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A Comparative Study on the Sustainable Evaluation of DGNB and G-SEED Focusing on IEQ Enhancement

Aysenur Gültekin [1] and Jihyun Park [2,*]

[1] Department of Architecture, Technical University of Darmstadt, El-Lissitzky-Straße, 64287 Darmstadt, Germany; aysenur.gueltekin@stud.tu-darmstadt.de
[2] Department of Architecture, Ewha Womans University, 52 Ewhayeodae-gil, Seodaemun-gu, Seoul 03760, Republic of Korea
* Correspondence: jh.park@ewha.ac.kr

Abstract: This paper aims to compare the sustainability assessment methods of DGNB and G-SEED, the two domestic green building rating systems, focusing on indoor environmental evaluation and reviewing recent laws, certifications systems, and guidelines from Germany and South Korea. According to existing studies, Korea's green building certification has similar evaluation items, environmental (62.6%), social aspects (25.4%), and economic aspects (3.0%) compared with DGNB. Continuing research comparing DGNB and G-SEED, this paper will present an insight into the DGNB and G-SEED green building rating systems' aspects and motives; furthermore, we intend to equate the sustainability assessment methods of the DGNB and G-SEED certification systems, in order to improve certification systems by comparing and finding solutions to differences, thereby making international systems more adaptable to each country. This analysis will unify property categorization systems and will promote green building and sustainable development globally. Findings: Regarding similarities and differences, the certification criteria for air, thermal, visual/light, and acoustic quality are based on domestic laws in both countries. DGNB and G-SEED are similar in terms of the requirements but differ in methods and domestic laws. Some findings regarding differences are that DGNB requires low VOC-emitting products, while G-SEED focuses on natural ventilation. Thermal comfort is measured through design-phase simulation in DGNB, while G-SEED lighting is evaluated on the basis of saving light energy. Finally, in G-SEED, acoustic quality is measured via indoor soundproofing performance, while DGNB takes room size into account.

Keywords: acoustic quality; air quality; DGNB; G-SEED; indoor environment quality; sustainable building certification systems; thermal quality; visual and lighting quality

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1. Introduction

With the increase in global climate change, several domestic and international government organizations have implemented policies to constrain greenhouse gas emissions and resource consumption across several industries, including the building industry [1].

Therefore, building environmental assessment systems have been developed and utilized globally since the 1990s, focusing primarily on energy, environmental impact, and sustainability [2].

This has led countries to develop certification systems, such as BREEAM in the UK, LEED in the USA, and CASBEE in Japan, which evaluate eco-friendly buildings [1,3].

All rating systems differ in terms of their criteria and implementation, but comparable evaluation items have not been suggested up until now [4,5]. International standards have been used to establish evaluation criteria for eco-friendly buildings, because buildings significantly impact the environment, consuming energy, water, and raw materials, generating waste, and emitting harmful emissions [6]. Concrete production, for example, causes 5–8% carbon dioxide worldwide [7,8]. Therefore, scores have been developed to address broader sustainability issues, such as reducing energy consumption, living, regenerative, and restorative building principles, and preserving nature's processes [6].

Currently, there are a growing number of standards, certifications, and rating packages on the market to guide sustainable, high-performance buildings. These certifications vary in their approach, with some outlining conditions and non-obligatory credits, while others use a prescriptive method. Some require performance-based requirements for unique products and tasks [6].

However, every country does manage these at a different level according to the circumstances of the nation, climate environment, and their evaluation methods [1].

DGNB and G-SEED are both certification systems that began with domestically considered building certifications.

DGNB was the first certification standard that accepted the international evaluation criteria [4], which made it an international standard [9]. G-SEED is currently developing more and more, and slowly reaching the standards of leading systems such as LEED [3,9].

According to a study, Korea's green building certification has similar evaluation items, environmental aspects (62.6%), social aspects (25.4%), and economic aspects (3.0%) when compared with DGNB [4].

As in previous years, 2022 saw a significant increase in certifications in Germany (Figure 1 [10]). There are now over 2800 certified buildings in Germany. An analysis of certifications by asset class shows that retail's relative share of certified buildings across the country has declined for several years. In Germany, DGNB (1670) remains the market leader in green building certificates, ahead of BREEAM (660) and LEED (490). In 2022, Germany's investment in certified green buildings remained at a level of around EUR 11.2 billion. Like the investment market, although the absolute amount decreased slightly year-on-year, the relative share of certified assets in the investment market rose to its highest ever, 30.6% [10]. Korea is also remarkably ahead in terms of certificated buildings. According to records from 2014, there were 1786 certified buildings, with an increase of around 3% per year (from 173 to 571) from 2006 to 2010 [11]. G-SEED in Korea had certified a total of 16,221 buildings by 2020 [12].

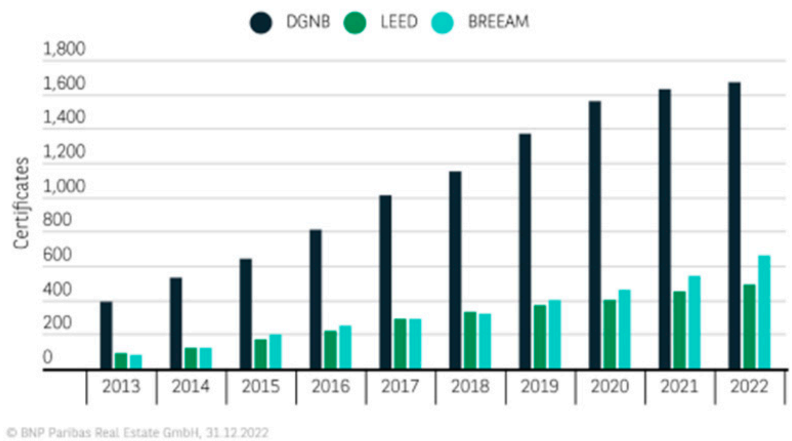

Figure 1. Market share of certification systems in Germany [10].

Nowadays, systems specifically recognize healthy buildings as much more recent arrivals on the global scene. Therefore, they have requirements like indoor air quality, thermal comfort, visual comfort, and acoustic comfort. Ergonomics and movements align with key topics related to health and productivity [13,14].

Certification systems have always considered sustainability, but according to DGNB, sustainability means not only protecting the natural environment and natural resources, but also ensuring health and comfort in buildings, and preserving economic, social and cultural values [13].

Building confirmation systems are used to evaluate the performance of a building or construction project in terms of sustainability and the environment. Indoor environment quality (IEQ) is one of the main factors that significantly impacts building sustainability and performance [15,16].

Therefore, the main question in this work is how IEQ is considered within the sustainable building certification systems DGNB and G-SEED. What are the differences in their assessment criteria and indicators, and how may these impact the overall sustainability evaluation of green buildings and become globalized?

In the following text, for comparison, both domestic certification systems will be briefly introduced. An evaluation of the indoor environment criteria of both systems with consideration of the recent laws and guidelines of Korea G-SEED and Germany DGNB will be presented. The processed common criteria are the indoor air quality, the thermal quality, the visual quality and the acoustic quality.

This analysis will be effective in unifying property categorization systems and will pave the way for coordinated efforts to encourage green buildings and sustainable development internationally. The paper also intends to improve the certification systems by comparing and finding solutions to differences, and to make international systems more adaptable to each country.

2. Materials and Methods

This study is based on research into different sustainable green certification systems. It aims to compare the sustainable evaluation between the certification systems DGNB (German Sustainable Building Council) and G-SEED (Green Standard for Energy and Environmental Design of South Korea).

Therefore, the following study will contain a short overview of DGNB and G-SEED, as well as indoor environment quality.

Furthermore, their requirements for IEQ will be compiled and reviewed. The criteria of IEQ, such as air quality, heat environment, light environment, and sound environment, in both certifications and the current law requirements will be compared, with analysis of both the rating and importance of the several criteria.

Additionally, we will compare and analyze the standard values presented by the current laws, certifications and guidelines; the differences between the standards of Korea and Germany are identified, and domestic laws and certification guidelines are sought. Since their implementation, both certification systems have been revised to improve existing problems, and DGNB has been made international. Currently, G-SEED is trying to reinforce these standards. Therefore, a lot of studies have been conducted on both certification systems. To reflect them, this study investigated examples from previous studies related to DGNB and G-SEED. To this end, through prior research and theory, the indoor environment is considered through factors such as air quality, heat environment, light environment, sound environment, etc., and the current laws, certifications, systems, and guidelines of Korea G-SEED and Germany DGNB are reviewed.

2.1. G-SEED

G-SEED is a domestic certification system evaluating environmentally friendly buildings, and was first introduced in 2002 to target multi-residential buildings and to be co-supervised by the Ministry of Land, Infrastructure and Transport, and the Ministry of Environment. This system is currently used to evaluate multi-residential housing, residential buildings and office buildings, residential complex building, schools, retail buildings, hotels, and other non-residential buildings, which are in the new building category. It is also used to evaluate existing multi-residential housing and existing office buildings. The G-SEED certification system is divided into seven categories, which are Land Use and Transport, Energy and Environment Pollution, Materials and Resources, Water Management, Management, Ecological Environment, and Indoor Environment (Table 1). The total number of points, 100, is obtained by multiplying the obtained score from each category with a weighting factor, and the final scores obtained are awarded one of four grades (for office buildings) [9,17].

The G-SEED certification system also has four evaluation grades (Green1, Green2, Green3, Green4). Scores over 80 points are classed as Green1, the superior grade [9,18].

2.2. DGNB

As a non-profit, non-governmental organization, DGNB is committed to serving the public. Founded in 2007, DGNB made its mission 'to show and promote content, methods, and solutions for planning, execution, and use of buildings that achieve the goals of sustainable building'. The founding members include well-known architects, planners, building product manufacturers, and investors and scientists; other members have joined over time. Their objectives are evaluating existing buildings, new constructions, interiors, and districts, and certifying planning, construction, operation, conservation/renovation, and end-of-life processes [19].

The DGNB system is based on the three central sustainability areas of ecology, economy, and sociocultural issues, which are weighted equally in its evaluations. The three columns of sustainability balance the same weightlessness, which overlaps with technical, process, and site quality. So, in total, there are six main categories considered (Table 1) [13].

The DGNB certification system has four evaluation grades (silver, platinum, gold, and bronze, only for existing buildings). The maximum reachable degree is 100%. For an overall degree of fulfillment of 50%, the building receives a silver DGNB certificate. For a degree of fulfillment of 65%, a gold DGNB certificate is awarded. To receive a platinum DGNB certificate, the project must achieve an overall degree of fulfillment of 80%. The same regulation applies to existing buildings, with the additional caveat that they receive a bronze certificate, as the lowest award, if they have an overall degree of fulfillment of 35% [19].

Table 1. General comparison of G-SEED and DGNB certification systems.

	G-SEED [9]	**DGNB [19]**
Objective	New buildings: multi-residential housing, residential complexes, offices, schools, retail buildings, hotels, homes and other buildings Existing buildings: multi-residential buildings, office buildings in pilot Building in use, existing buildings, renovated buildings New construction: Educational buildings, offices, healthcare buildings, retail buildings, hotels, industrial buildings, (small) apartment buildings, laboratory buildings, mixed-use buildings, multi-story car parks, sports halls, apartment buildings, buildings used for meetings/assemblies/gatherings Interiors: Retail spaces, offices, hotels, restaurants Districts: Urban districts, office and business districts, industrial sites, event areas, resorts, vertical cities	Existing buildings: Building in use, existing buildings, renovated buildings New construction: Educational buildings, offices, healthcare buildings, retail buildings, hotels, industrial buildings, (small) apartment buildings, laboratory buildings, mixed-use buildings, multi-story car parks, sports halls, apartment buildings, buildings used for meetings/assemblies/gatherings Interiors: Retail spaces, offices, hotels, restaurants Districts: Urban districts, office and business districts, industrial sites, event areas, resorts, vertical cities
Assessment	7 categories (23–43 criteria)	6 categories (29 criteria, 2023)
Categories	Land Use and Transport, Energy and Environment Pollution, Materials and Resources, Water Management, Management, Ecological Environment, Indoor Environment	Environmental quality Economic quality Sociocultural and functional quality Technical quality Process quality Site quality

Table 1. *Cont.*

	G-SEED [9]	DGNB [19]
Rating	Green1 (above 80 points) Green2 (above 70 points) Green3 (above 60 points) Green4 (above 50 points)	Platin→80% Gold→65% Silver→50% Bronze→35% (only for existing buildings)
Significance	Request mandatory criteria Weighting factor for total 100 points	Request mandatory criteria = Minimum performance index of the three main categories in total "Environmental Quality" "Economic Quality" "Sociocultural and functional quality"

3. Indoor Environmental Quality

People today spend up to 90 percent of their time in closed spaces, which increases the significance of air quality in terms of performance and health [20]. Ensuring high air quality through adequate air change rates increases peoples' well-being and represents an important contribution to ensuring their workability or satisfaction [20,21].

Indoor environment quality is a category that shows the similar purposes of both countries' certification criteria; the importance of the indoor environment among domestic residents' living environments is increasing rapidly [4,22].

In the case of DGNB, IEQ is considered within the 'Sociocultural and functional quality' category [19]. DGNB interprets it as the basic comfort of users, the building's functionality that emphasizes publicity, and the aesthetic value of buildings; these factors are reflected in the evaluation sector [4]. This is why the DGNB, in addition to thermal, indoor air, acoustic and visual quality, includes the 'design for all' category. Above all else, the mandatory requirements are the indoor air quality and 'design for all' categories [19].

In contrast, G-SEED only considers thermal, indoor air, and acoustic quality. The quality of the indoor environment is evaluated using four major environmental criteria: air quality, thermal environment, light/visual quality, and acoustic quality [4,23].

To compare the indoor environment evaluation factors between G-SEED and DGNB, we present the elements of indoor environment evaluation in the current laws and certification guidelines of Korea (Republic of Korea) and Germany (Republic of Germany), as follows. (Table 2)

Table 2. Indoor environmental quality assessment in Korea and Germany.

IEQ Criteria		Korea		Germany	
		Current Law	G-SEED	Current Law	DGNB
Air Quality	Air Pollutant Concentrations	V	V	V	V
	Ventilation	V	V	V	V
	Air Flow	V	-	V	-
Thermal Quality	Air Temperature	V	-	V	V
	Air Velocity	-	-	-	-
	Relative Humidity	V	-	-	V
Lighting Quality	Light/Daylight Level	V	-	-	V
	Conditions for Maintaining Illuminance	V	V	-	-

Table 2. *Cont.*

IEQ Criteria		Korea		Germany	
		Current Law	G-SEED	Current Law	DGNB
Acoustic Quality	Noise Level (dB) Outside	V	V	V	V
	Noise Level (dB) Inside	-	-	-	-
	Reverberation Time	-	-	V	V
	Noise Blocking, Soundproofing	-	V	V	V

3.1. Indoor Air Quality

Indoor air quality has a significant impact on office workers, potentially affecting comfort, health issues, sickness absence, and performance. The importance of how a building is operated, its specific materials, and the elements within that building is huge, and has a direct impact on IAQ; many studies have investigated the specific impact of these characteristics on occupants within the space [2,24].

Several chemicals are recognized as harmful within the built environment, among which several are commonly emitted by construction materials and thus occur at hazardous concentrations inside buildings (VOCs, radon, formaldehyde, heavy metals such as lead and mercury, PCBs, and asbestos). Additionally, some toxins of concern are bio-effluents such as ozone and CO_2, particulate matter, and cigarette smoke, which are primarily generated outdoors [2,24].

In this case, DGNB only requires toxic chemicals and VOCs [2] to be limited; the same is true of G-SEED, which requires low VOC-emitting products to be used. The criterion "using low VOC-emitting products" of G-SEED is evaluated by minimally applying the products emitting harmful chemicals, and evaluating their influence on the health of residents [9]. Additionally, the "indoor chemical and pollutant source control" criterion of G-SEED is evaluated based on whether any asbestos is used as a construction material [2,25]. In the case of DGNB, the remaining IAQ credits are less related to the physical aspects of the building, and are more policy-focused. Air quality monitoring as a requirement for toxin-limiting credits is common, and is used to improve a building's air quality and its occupants' health by extension [2].

Regarding the concentration of pollution, current domestic laws and regulations present the allowable concentrations of pollution in the indoor air quality of new apartments, residential buildings, and business facilities (Table 3) [26]. Unlike Korea, which has relatively low-level standards for indoor pollution concentration figures, Germany has a high standard value for pollution concentrations in its building laws [27].

Table 3. Air pollutant concentration standards of South Korea and Germany.

Air Quality	Korea		Germany	
Air Pollutant Concentrations	Current Law [26]	G-SEED	Current Law [27]	DGNB [28]
PM10 ($\mu g/mg^3$)	100	-	-	-
PM2.5 ($\mu g/mg^3$)	50	-	15	-
CO_2 (ppm)	1000	-	<1000	<1000
CO (ppm)	10	-	-	
Formaldehyde ($\mu g/mg^3$)	100	-	100	<100
Radon (Bq/m^3)	148	-	-	-
Styrene ($\mu g/mg^3$)	-	-	0.3	-

The two countries' pollution concentration standards vary depending on the country and building use; fine dust, ultrafine dust, carbon monoxide, and formaldehyde are held to stricter standards in Korea than in Germany in terms of construction and accumulation; they are also permitted in smaller amounts than radon [27].

Looking at the current domestic laws on ventilation, Korea presents a minimum number of ventilation points and frequencies. The Ministry of Environment recommends natural ventilation at least three times a day between 10 a.m. and 10 p.m., and four times per hour in the ventilation standards of the office's air management guidelines, according to domestic and international certification guidelines (Table 4) [26]. Germany does not present a standard CIE for ventilation, but the DGNB has requirements based on technical rules for workplaces, such as airing for 5 min per hour in winter and 10 min per hour in summer, as well as a size of opening for ventilation of 0.35 m^2 per person (Table 4) [28,29].

Table 4. Ventilation standards of South Korea and Germany.

Country	Korea		Germany	
Criteria	**Current Law [26]**	**G-SEED**	**Current Law**	**DGNB [28,30]**
Ventilation Frequency	At least 3 times (more than 30 min) a day for between 10 am.~9 p.m.	-	-	Winter, 5 min airing per hour Summer, 10 min airing per hour (required for working spaces)
Size of Opening for Ventilation m^2/per person	-	-	-	0.35

3.2. Thermal Comfort

Temperature control is by far the most common requirement across rating systems. They prescribe either a set temperature range or compliance with a thermal comfort standard that considers temperature in conjunction with factors such as relative humidity, radiant heat, and air speed. DGNB's mandatory requirement is a design-phase simulation [2].

The improper design of air diffusion systems can cause localized drafts or poor air circulation. To avoid thermal discomfort, DGNB demands a limitation on peak air volumes for heating and cooling. They also provide the credit only for the latter, awarding bonus credits for simulating 2030 and 2050 climate conditions and adapting designs based on results [2,31].

In the case of G-SEED, evaluation of the thermal environment is based on the adoption of an indoor automatic temperature control section. In the case of DGNB, the temperature control ability, air supply performance, relative humidity, airflow rate during heating and cooling, and surface temperature consider the radiant heat of floors, walls, and ceilings [4]. The "auto temperature-adjusting device for indoor space" criterion of G-SEED is evaluated based on the installation rate of indoor automatic temperature controllers [4].

DGNB considers ventilation, which is referenced to EN 15251 [2], in terms of specifying the recommended level of ventilation (outside air), which depends on the number of occupants in the space, and the contribution, which depends on the floor area of the space. There is the prescriptive method; a minimum ventilation rate per person and the minimum ventilation rate per square meter floor area are required [32]. The two ventilation rates are then added. The person-related ventilation rate should concern the pollution emitted from the person (odor and other bio-effluents) and the ventilation rate based on the person's activity, and the floor area should concern emissions from the building, furnishing, HVAC system, etc. [32].

The criterion "natural ventilation" of G-SEED is evaluated based on whether a vent is installed or not. The criterion "ventilation performance of unit residence" of G-SEED is evaluated based on the installation of air inlets/outlets and the air volume [4].

In the case of G-SEED, the natural ventilation performance and air conditioning ventilation performance are evaluated according to the ratio of openable windows to floor area; with DGNB, the volatile organic compounds in the air and water, natural ventilation, and air conditioning ventilation performance are evaluated [4,33].

Regarding indoor temperature, current Korean domestic laws present seasonal appropriate temperatures for housing and business buildings; these are included in the manual for the indoor air quality management of housing and the promotion of energy rationalization in public institutions [26]. In Germany, there is a general minimum requirement for indoor heated facilities [34] (Table 5).

Table 5. Temperature quality standards of South Korea and Germany.

	Country	Korea		Germany	
Criteria		**Current Law**	**G-SEED**	**Current Law**	**DGNB ***
Temperature (°C)	Spring, Autumn	19~22 [26]	-	≥19 [34]	-
	Summer	24~27/28 [26]	-	≥19 [34]	≥20 [35]
	Winter	18~21/18 [26]	-	≥19 [34]	≥22 [35]
Air Velocity (m^3/h)	Summer	-	-	20 [34]	-
	Winter	-	-	20 [34]	-
Relative Humidity (%)	Spring, Autumn	50 [26]	-	-	-
	Summer	60 [26]	-	-	30–50 [35]
	Winter	40 [9]	-	-	20–60 [35]

* Based on DIN EN 16798-1 [36], DIN EN ISO 7730 [36], DIN EN ISO 7730 [36], DIN 4108 [36].

Regarding wind speed, German law presents minimum requirements for thermal protection through an appropriate wind speed standard [34], while G-SEED does not represent the CIE (Commission Internationale de l'Eclairage) standard [37] for wind speed in its current domestic laws (Table 5).

Regarding relative humidity, current Korean domestic laws stipulate the appropriate level of indoor humidity in housing for each season [26], while there is no German law with specific requirements for humidity.

3.3. Visual Quality

Review papers have highlighted lightning as a critical element impacting occupants' health. Studies have shown a strong preference for daylight over artificial light, and elucidated the potential relationships between visual comfort and circadian rhythm [2,38]. Building rating systems primarily cluster the key elements of daylight, internal lighting, external lighting, management of glare, occupant control, and access to views. The majority of visual comfort indices consider one of the following elements: luminance/glare (50%), luminance/quantity of light (26%), and light quality (21%) [2,39]. DGNB prescribes flicker or minimum illuminance requirements, though compatible international lighting standards, most notably EN 12464-1, were referenced across multiple systems and provided a common baseline for artificial lighting requirements. For outdoor artificial lighting, there are requirements to limit lighting pollutants [2]. G-SEED does not consider lightning in terms of indoor quality, but the topic of light is evaluated within the criterion "saving of lighting energy", considering the average crude density of a ceiling [6,40]. The ability of occupants to control their lighting level has been correlated with higher ratings of lighting quality and comfort, as well as lower perceptions of task difficulty. Two primary types of occupant control are considered in these rating systems: glare control and illuminance control. The former is most frequently achieved through user-controlled shading devices, which DGNB requires/provides [2]. In evaluating the light environment, DGNB considers the ratio of areas where natural light can be used indoors, the prevention of glare for natural light and artificial lighting, and the degree of color expression of objects [4]. Regarding illumination, the current law in Korea presents a minimum illumination standard for each room used for housing and business purposes [26], for example, the evacuation and fire protection structure of buildings [26]. The German law “Arbeitsstättenverordnung” (workplace regulation) does not provide specific standards for the indoor light environment [29]. However, current domestic law suggests separate conditions for maintaining proper indoor illumination [29] (Table 6).

Table 6. Light/daylight standards of South Korea and Germany.

	Country	Korea		Germany	
Light/Daylight	**Level**	**Current Law [26]**		**Current Law [29]**	**DGNB [29]**
Lux		Reading, Dining, Cooking	150	Reading, Dining, Cooking	200
		Exams, Surgery, Calculation, Design	700	Medical rooms with high risks	1000
		General Work	300	General Work	500
		Packaging, Washing	150	Packaging, Washing	200
		ETC	70	-	

3.4. Acoustic Quality

It is known that environmental noise exposure has an impact on human physical and psychological health. Studies have identified adverse effects of it on cardiac risk and sleep disturbance, with corresponding stress, psychological health risks, fatigue, and reduced productivity. The literature shows that there are substantial impacts on health and wellness when acoustic comfort is not maintained, particularly from a total noise level and speech intelligibility perspective [41].

To measure the sound environment, indicators such as airborne sound insulation, shock isolation cups, reverberation time, and sound absorption have been observed between indoor–indoor and indoor–outdoor environments [2].

The acoustic design of a space is defined across most systems, requiring acoustic planning, modeling, and documentation of the acoustic comfort strategy. While prescriptive requirements are inherent in this design activity, the focus of these credits within DGNB is on identifying the necessary techniques and design strategies [2].

Acoustic privacy is a significant concern, especially in the office environment. Several ‘green’ office buildings lack speech privacy, and this is exacerbated in open-plan offices. Here, a lack of speech privacy, resulting in significant distraction, may offset the perceived benefits of such a layout for collaboration. The systems reviewed recognize that open-plan offices result in a noisier environment, typically permitting a 5–10 dBA higher background noise level in these areas, further increasing the potential level of distraction. DGNB prescribes minimum sound differentials between spaces [2].

Within G-SEED, only the criteria ‘indoor sound impact from transport rest area for users’ and ‘comfortable indoor environment for user’ are evaluated. These evaluation criteria are for used evaluating regional characteristics, focusing on cities with a high population density [9].

In the case of G-SEED, the soundproof performance of a building is measured by measuring the noise in a room facing external roads and railways, while DGNB considers the sound environment quality generated in indoor spaces through evaluating the use and size of a given room [4].

Regarding appropriate levels of indoor noise, the current law in Korea presents a value of 9 for “maximum allowable indoor noise in housing” in regulations on housing construction standards, etc. (Table 7) [26]. According to regional building regulations in

Germany, buildings must have sound insulation that is appropriate for their use (Table 7). Noises emanating from fixed installations in structures or on land must be insulated in such a way that dangers, unreasonable nuisances, and significant disadvantages do not arise [42].

Table 7. Indoor noise level and reverberation time standards in South Korea and Germany.

	Country	Korea		Germany	
Criteria		**Current Law**	**G-SEED ***	**Current Law**	**DGNB ****
Indoor Noise Level (dB)		≤45 dB [26]	-	25 dB [42]	25 dB [42]
Reverberation Time		-	-	0.163 m/s [42]	0.163 m/s [42]

* No standards for indoor noise level within G-SEED, ** Measured in the living room with all windows closed According to model administrative regulations, sound insulations are based on the requirements of DIN 4109-1 [42], DIN 4109-2 [42], DIN 4109-31 [42], and DIN 4109-36 [42].

In terms of G-SEED, there are no separate regulations for indoor properties [43], while in case of DGNB, acoustic comfort is evaluated based on the different room types using several individual indicators. This assessment is based on the requirements of DIN 18041:2016-03, "audibility in rooms", or the current VDI 256, "sound insulation and acoustic design in the office" [21,44]. However, the most important and minimum requirement is to fulfill DIN 4109-1 [45].

G-SEED measures of light impact blocking performance (L'n, AW), (L'i, Fmax, AW), sound insulation performance at boundary walls between generations, and toilet drainage noise reduction (Rw+ C) are shown (Level 4). While there are no standards set out by law in Korea, Germany's legal minimum requirements are also the basis of DGNB requirements (Table 8).

Table 8. Noise blocking, soundproofing standards of South Korea and Germany.

	Country	Korea		Germany	
Criteria		**Current Law**	**G-SEED**	**Current Law ***	**DGNB**
Impact sound blocking	Light-weight	-	1st ≤43 2nd 43~48 3rd 48~53 4th 53~58 [24]	≥50 [23]	≥50 [25]
	Heavy	-	1st ≤ 40 2nd 40~43 3rd 43~47 4th 47~50 [24]		
Sound proofing of walls between dwellings		-	1st ≥63 or * 2nd 58~63 3rd 53~58 4th 48~53 [24]	≥63 [23]	≥63 [25]
Sound level difference (Dnt,w)		-	-	≥25 [23]	≥25 [25]

* Consideration of minimum sound insulation values.

4. Conclusions

This study compared and analyzed the current laws, certification systems (DGNB and G-SEED), and guidelines of Korea and Germany to evaluate the domestic indoor environment and seek ways to improve appropriate indoor environment standards.

A comparison of both certification systems and their criteria and methods showed that the following domestic standards are supplemented when comparing the current laws and green building certification systems of Korea's (G-SEED) Classification for Indoor Environments 2018. G-SEED evaluates whether an office building obtains the minimum scores in six mandatory criteria, but DGNB evaluation can be initiated only after the prerequisites of each criterion are obtained [9].

Mostly, the criteria of the certifications are based on the given law requirements of both countries. The main difference is that G-SEED is based on domestic laws for every category except the acoustic quality. For acoustic quality, there is no given current law in South Korea. In cases wherein nothing is required by the government, DNGB relies on DIN EN regulations, and for given criteria, DGNB has regulations in some categories that are based more on expectation than on the law itself.

We compared the IEQ criteria of air, thermal, visual/light, and acoustic quality. Structurally, DGNB and G-SEED are similar, and both considered 24 of 40 compared categories and points, in which they differ mostly in terms of methods and their given domestic laws.

1. In terms of air quality, they consider limiting both toxic chemicals and VOCs; G-SEED requires low levels of VOC-emitting products, and DGNB relies on the existing policy. Overall, natural ventilation is the focus.
2. The thermal comfort of DGNB is measured in design-phase simulation, which should lead to a limitation on the peak air volume for heating and cooling by considering the radiant heat of floors, walls and ceilings. The G-SEED thermal environment criteria are based on the adoption of an indoor automatic temperature control section, which is based on the installation rate of the indoor automatic temperature controllers.
3. For lightning, DGNB prescribes certain light regulations, like flicker or minimum illuminance requirements, through compatible international lighting standards, most notably EN 12464-1. G-SEED does not consider lightning in terms of indoor quality, but the topic of light is evaluated through the criterion "saving of lighting energy", considering the average crude density of a ceiling.
4. In terms of acoustic quality, G-SEED measures soundproofing performance by measuring the indoor sound in rooms facing external sounds, and DGNB takes the size of the room into account.

Recommendations

In conclusion, it is visible that these two different countries' domestic building certification systems are similar to each other, but G-SEED has implemented more global standards, considering the differences in the topographical and social–cultural characteristics of the two countries. Since these aspects have not been considered, and differences could be due to differences in topographical and social–cultural characteristics, after a detailed IEQ criteria analysis considering these aspects, the method of evaluation could be improved, and more global standards could be evaluated. After such detailed analysis, it may be possible to find (considering the different law systems) an average of the given criteria, and to harmonize the assessments made within these certification systems. At least, we could provide global sustainable development goals for each country, which these certification systems could adapt to their processes.

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Abbreviation

Aw	Time average, frequency-weighted, single-axis vibration acceleration
BREEAM	Building Research Establishment Environmental Assessment Methodology
Bq	Becquerel (unit of radioactivity)
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CIE	Commission Internationale de l'Eclairage
CO	Carbon monoxide
CO_2	Carbon dioxide
dB	Decibel
DGNB	Deutsche Gesellschaft für nachhaltiges Bauen 'German Sustainable Building Counsil'
DIN	Deutsches Institut für Normung 'German Institute for Standardization'
Dnt, w	On-site sound insulation
EN	European norms
G-SEED	Green Standard for Energy and Environmental Design
HVAC	Heating, ventilation and air conditioning
IAQ	Indoor air quality
IEQ	Indoor environmental quality
LEED	Leadership in Energy and Environmental Design
L'i	Impact sound pressure level
L'n	Normalised impact sound pressure level
Lux	Unit of illumination
PCB	Polychlornated biphenyls
PM	Particle pollution
PPM	Part per million
Rw+ C	Weighted sound reduction index
VDI	Verein Deutscher Ingenieure 'Association of German Engineers'
VOC	Volatile organic compounds

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