reference point for the

professional world that works within the framework of healthy architecture and offers the possibility of entering the network of sustainable construction that goes beyond national borders. This is therefore a measure that increases its own competitiveness in the market. In the U.S., for instance, it often happens that the media announces the projects that stand out for their high score in LEED certification, thus becoming study cases and examples for other buildings. In the case of companies, LEED certification is above all an attestation of transparency to their own clientele. Customer satisfaction, one of the most important business objectives, is only maintained thanks to the high-quality level of the results produced by the companies (Eiffelgres, 2014).

Originally, the individual systems were tailored to a specific country. In the meantime, some have been adapted to other markets and now have worldwide significance. Even within Germany, therefore, different labels compete with each other. At the same time, they are constantly evolving. The areas of application of the individual systems are: New buildings, existing buildings and spaces, new interiors, core and building envelopes, interior office and administration, retail, residential, district and neighborhood development, communities and schools, and health and care facilities. The first German building to be certified with the highest LEED award is the new corporate headquarters of Deutsche Börse AG. The high-rise building, located in Eschborn near Frankfurt, has received the platinum standard of the American sustainability certification LEED. The new building was designed by KSP Jürgen Engel Architects and scored a total of 58 points in the rating system in July 2010 after an extremely short planning and construction period of just under two years. The threshold of 52 points required for the desired platinum award was thus clearly exceeded (Detail, 2010).

Figure 5. Front view of the Deutsche Börse AG building in Eschborn.
Jean-Luc Valentin, KSP Jürgen Engel Architekten, Frankfurt, 2010

DGNB

DGNB stands for "Deutsche Gesellschaft für Nachhaltiges Bauen" (German Sustainable Building Council) and was first used as a certification system in 2009. The DGNB has set itself the goal of making sustainable construction applicable, measurable, and comparable. The certification system considers the three essential criteria of the entire life cycle, the holistic approach, and the performance orientation and due to the holistic approach, it stands out from other systems that only consider individual measures. The evaluation criteria are based on the well-known three pillars of sustainability: ecology, economy, and socio-cultural but also on parameters such as technology, processes, and site quality (DGNB GmbH, n.d.).

History

Founded as a non-profit organization in 2007 with its headquarters in Stuttgart the DGNB has since been active in the implementation of sustainable buildings and livable districts. The association now consists of around 1,500 member organizations and is Europe's largest network for sustainable building. In 2009 the first 16 buildings were awarded a DGNB certificate and further twelve projects have acquired a so-called pre-certificate. The first buildings and projects were entirely office and administration buildings. In the same year, the performance segment was expanded by six additional system variants so that other building types could receive certification. Since then, the number of system variants has increased continuously. The DGNB system gained access to the global market in 2010 and has since been used internationally. The advantage is that all assessment criteria are aligned with the legal standards and regulations of the European Union. Since 2019 the DGNB Sustainability Day has been held annually where stakeholders in the construction and real estate industry have the opportunity to exchange ideas. In the meantime, more than 3,500 people in almost 40 countries have been qualified as experts in sustainable construction with the help of the DGNB Academy (DGNB GmbH, n.d.). With a certification rate for commercial real estate of 80% in new construction and 60% on the overall market the DGNB is the market leader of certification systems in Germany and leads Europe-wide in the certification of districts (DGNB GmbH, n.d.).

System variants

The DGNB differentiates between the following three variants for certification: Buildings, districts, and interiors. The applicability is for new buildings and existing projects. Within the variants, there is a further division which will be explained briefly below and illustrated later.

In the "Buildings" system certificates are issued for the entire life cycle of a building. Starting with pre-certification in the planning phase, certification then follows during construction,

operation, renovation, recertification when operations are resumed and finally certification for deconstruction is possible at the end of a property's life. The following types of use can be certified with DGNB: Educational buildings, office, and administrative buildings, commercial buildings, healthcare buildings, hotel buildings, small residential buildings with up to six, units, laboratory buildings, logistics buildings, mixed-use buildings, parking garages, production facilities, shopping centers, sports halls, consumer markets, consumer markets and residential buildings with more than six units (DGNB GmbH, n.d.).

For the "districts" the topics of climate protection, climate adaptation, and resilience are taken into account in the certification. The aim is to minimize the CO_2 emissions of entire settlements in a holistic manner. But factors such as urban- and microclimate, environmental risks, and biodiversity also ensure that the value of the districts is maintained. Sustainable mobility strategies are also included in the assessment. The "Circular Economy" approach also aims to promote circularity and the conscious use of limited resources and land as well as a good mix of structures (DGNB GmbH, n.d.).

The last system variant "Interiors" is also part of the DGNB. Since people spend most of their time in buildings a healthy environment is important. For this reason, the DGNB has set itself the goal of promoting the health, ergonomics, well-being, and performance of users with the help of environmentally friendly, health-conscious, and economical interior design. Certification can also be obtained here for new buildings or existing buildings but also for buildings that have not yet been certified. The following uses can be certified in this system variant: Office and administration, hospitality, hotels, shopping, and mixed-use (DGNB GmbH, n.d.).

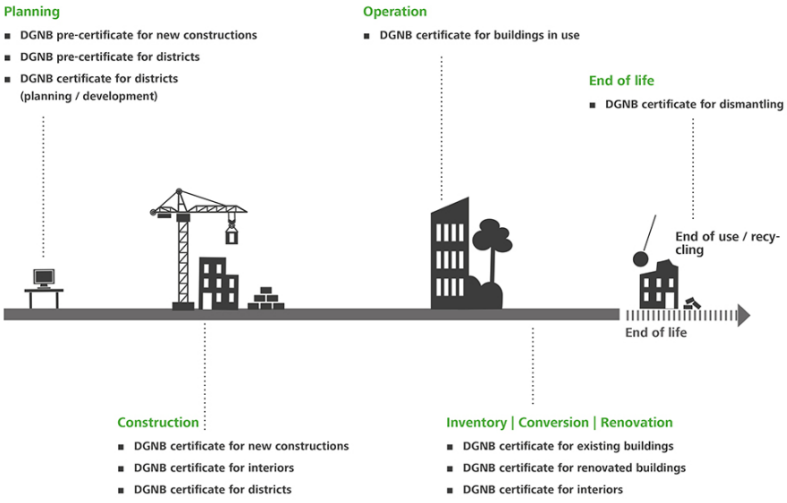

Figure 6. The DGNB System

Source: https://www.dgnb-system.de/en/system/

Certification process

Why does it make sense to certify buildings? Certification can create advantages that can be decisive in comparison to "normal" objects or projects. This also creates advantages for all involved parties and the composition of synergies makes the management of DGNB properties more valuable. For the user certification results in a higher quality of life through a greater sense of well-being and lower additional costs through efficient technology and process optimization. Investors and building owners can ensure the high quality of their property from the beginning through the DGNB. A certified building carries fewer risks in terms of vacancies, sales, and rentals and investors also receive faster and more favorable loans from banks. Another advantage is that certified buildings can be compared worldwide what makes investment decisions easier for foreign investors or developers. High efficiency in planning with the help of the DGNB makes it much easier for planners and architects to implement such projects. Optimization potentials can be identified and implemented early in the planning process thus ensuring the desired quality of the building and implementing it in a cost-optimized manner. Due to the forward-looking planning, the entire building can be planned and realized over the complete life cycle by means of an innovative building concept. Product manufacturers also benefit from certification systems in that they can further develop and optimize their products under the aspects of sustainability (DGNB GmbH, n.d.).

In order to obtain DGNB certification, a trained auditor must be commissioned. A contract is then concluded between the client and the DGNB as well as a further contract between the client and the auditor. The auditor accompanies and supports the process of certification and subsequently carries out the relevant documentation. Once the necessary documentation has been compiled the auditor submits it to the DGNB for further review. After the DGNB has comprehensively checked the documents, the certificate including plaque is awarded to the applicant (DGNB GmbH, n.d.).

Due to the international activities of the DGNB and the individual adaptation of the certification criteria to the respective countries and regions more than 7,200 projects in 29 countries worldwide have already been planned, built, and certified with the help of the DGNB certification (Status: 12.2020) (DGNB GmbH, n.d.).

Evaluation criteria

In principle, the DGNB system does not evaluate individual measures but focuses on the entirety of a building. This applies to all three variants: Buildings, districts, and interiors. The three pillars of sustainability mentioned above as well as technical aspects and processes are evaluated.

After successful assessment, a DGNB certificate is awarded in platinum, gold, or silver. For the existing building certificate and the "Building Operation" certificate, the bronze certificate is also awarded. Based on the respective assessment criteria minimum and overall levels of achievement are determined as part of the certification process with the help of defined DGNB target values. Projects with an overall degree of fulfillment of at least 80% and a minimum degree of fulfillment of 65% in all five result-relevant subject areas receive a platinum certificate. Gold is awarded for an overall fulfillment level of more than 65% and a project with a fulfillment level of more than 50% receives a silver certificate. Bronze certification is only awarded for existing projects with a compliance rate of 35% or more. The weighting of the respective criteria varies depending on the use of the property.

Figure 7. The DGNB System

Source: https://www.dgnb-system.de/en/system/

There are different catalogs of criteria for the certification of buildings. The evaluation criteria are divided into the following categories: Buildings in new construction with a total of 37 criteria, buildings in existing buildings, refurbishment, buildings in operation with a total of nine criteria, deconstruction with a total of twelve criteria, and construction sites (DGNB GmbH, n.d.). In the certification of districts, the criteria catalog consists of six criteria of ecological quality, five criteria of economic quality, and eight criteria that apply to the socio-cultural and functional quality of districts (DGNB GmbH, n.d.). Interiors have the smallest criteria catalog with four criteria for ecological quality, two criteria for economic quality, seven criteria for socio-cultural and functional quality, two criteria for technical quality, and four criteria for process quality (DGNB GmbH, n.d.). It becomes clear that the focus of the DGNB certification is predominantly on the certification of the building variant. Here performance requirements and evaluation criteria have already been comprehensively elaborated and thus a good basis for a sustainable certification of buildings during the entire life cycle of a property has been created.

An example of the percentage distribution of districts looks as follows: Ecological quality is rated at 20%. This includes factors such as the global and local environment and the urban climate as well as the use of resources and recyclable materials through planning and

construction. A further 20% is allocated to the evaluation of the economic quality with the assessment of the long-term economic efficiency (life cycle costs) and the value development as well as the adaptability of the district. The socio-cultural and functional quality with criteria on health, comfort, and user satisfaction, as well as essential aspects of the social and infrastructural mix, also receives 20%. The technical quality rating of 20% is considered a measure of the quality of technical execution concerning relevant sustainability aspects as well as the quality of mobility and its contribution to the sustainability of the district. Finally, process quality is also rated at 20%. It pursues the goal of increasing the quality of planning and planning participation as well as the quality of construction and operation of the district.

Conclusion

The three building certification systems BREEAM, LEED and DGNB have a large number of common features. But they are different in more detailed components. The requirements set for certification depend on the choice of the system. The certification systems deal with classifications, characterizations, and assessments. DGNB focuses on the holistic approach of a sustainable assessment of real estate. LEED and BREEAM deal more with ecological and energy-saving aspects. Characterization is about the assignment to a category. The evaluation can be carried out as a point system, as in LEED, or with the different weighting of the categories, as in BREEAM and DGNB. Estimation refers to the category's share of the total score. The advantage of the point rating in LEED is the simplicity of the system. Weighting has the advantage that the individual criteria at DGNB or the main criteria groups at BREEAM are additionally valued depending on their impact on the environment.

Because BREEAM was the first certification system on the international real estate market, due to its early development, it is one of the best-known green building labels and therefore has a great advantage over other systems: Due to the foundation in 1990, 590,000 buildings have already been certified in the meantime in over 78 countries worldwide. In contrast to DGNB the system founded in 2007, over 7,200 projects certified in 29 countries worldwide. LEED was developed in 1998. With more than 96,000 projects in over 150 countries, LEED is the most used certification system in the world.

All three certification systems have the claim to increase the value of the property, reduce the risk of vacancy and increase the chances of resale. They also lower additional costs through efficient technology and optimized processes, simplify planning in new construction for building construction, and make properties comparable.

It is believed that in the future national interests of the certification systems will have less weighting and instead a uniform intention to protect the environment for future generations will be pursued. The creation of a homogeneous basis will be desirable.

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