

Review

Comparison of Health and Well-Being Aspects in Building Certification Schemes

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Abstract: The quality of the indoor environment is becoming increasingly important because people are spending the majority of their time indoors. This has led to an increased interest in the field of health and well-being of users of buildings and to the development of various assessment schemes dealing with this issue. In this study, *LEED O+M Building Operations and Maintenance* (hereinafter *LEED O+M*), *BREEAM In-Use* and *DGNB Buildings In-Use* were compared with a specialized BCS *WELL* that is focused on the health and well-being of building occupants. The aim of the comparison was to evaluate to what extent the selected building certification schemes (BCSs) cover the aspects of health and well-being in buildings. Based on the analysis, it was found that the observed BCSs mostly pay attention to indoor air quality, light and thermal comfort. In other areas, only certain topics are covered or the topics have a different focus. Another important finding of the study was that certain aspects that are important for the health and well-being of the occupants are not dependent only on the building design but also on the management of the building and the services provided within the building. This kind of information is especially valuable for building developers, managers and owners so they know how to improve health and well-being in a building. The present study provides them with a comprehensive overview of the certification schemes that are widely used in current practice.

Keywords: building certification schemes; health; well-being; sustainable buildings

1. Introduction

We are spending the majority of our time indoors and consequently the indoor environment is becoming increasingly important. Different studies emphasise that the indoor environment can affect human health. A connection between key public health concerns of the modern society, such as asthma, cancer, and obesity, and indoor building conditions has been recognised [1]. Exposure to various health risks in the indoor environment results in the occurrence of Sick Building Syndrome (SBS) or Building-Related Illnesses (BRI). SBS is described as a situation in which building occupants experience acute health and comfort effects that appear to be linked to the time spent in the building, although no specific illness or cause can be identified [2,3]. The complaints are sometimes localised to a particular room or may be spread through the whole building. The symptoms associated with SBS are headache, irritation of the eyes, nose or throat, dry cough, dry or itchy skin, dizziness and nausea, difficulty concentrating, fatigue, and sensitivity to odours [3]. In contrast, the term Building-Related Illness (BRI) is used when symptoms of a diagnosable illness are identified and can be attributed directly to airborne building contaminants [2].

A range of existing technologies and measures are able to improve indoor environments in a manner that significantly improves the health of the occupants [4]. Additionally, a better indoor environment quality (IEQ) of working environment is beneficial for employees, increasing productivity and decreasing absenteeism [5,6]. The current trends in the construction sector are shifting from focusing only on the energy performance of the buildings towards a more holistic approach that covers the whole building lifecycle, such as the use of resources, and also includes other aspects, such as the impact on human health [7–10]. The aim is to build sustainable buildings that address social, economic, functional and technical aspects. The evaluation of economic and environmental aspects for buildings is almost in common use now and already well known. In contrast, the social aspects, often also including the health aspects, have only recently gained importance. EU Regulation No. 305/2011 [11] defined the basic requirements for construction works, stating that they should be mechanically resistant and fire-safe, but also designed in such a way as not to be a threat to the hygiene or health or safety of workers, occupants or neighbours, and that they should not have any exceedingly high impact on the environment. The document also emphasises the importance of safety and accessibility of the building, protection against noise and energy efficiency and heat retention. Similar policies are being developed all over the world [12]. Therefore, to label a building as sustainable, the evaluation should also include aspects that are connected to the health of the occupants in the building.

The existing well-known general certification schemes like Leadership in Energy and Environmental Design (LEED), British Research Establishment Environment Assessment Methodology (BREEAM), Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), Haute Qualité Environnementale (HQE), etc., that were developed as tools to measure the sustainability of buildings only partly cover these aspects [13,14]. It should also be emphasised that they are commercial schemes and their practice is not mandatory for all buildings and other activities connected with construction. Nevertheless, many investors decide to perform a certification according to above-mentioned BCSs to demonstrate their awareness and to gain a better insight into the performance of their buildings. With the help of these BCSs, an audit of certain (more or less) building criteria can be performed, putting a score to the investigated parameter and summing up and weighting the partial scores into a final score that rates the extent of sustainability of a given building. The parameters can be quantitative and the score is usually obtained based on the quantitative result of a parameter. Qualitative parameters are most often assessed based on the criterion of whether a certain standard is achieved or not [15]. Apart from assessing the effects on the environment, the majority of schemes also address the health and well-being of the humans within the building to some extent [16]. The research conducted by Chethana et al. identified seven key credit criteria for the often-used certification schemes, namely Site, Energy, Water, Indoor Environment Quality (IEQ), Material, Waste and Pollution, and Management. Energy, however, remains the most important criterion, followed by IEQ and Water [17]. Particularly, the IEQ key credit assesses quite a number of topics that are connected with health and well-being of the occupants but the huge extent of different topics that are covered in the BCSs that evaluate the sustainability of buildings omits certain topics related to health and well-being.

In contrast to the above-mentioned BCSs and due to increasing attention to building-related health problems, special schemes have been developed focusing only on topics related to these aspects. Such schemes are, for example, *WELL* launched in 2014 by the International Well Building Institute [18], *Living Building Challenge*, created by the International Living Future Institute in 2006 [19], *Health, Well-being and Productivity in Offices*, published by the World Green Building Council [20], and *FitWell*, launched by the Centre for Active Design [21]. These dedicated schemes were developed not to replace the existing BCSs that evaluate the sustainability of buildings, but to emphasise that within a building special attention is needed to ensure the health and well-being of the occupants. However, among them, *WELL* is the most well-known certification system that has very carefully developed specific topics and criteria for the evaluation of buildings, and extended the scope beyond the boundaries of the physical building. It is claimed to be the leading certification scheme for assessing health and sustainability in buildings [18].

The main objective of this review is to analyse which topics related to health and well-being of the occupants are represented in specific BCSs that deal with the sustainability of already constructed buildings, what the topics are specifically referring to and to what extent they are processed. The review was conducted as a comparison of schemes derived as subsidiary schemes from most common sustainability BCSs with BCS *WELL*, in such a way that *WELL* serves as a reference BCS. It shows where the potential is of the chosen BCSs in terms of their improvement of particular topics and consequently it provides valuable information for the development of the compared BCSs. Finally, it also helps investors to decide whether they want to perform supplementary certification that evaluates the existing building according to the health and well-being of the occupants, or not.

2. Comparison of Building Certification Schemes (BCS)

2.1. Methodology

In the study, the three most commonly used sustainability BCSs for buildings—*LEED O+M Building Operations and Maintenance* (hereinafter *LEED O+M*) [22], *BREEAM In-Use* [23] und *DGNB Buildings In-Use* [24]—are compared with the specialised BCS *WELL* by using the structure of its main areas that is proposed in the certification system *WELL*. We have chosen the BCS on the basis of a market study for the European Commission. The defined leading sustainability BCSs for Europe are *BREEAM*, *LEED*, *DGNB* and *HQE* [25]. According to the study, *BREEAM* has the largest market share (80.6%), followed by *HQE* (11.3%), *DGNB* (4.4%) and *LEED* (3.4%). Because the *HQE* is mainly focused on the French market while other BCSs are used internationally, we have focused the study on the *LEED*, *BREEAM* and *DGNB* rating systems. These are also the rating systems that have been assessed in the study by Bernardi et al. and are claimed to be the most used rating systems for assessing the environmental impact of buildings [26]. They have been compared with the *WELL* certification system specialised in health and well-being that is also present in the European market [27]. Because *WELL* assesses already-constructed buildings, we have compared it with the sustainability BCSs versions that also focus on already constructed buildings, namely *LEED O+M*, *BREEAM In-Use* und *DGNB Buildings In-Use*.

The structure of the areas that are compared in the study is derived from the *WELL*: air, water, light, nourishment, fitness, comfort and mind. These areas are further divided into topics. The great majority of data used for the comparison was acquired directly from the official technical manuals of the BCSs. We have not applied the selected rating systems in the paper. The analysis focuses on the comparison of the officially declared topics of the certification systems.

Firstly, we present the health aspects assessed in the study in Section 2.2. Secondly, in Section 2.3 we compare the selected areas based on the topics they assess, the standards they build on and the benchmarks they are setting. The topics were divided into those that are dependent on the management of the building and those dependent on the building design. The topics related to the building design are identified by bold print in the tables.

2.2. Health Aspects Assessed in the Study

This chapter describes the relation between the indoor building environment and the occupants' health and well-being in the selected areas. The division into areas dictated how this and the following chapter are structured.

2.2.1. Air

The indoor air quality (IAQ) influences the health of the occupants significantly, especially since people of developed countries in temperate climate regions spend most of their time indoors [28]. The World Health Organization (WHO) has published a study in which it is estimated that 1.6 million excess deaths are associated with exposure to indoor air pollutants. [29]. The pollutants are mainly fine particles, carbon monoxide, polycyclic aromatic hydrocarbons, nitrogen dioxides, sulphur oxides,

arsenic and fluorine, volatile and semi-volatile organic compounds, aldehydes, pesticides, asbestos, lead, biological pollutants, radon, free chemicals, etc. [28]. The hypothesis that exposure to air pollution increases the risk of developing various illnesses, such as cardiovascular or respiratory diseases, has been demonstrated in a number of studies [30]. In recent research by Wei et al. [31] it was found that the average share of the evaluated IAQ in the total rating of individual certification schemes surveyed was 7.5%. However, in American BCSs, the emphasis on IAQ is considerably higher.

2.2.2. Water

Providing access to drinking water is an important aspect of health in buildings. Different legislation and policies worldwide have been developed to ensure the safety of drinking water in the built environment with an approach that ensures systematic assessment of risks over the entire water cycle, from catchment to the consumer. The WHO has developed strategies for managing drinking water during everyday consumption. The document includes supporting information about microbial, chemical, radiological and other acceptability aspects. It also deals with water quality and management inside buildings [32]. In the current research there is a lot of emphasis on efficient water use [33,34] and less on water quality.

2.2.3. Nourishment

Nourishment is a specific area covering food or other substances necessary for growth, health, and good condition. Today the benefits of healthy and wholesome nutrition are fully recognised and are part of the basic requirements for healthy living [35]. Access to healthy food is determined by the location of the building and what is available in the building [36]. Another possibility is to grow the food inside the building, such as in the form of vertical farming or rooftop gardening [37].

2.2.4. Light

The indoor space is an artificial environment with restricted access to daylight. It is generally known that light affects the physical, physiological and psychological condition of people. Installing artificial lighting devices light cannot completely compensate all the positive aspects of daylight. Webb [38] states that any kind of light suitable from the visual aspect does not necessarily cover non-visual needs such as the influence on the occupant's sleeping patterns, daily hormone secretion patterns, the body's temperature cycles, etc. The study by Bellia et al. [39] confirms that unsuitable light conditions influence the performance, safety and health of the occupants. Their non-visual characteristics influence the occupants' circadian rhythm. In their study, Galasiu and Vietch [40] stated that people have a strong preference for daylight in buildings, especially in office buildings. Moreover, if the windows provide a nice view of the outside, the glare from the sky is not so distracting.

2.2.5. Fitness

Research performed by the WHO [41] identified physical inactivity as one of the leading risk factors for global mortality and it consequently published recommendations for how to increase physical activity, called The Global Recommendations on Physical Activity for Health. The role of buildings in a built environment is significant, as their design can greatly contribute to the promotion of human physical activity. For example, a study conducted by Bullock et al. [42] showed that bike-sharing schemes had several benefits, like journey time savings, health benefits and reductions in motor vehicle use or similar, and the use of bikes could be easily promoted by building design. The proximity of green spaces can also increase the physical activity of the occupants [43]. Another possibility is the promotion of walking inside the building, integration of active furnishing, incentives encouraging greater levels of physical activity, etc.

2.2.6. Comfort

Buildings have to ensure a comfortable living and working environment. Not only the acoustic, thermal, ergonomic and olfactory comfort, but also the physical and psychological comfort are crucial to prevent stress and may help to increase the productivity of the occupants. However, the current studies mainly focus on thermal and acoustic comfort [43–45]; ergonomic and olfactory comfort are rarely discussed.

2.2.7. Mind

The area Mind involves human mood or mental state at a particular time and situation. The state of mind and human physical health are inextricably connected. Each environment that is able to support a healthy mental state can offer significant psychological and also physical benefits for the occupants [43]. The building design plays a significant role in this area. For instance, it impacts the mood and the quality of sleep, and in this manner affects the stress levels [46].

2.3. Comparison of Different Areas

The majority of topics assessed in the *WELL* scheme are partly covered in other BCSs compared in this study. For instance, the *LEED O+M* covers topics connected to air quality, water quality, visual comfort and overall comfort, mostly related to thermal and acoustic comfort. *BREEAM In-Use* covers a similar set. *DGNB Buildings In-Use* additionally covers some aspects of the area Mind, assessing parameters influencing the mental state of the occupants, but it does not cover areas like Water, Nourishment, Light or Comfort. Figure 1 illustrates the coverage of topics with respect to the BCS in a certain area. Although this gives us some basic information about how many topics a particular BCS is actually dealing with, the topics in each BCS are covered to a different extent.

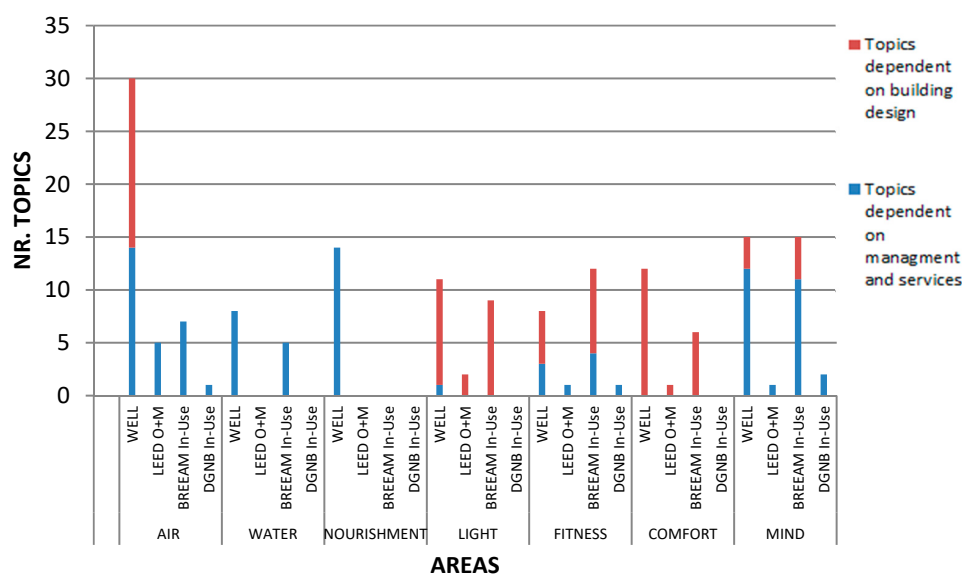


Figure 1. Number and type of topics (marked with two colors) in the particular area for compared building certification schemes (BCSs).

A lot of topics related to the health and well-being of the occupants are not directly dependent on the design of the building, but are more relevant to the management of the building and services provided within the building. To be distinguished they are marked with two colors in Figure 1. The topics air quality, water quality and topics from the areas Nourishment and Mind are predominantly related to the management of buildings. The topics from the areas Light, Fitness and Comfort are mainly dependent on or influenced by the building design.

A comparison of the studied BCSs for each of the selected area follows.

2.3.1. Air

Indoor air quality (IAQ) is assessed in all studied certification schemes. However, the BCS *DGNB In-Use* does not directly address this topic. The other three BCSs compared, *BREEAM In-Use*, *LEED O+M* and *WELL*, provide more direct requirements for the quality of air inside the building. The *WELL* provides exact numerical benchmarks, while the other two either refer to standards (*LEED O+M*) or give advice on monitoring the air quality (*BREEAM In-Use* and *LEED O+M*). Volatile organic compounds (VOCs) as well as the ventilation rates are addressed in all three BCSs except *DGNB Buildings In-Use*. A great advantage of *WELL* over other BCSs is that it covers several additional topics like microbe and mould control, pesticide management and construction pollution management, healthy entrance, cleaning protocol, fundamental material safety, and moisture management. These topics are mostly neglected by other BCS.

WELL and *LEED O+M* additionally refer to national or international standards, like the ASHRAE Standard or CEN Standards, while *BREEAM In-Use* and *DGNB Buildings In-Use* do not refer to any of them. *WELL* mentions the ASHRAE standard, while *LEED O+M* offers the possibility to choose other standards as well, making it easier to apply internationally. In addition, *WELL* gives exact benchmarks, while in other BCSs no benchmarks are given. The results of the analysis are presented in Table 1.

Table 1. Indoor air quality (IAQ) topics, legislation and benchmarks of studied BCSs (topics associated with the design of the building are marked in bold).

	Topic	Legislative Framework	Benchmark
WELL [18]	Air quality standards, Smoking ban, Ventilation effectiveness , Volatile organic compound (VOC) reduction , Air filtration , Microbe and mold control, Construction pollution management, Healthy entrance , Cleaning protocol, Pesticide management, Fundamental material safety , Moisture management, Air flush , Air infiltration management, Increased ventilation, Humidity control, Direct source ventilation , Air quality monitoring and feedback, Operable windows , Outdoor air systems , Displacement ventilation , Pest control, Advanced air purification , Combustion minimization , Toxic material reduction , Enhanced material safety , Antimicrobial activity for surfaces , Cleanable environment , Cleaning equipment	ASHRAE 62.1-2013, standards for states	Formaldehyde < 27 ppb, Total volatile organic compounds < 500 µg/m ³ , Carbon < 9 ppm, PM _{2.5} < 15 µg/m ³ , PM ₁₀ < 50 µg/m ³ , Ozone < 51 ppb, carbon dioxide levels < 800 ppm, Radon < 4 pCi/L in the lowest occupied level of the project, asbestos, lead and polychlorinated biphenyl abatement, mercury limitation,
LEED O+M [22]	Minimum Indoor Air Quality Performance, Environmental Tobacco Smoke Control, Green Cleaning Policy, Indoor Air Quality Management Program, Enhanced Indoor Air Quality Strategies.	ASHRAE Standard 62.1-2010 or CEN Standards EN 15251-2007 and EN 13779-2007	
BREEAM In-Use [23]	Fresh air rates Internal environment: CO ₂ monitoring Internal environment: CO monitoring Internal environment: NO _x monitoring Volatile organic compounds Control of chemicals Deep cleaning	/	/
DGNB BUILDINGS In-Use [24]	Guidelines for sustainable cleaning	/	/

2.3.2. Water

Among the compared certification systems, only *BREEAM In-Use* and *WELL* include a chapter about the quality of drinking water that is directly related to the health of the occupants (Table 2).

The *WELL* certification system evaluates the quality of drinking water, especially its possible contamination with inorganic, organic or agricultural releases. It gives strict benchmarks for water quality that are necessary to obtain the evaluation credits. The certification scheme proposes periodic testing of water quality and encourages the use of diverse water treatment procedures. Moreover,

WELL evaluates the promotion of using drinking water inside a building. *BREEAM In-Use* also encourages the promotion of drinking water for the occupants. Credits are also given for ensuring water safety through legionella management and for the development of a water-quality management strategy.

Neither *WELL* nor *BREEAM In-Use* has a legislative background concerning the quality of water. The benchmarks that can be used for the evaluation to certify the quality of the water in the building were developed exclusively within BCS *WELL*.

Table 2. Water quality topics, legislation and benchmarks of studied BCSs (topics associated with the design of the building are marked in bold).

	Topic	Legislative Framework	Benchmark
WELL [18]	Fundamental water quality		Turbidity < 1.0 NTU.
	Inorganic contaminants		E. coli not detected,
	Organic contaminants		Lead < 0.01 mg/L.
	Agricultural contaminants		Arsenic < 0.01 mg/L.
	Public water additives		Antimony < 0.006 mg/L.
	Periodic water quality testing		Mercury < 0.002 mg/L.
	Water treatment		Nickel < 0.012 mg/L.
	Drinking water promotion		Copper < 1.0 mg/L.
			Styrene < 0.0005 mg/L.
			Benzene < 0.001 mg/L.
			Ethylbenzene < 0.3 mg/L.
			Polychlorinated biphenyls < 0.0005 mg/L.
			Vinyl chloride < 0.002 mg/L.
			Toluene < 0.15 mg/L.
LEED O+M [22]	/	/	Xylenes (total: m, p and o) < 0.5 mg/L.
	Microbial contamination		Tetrachloroethylene < 0.005 mg/L.
BREEAM In-Use [23]	Water provision		Atrazine < 0.001 mg/L.
	Legionella management		Simazine < 0.002 mg/L.
DGNB BUILDINGS In-Use [24]	Drinking water		Glyphosate < 0.70 mg/L.
	Water strategy		2,4-Dichlorophenoxyacetic acid < 0.07 mg/L.
			Nitrate < 10 mg/L nitrogen.
			Residual chlorine < 0.6 mg/L.
			Residual chloramine < 4 mg/L.
			Total trihalomethanes < 0.08 mg/L
			Total haloacetic acids < 0.06 mg/L
			Fluoride < 4.0 mg/L.

2.3.3. Nourishment

Nourishment is covered only by the *WELL* building certification scheme, which specifically focuses on the health and well-being of the occupants. The scheme evaluates whether food provided either in vending machines or in restaurants is fresh and wholesome. Additionally, it proposes limiting some food ingredients that are not considered healthy. Promotion of healthy eating habits and raising awareness about unhealthy food are also rewarded. Besides the food provided inside the building, the certification scheme also evaluates the access to farmers markets, the proximity of other stores offering healthy and fresh food, and the promotion of consumption of fruit and vegetables. A few assessment topics of this area are actually directly related to the building itself, and not to services provided in the building or the location of the building. These are on-site food production, provision of areas for eating and proximity to farmers markets or food stores. The results are presented in Table 3.

Table 3. Nourishment topics, legislation and benchmarks of studied BCSs (topics associated with the design of the building are marked in bold).

	Topic	Legislative Framework	Benchmark
WELL [18]	Fruits and vegetables		
	Processed foods		
	Food allergies		
	Food contamination		
	Artificial ingredients		
	Nutritional information		
	Food advertising	/	/
	Safe food preparation materials		
	Serving sizes		
	Special diets		
	Responsible food production		
	Food storage		
LEED O+M [22]	Food production		
	Mindful eating		
BREEAM In-Use [23]	/	/	/
DGNB BUILDINGS	/	/	/
In-Use [24]	/	/	/

2.3.4. Light

According to our review, all the building certification schemes studied deal with the evaluation of the influence of light in the building on the well-being of the occupants, except *DGNB Buildings In-Use*. Topics that are assessed in the studied BCSs are presented in Table 4.

Table 4. Light topics, legislation and benchmarks of studied BCSs (topics associated with the design of the building are marked in bold).

	Topic	Legislative Framework	Benchmark
WELL [18]	Visual lighting design		Average light intensity 215 lux
	Circadian lighting design		<250 equivalent melanotopic lux present at 75% or more workstations
	Electric light glare control		Shielding angles for lights at certain luminance
	Solar glare control		Color Rendering Index 80 or higher
	Low-glare workstation design		Ceiling Light Reflectance Values (LRV) > 0.8
	Color quality		Wall LRV > 0.7
	Surface design		Furniture LRV 0.5
	Automated shading and dimming controls		75% occupied spaces within 7.5 m of view window
	Right to light		Window-to-wall ratio between 20 and 60%
	Daylight modelling		Visible Transmittance < 60%
	Daylighting fenestration		Luminance of > 2500 cd/m2 between 45 and 90 degrees nadir
			CRI of 80 and higher
LEED O+M [22]	Interior Lighting		75% of the total connected load have a rated life of at least 24,000 hours
	Daylight and Quality Views		average surface reflectance: 85% for ceilings, 60% for walls, and 25% for floors 45% for work surfaces and 50% for movable partitions
BREEAM In-Use [23]			75% of the regularly occupied floor area, meet a ratio of average wall/ceiling surface illuminance (excluding fenestration) to average work surface illuminance that does not exceed 1:10
			Achieve illuminance between 300 lux and 3000 lux for at least 50% of regularly occupied floor area
			50% of all regularly occupied floor area achieves a direct line to the outdoors view- vision glazing
	Glazing		
	Glare control	EN	
	Illuminance levels (Lux)	12464-1 Light and lighting—Lighting of workspaces	
DGNB BUILDINGS In-Use [24]	Lighting control	EN 12464-2 Lighting of work places—Part 2: Outdoor work places, 2007	
	Glazing		
	Internal lighting types		
	Automatic lightning control		
	Occupancy sensors		
	View out		
	/	/	/

The *WELL* evaluates natural and artificial lighting, the prevention of glare as well as colour quality and surface design. The occupant's visual connection with the exterior is also included. *WELL* also gives credits for an optimal window-to-wall ratio that is determined in the *WELL* BCS and the visibility parameters for lights are also set. The *LEED O+M* provides the strictest requirements not only for interior lighting but also for providing daylight to the indoor environment and appropriate visual connections to the exterior. *BREEAM In-Use* focuses on glazing ratios of the façade, the prevention of glare, and adequate illuminance levels and control of artificial lighting.

The only BCS referring to the standards in this particular area is *BREEAM In-Use*. It declares that for the assessment of the credits EN standards should be used. This is additional proof that *BREEAM In-Use* is focused on the European market.

The benchmarks for acquiring the credits in the certification process are given in two BCSs, *WELL* and *LEED O+M*. It is worth mentioning that the benchmarks are quite strict and even comparable between both systems, since they refer to the same standards.

2.3.5. Fitness

One would expect the BCSs under consideration to tackle the topics dealing with the physical activities of the occupants in buildings as well. However, with the exception of *WELL*, none of them addresses this issue directly. Instead, by addressing specific topics they promote good bicycle access or alternative means of transport to the building (*LEED O+M*, *BREEAM In-Use* and *DGNB Buildings In-Use*). These topics are associated mainly with the location of buildings and their design. Again, *WELL* is quite the opposite, as it includes eight topics related to physical activity in the building (Table 5), yet with no direct standards or benchmarks.

Table 5. Fitness topics, legislation and benchmarks of studied BCSs (topics associated with the design of the building are marked in bold).

	Topic	Legislative Framework	Benchmark
WELL [18]	Interior fitness circulation		
	Activity incentive programs		
	Structured fitness opportunities		
	Exterior active design	/	/
	Physical activity spaces		
LEED O+M [22]	Active transport support		
	Fitness equipment		
	Active furnishing		
	Alternative transportation	/	/
	Cyclist facilities		
BREEAM In-Use [23]	Proximity to public transport		
	Proximity to amenities		
	Pedestrian and cyclist safety		
	Transport requirements		
	Transport management arrangements	/	/
DGNB BUILDINGS In-Use [24]	Local public transport		
	Local amenities		
	Transport objectives		
	Transport impact of commuting		
	Transport impact of business travel		
	Transport impact of goods delivery		
	Mobility provisions	/	/

2.3.6. Comfort

WELL, *LEED O+M* and *BREEAM In-Use* evaluate comfort inside the building. The *DGNB Buildings In-Use* does not directly evaluate any topic from this area (neither thermal, ergonomic, acoustic nor

olfactory comfort is assessed). It proposes surveys for the occupants to check their satisfaction with the building.

WELL, *LEED O+M* and *BREEAM In-Use* all evaluate thermal comfort within the buildings. Acoustic comfort is covered by *WELL* and *BREEAM In-Use*. In comparison with *BREEAM In-Use*, which only assesses whether the building has been evaluated by an appropriate expert, *WELL* gives more precise acoustic requirements. *BREEAM In-Use* additionally covers the comfort related to the ventilation in the building. *WELL* has precise requirements about ergonomics for the occupants, the olfactory comfort and provision of adequate measures for disabled people.

LEED O+M and *WELL* use ASHRAE standards that should be fulfilled in order to achieve credit for the thermal comfort. *WELL* additionally requires the use of ADA Standards for accessible design and HFES 100 standard for chair ergonomics.

Nevertheless, the only BCS that uses exact benchmarks is the *WELL* methodology. The results are shown in Table 6.

Table 6. Comfort topics, legislation and benchmarks of studied BCSs (topics associated with the design of the building are marked bold).

	Topic	Legislative Framework	Benchmark
WELL [18]	ADA Accessible design standards		Air sound pressure < 50 dBA
	Ergonomics: Visual and Physical		Maximum noise criteria: (NC) 40 for open spaces, 35 for enclosed office, 30 for conference rooms, 20 for teleconference rooms
	Exterior noise intrusion		Maximum reverberation time (RT 60) 0.6 seconds for conference rooms, 0.5 for open workspaces
	Internally generated noise	ADA Standards for accessible design	Sound masking levels should fall within the range 45–48 for open workspaces and 40–42 for enclosed offices
	Thermal comfort	HFES 100 standard	Minimum noise reduction coefficients 0.9 or 0.8 for the ceiling and 0.8 for walls
	Olfactory comfort	ASHRAE Standard 55-2013	Noise Isolation Class 35 for enclosed offices
	Reverberation time		
	Sound masking		
	Sound reducing surfaces		
	Sound barriers		
LEED O+M [22]	Individual thermal control	ASHRAE Standard 55-2010 or ISO 7730:2005 or CEN Standard EN 15251:2007	
	Radiant thermal control		
BREEAM In-Use [23]	EQ Credit: Thermal comfort		
	Thermal control		
	Ventilation controls		
	Ventilation requirements	/	/
DGNB BUILDINGS In-Use [24]	Operating temperature		
	Inclusive design		
	Acoustic conditions	/	/

2.3.7. Mind

The topics assessed in the area Mind are related partly to the services provided in the building and partly to the building design. Topics related to the building design are the adaptability of spaces, as evaluated by *WELL* and *BREEAM In-Use*, the inclusion of nature in the design, the assurance of safety by different alarm systems, etc. On the other hand, the area Mind assesses a lot of aspects that are actually services for the occupants. For example, *WELL*, *BREEAM In-Use* and *LEED O+M* all give credits for conducting surveys about the satisfaction of the building's occupants (Table 7). These surveys cover different topics related to various issues of comfort and offer the possibility for the occupants to express their opinion and will. Additionally, *WELL* and *BREEAM In-use* promote health and wellness awareness of the building's occupants. None of the BCSs studied provide standards or benchmarks that should be followed to obtain the credits.

Table 7. Mind topics, legislation and benchmarks of studied BCSs (topics associated with the design of the building are marked in bold).

	Topic	Legislative Framework	Benchmark
WELL [18]	Health and wellness awareness		
	Integrative design		
	Post-occupancy survey		
	Beauty and design		
	Biophilia		
	Adaptable spaces		
	Healthy sleep policy		
	Business travel	/	/
	Building health policy		
	Workplace family support		
LEED O+M [22]	Self-monitoring		
	Stress and addiction treatment		
	Altruism		
	Material transparency		
	Organizational transparency		
	EQ Credit: Occupant Comfort Survey	/	/
	Condition survey		
	Security advice		
	Intruder alert system		
	Alarm system monitoring		
BREEAM In-Use [23]	Natural hazards		
	Future adaptation		
	Designing for robustness		
	User guide	/	/
	Building user education		
	Building user information		
	Occupant satisfaction		
	Occupant satisfaction- feedback		
	Occupier satisfaction		
	Health and well-being management targets		
DGNB BUILDINGS In-Use [24]	Health and well-being management objectives		
	Sociocultural provisions	/	/
	Safety and operator obligations		

3. Discussion

The construction industry uses certification schemes to evaluate the performance of buildings, including their effect on the health and well-being of the occupants. However, BCSs evaluate topics connected to health and well-being differently. An overview of the content of the studied BCSs is presented in Table 8.

Table 8. An overview of the content of the studied BCSs.

Topic	WELL [18]	LEED O+M [22]	BREEAM In-Use [23]	DGNB BUILDINGS In-Use [24]
Air	●●●	●●●	●●	●
Water	●●●		●●	
Light	●●●	●●●	●●●	
Nourishment	●●●			
Fitness	●●●	●	●●	●
Comfort	●●●	●	●●	
Mind	●●●	●	●●	●

● addressing; ●● addressing most important topics; ●●● addressing topics in great depth.

For example, the topics connected to the area Air are covered to a great extent in all of the studied BCSs except *DGNB In-Use*. *DGNB In-Use* should be improved to be comparable with other BCS that deal with buildings in use since other schemes already pay a lot of attention to this area.

In the area Water, the studied BCSs should target the quality of the water inside the building more to ensure that the occupants have access to clean and healthy water. This means they should focus on

the water system management and ensure that the water inside the building is drinkable, instead of dealing only with reduced water use.

Most topics in the area Nourishment are related to food provision services in buildings and are therefore predominantly appropriate for evaluation of buildings where food is served. Consequently, they are completely neglected by all BCSs under consideration, except *WELL*. In our opinion, the area Nourishment is very specific and most countries already have national standards covering this issue. Therefore, there is no need to include it in sustainability BCSs.

Furthermore, the area Light is well addressed by all of the compared BCSs except *DGNB In-Use*; the topics are mostly covered by standards and benchmarks. This suggests that the authors of these BCSs are already aware of the importance of visual comfort for the well-being of the occupants.

Fitness is addressed in all of the studied schemes but the topics deal predominantly with fitness linked to transport to and from the building. They do not provide opportunities for actual physical activities for the occupants inside the building.

Then there is the area Comfort in buildings, which is addressed by the studied schemes in various ways. Thermal comfort is addressed in all of the studied BCSs, since it is also related to the energy consumption of the building. Ergonomic comfort on the other hand, which is difficult to include in the evaluation, since it is mainly dependent on the furnishings, is generally not represented. Acoustic and olfactory comfort, which have a strong effect on the occupants, are also underrepresented, and the segments of their evaluation must be supplemented and strengthened.

The last area, Mind, is rather special due to its complexity. It deals with providing safety and additional services for the occupants; among them there are topics that can partially include the design of the building. Here, an extremely valuable assessment topic is education about the use of the building. Despite its importance, it is only involved in the BCS *BREEAM In-use*. In our opinion, education of building occupants about the sustainable functioning of the building and providing safety should be addressed in all BCSs. Another important piece of information for building managers, not to be omitted from the topics of the evaluation process in BCS, is the level of occupant satisfaction. In general, many topics addressed in the area Mind are services-related and therefore it is difficult to include them in sustainability BCSs.

For building designers, it is important to know which topic to address in which phase of building design. So, a general recommendation for the further development of BCSs would be that the topics that are directly connected to building design should be specially indicated, since it is important to address them in the early design phases. For example, it is difficult to improve the lighting conditions in the building since it is often not possible to change the position of windows or light fittings or this involves a larger financial investment, so it is better to pay attention to these elements in the design phase. In contrast, many elements in topics from areas Water, Nourishment, Fitness, Comfort and Mind, which are mainly related to the management and services provided in the building, can be improved also after the construction of the building and in buildings that are already in use.

The analysis of this study may serve also as a foundation for further development of a list of management duties and services that should be provided within a building. However, it is important to stress that some services are important for building maintenance only, while many of them provide a healthy and comfortable environment for the occupants as well. However, the boundaries between them are not always easy to discern.

4. Conclusions

Most of the common sustainability BCSs address the aspects of health and well-being of the occupants in one way or another, but in general they lack a comprehensive and thorough approach. For this reason, specialised BCSs were developed, which are intended not only for dedicated evaluation, but also to offer a better insight into which particular issues have to be followed in buildings to ensure health and well-being of the occupants.

In this review paper, the three most widely used BCSs for buildings in use, *LEED O+M*, *BREEAM In-Use* and *DGNB Buildings In-Use*, were compared with the specialised BCS *WELL*. These specific BCSs can be used as an extended evaluation instrument in the frame of each particular parent BCS that assesses the sustainability of the building, *LEED*, *BREEAM* und *DGNB*, or as an independent evaluation tool with focus on the health and well-being of users. The review showed that the chosen sustainability BCSs cover the basic requirements for health and well-being of the occupants. The potential for future development of the current sustainability BCSs in terms of occupant health and well-being is also discussed.

The analysis of the reviewed BCSs has shown that basic well-known issues which affect the occupant, such as air quality, comfort and light, are addressed to a certain extent in all of them. In contrast, topics related to nourishment, fitness, water quality and state of mind are less represented or are not represented in an optimal extent regarding their influence on health and well-being of the occupants. The division of the topics into design-dependent and service-management-dependent topics is an important contribution of the study, especially for building developers because they have to know at what point they have to address certain aspects.

It can be established that the specialised BCS *WELL* is by far the most precise and in some aspects exceeds the scope of sustainable BCSs, for example in providing healthy food, opportunities for physical recreation, etc. It offers a more comprehensive insight yet at the same time it is quite time-consuming and demands that a lot of effort be devoted to very specific topics, which is not always in the interest of the investor.

It is also necessary to mention that some of the studied schemes are already setting specific requirements for a particular use of a building. Good examples for this are the *LEED O+M* and the *DGNB In-Use*. To distinguish between different uses is reasonable since the health and well-being requirements of the occupants can strongly depend on the type and use of the building, though it should be noted that many criteria in BCSs are actually targeted at office buildings. Consequently, most of the BCSs are essentially evaluating public, typically office buildings. However, it is quite clear that, in the future, BCSs for other building types will need to be developed.

Another important finding is that a lot of topics connected with health and well-being of the occupants refer to specific legislation. The BCSs often indicate their country of origin since they refer to specific standards, for example ASHRAE standards in *WELL* and *LEED O+M*. This means that such BCSs are more appropriate for use in certain countries and cannot be simply substituted for others. Nevertheless, there is still a lack of knowledge around the extent to which health and well-being are covered within the national legislation of countries, so similar studies need to be done in this field of the built environment.

It is particularly important to emphasise the fact that the sustainability of a building is reflected in its full occupancy and that such a level of occupancy can only be achieved by ensuring the health and well-being of the occupants.

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References

1. Mahesh Ramanujam Healthy Buildings and Healthy People: The Next Generation of Green Building. Available online: <https://www.usgbc.org/articles/healthy-buildings-and-healthy-people-next-generation-green-building> (accessed on 3 November 2017).
2. United States Environmental Protection Agency (EPA). *Indoor Air Facts No. 4 (Revised). Sick Building Syndrome. Air and Radiation*; United States Environmental Protection Agency: Washington, DC, USA, 1991. Available online: https://www.epa.gov/sites/production/files/2014-08/documents/sick_building_factsheet.pdf (accessed on 3 May 2019).
3. Kukec, A.; Dovjak, M. Prevention and control of Sick Building Syndrome (SBS). Part 1: Identification of risk factors. *Int. J. Sanit. Eng.* **2014**, *8*, 16–40.
4. Fisk, W.J. Health and productivity gains form better indoor environments and their relationships with building energy efficiency. *Annu. Rev. Energy Env.* **2000**, 537–566. [CrossRef]
5. Singh, A.; Syal, M. Effects of Green Buildings on Employee Health and Productivity. *Am. J. Public Health* **2010**, *100*, 1665–1669. [CrossRef] [PubMed]
6. Xue, F.; Gou, Z.; Siu, S.; Lau, Y. Human Factors in Green Office Building Design: The Impact of Workplace Green Features on Health Perceptions in High-Rise High-Density Asian Cities. *Sustainability* **2016**, *8*, 1095. [CrossRef]
7. Denac, M.; Obrecht, M.; Radonjič, G. Current and potential ecodesign integration in small and medium enterprises: Construction and related industries. *Bus. Strateg. Environ.* **2018**, *27*, 825–837. [CrossRef]
8. Roh, S. Developing a Green Building Index (GBI) Certification System to Effectively Reduce Carbon Emissions in South Korea's Building Industry. *Sustainability* **2018**, *10*, 1872. [CrossRef]
9. Krainer, A. Passivhaus contra bioclimatic design. *Bauphysik* **2008**, *30*, 393–404. [CrossRef]
10. Dovjak, M.; Shukuya, M.; Krainer, A. User-Centred Healing-Oriented Conditions in the Design of Hospital Environments. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2140. [CrossRef]
11. *Regulation (EU) No 305/2011 of the European Parliament and of the Council*; European Union Law: Brussels, Belgium, 2011. Available online: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011R0305> (accessed on 3 May 2019).
12. Park, M.; Tae, S. Suggestions of Policy Direction to Improve the Housing Quality in South Korea. *Sustainability* **2016**, *8*, 438. [CrossRef]
13. Griffiths, K. Beyond the Certification Badge—How Infrastructure Sustainability Rating Tools Impact on Individual, Organizational, and Industry Practice. *Sustainability* **2018**, *10*, 1038. [CrossRef]
14. Shin, M.H.; Kim, H.Y.; Gu, D.; Kim, H. LEED, Its Efficacy and Fallacy in a Regional Context—An Urban Heat Island Case in California. *Sustainability* **2017**, *9*, 1674. [CrossRef]
15. Forsberg, A.; von Malmberg, F. Tools for environmental assessment of the built environment. *Build. Environ.* **2004**, *39*, 223–228. [CrossRef]
16. Doan, D.T.; Ghaffarianhoseini, A.; Naismith, N.; Zhang, T.; Ghaffarianhoseini, A.; Tookey, J. A critical comparison of green building rating systems. *Build. Environ.* **2017**, *123*, 243–260. [CrossRef]
17. Illankoon, I.M.C.S.; Tam, V.W.Y.; Le, K.N.; Shen, L. Key credit criteria among international green building rating tools. *J. Clean. Prod.* **2017**, *164*, 209–220. [CrossRef]
18. WELL. Available online: <https://www.wellcertified.com/> (accessed on 4 November 2016).
19. Living Building Challenge. Available online: <http://living-future.org/lbc> (accessed on 4 November 2016).
20. Health, Wellbeing and Productivity in Offices. Available online: http://www.worldgbc.org/files/9714/3401/7431/WorldGBC_Health_Wellbeing_Productivity_Full_Report_Dbl_Med_Res_Feb_2015.pdf (accessed on 4 November 2016).
21. Fitwel. Available online: <https://fitwel.org/assets/pdf/brochure.pdf> (accessed on 4 November 2016).
22. LEED O+M. Available online: <https://www.usgbc.org/resources/leed-v4-building-operations-and-maintenance-current-version> (accessed on 10 January 2019).
23. BREEAM In-Use. Available online: <https://www.breeam.com/discover/technical-standards/breeam-in-use/> (accessed on 10 January 2019).
24. DGNB In-Use. Available online: https://www.dgnb-system.de/en/schemes/scheme-overview/buildings_in_use.php (accessed on 10 January 2019).

25. Market Study for a Voluntary Common European Union Certification Scheme for the Energy Performance of Nonresidential Buildings. Available online: <https://ec.europa.eu/energy/sites/ener/files/documents/Finalreport-BuildingCertificationSchemes-FINAL26112014.pdf> (accessed on 6 March 2017).
26. Bernardi, E.; Carlucci, S.; Cornaro, C.; Bohne, R. An Analysis of the Most Adopted Rating Systems for Assessing the Environmental Impact of Buildings. *Sustainability* **2017**, *9*, 1226. [CrossRef]
27. Health and Wellness Rating System Comparison. Available online: <https://www.buildinggreen.com/infographic/health-and-wellness-rating-system-comparison> (accessed on 6 March 2018).
28. Allen, J.G.; Macnaughton, P.; Guillermo, J.; Laurent, C.; Flanigan, S.S.; Eitland, E.S.; Spengler, J.D.; Allen, J.G. Green Buildings and Health. *Curr. Environ. Health Rep.* **2015**, *2*, 250–258. [CrossRef]
29. World Health Organization (WHO). *Air Quality Guidelines*; World Health Organization: Geneva, Switzerland, 2005.
30. Shekarrizfard, M.; Faghih-Imani, A.; Tétreault, L.F.; Yasmin, S.; Reynaud, F.; Morency, P.; Plante, C.; Drouin, L.; Smargiassi, A.; Eluru, N.; et al. Regional assessment of exposure to traffic-related air pollution: Impacts of individual mobility and transit investment scenarios. *Sustain. Cities Soc.* **2017**, *29*, 68–76. [CrossRef]
31. Wei, W.; Ramalho, O.; Mandin, C. Indoor air quality requirements in green building certifications. *Build. Environ.* **2015**, *92*, 10–19. [CrossRef]
32. World Health Organization (WHO). *Guidelines for Drinking-Water Quality*; World Health Organization: Geneva, Switzerland, 2011.
33. Flores, T.; Kalbusch, A.; Henning, E. Factors in influencing water consumption in buildings in southern Brazil. *J. Clean. Prod.* **2018**, *184*, 160–167. [CrossRef]
34. Wong, L.T.Á.; Mui, K.W. Epistemic water consumption benchmarks for residential buildings. *Build. Environ.* **2008**, *43*, 1031–1035. [CrossRef]
35. Rover, O.J.; De Gennaro, B.C.; Roselli, L. Social Innovation and Sustainable Rural Development: The Case of a Brazilian Agroecology Network. *Sustainability* **2016**, *9*, 3. [CrossRef]
36. Moore, J. Ecological Footprints and Lifestyle Archetypes: Exploring Dimensions of Consumption and the Transformation Needed to Achieve Urban Sustainability. *Sustainability* **2015**, *7*, 4747–4763. [CrossRef]
37. Llorach-massana, P.; Nadal, A.; Sanjuan-delma, D.; Ignacio, J.; Josa, A.; Rieradevall, J.; Gabarrell, X. Environmental assessment of an integrated rooftop greenhouse for food production in cities. *J. Clean. Prod.* **2018**, *177*, 326–337.
38. Webb, A.R. Considerations for lighting in the built environment: Non-visual effects of light. *Energy Build.* **2006**, *38*, 721–727. [CrossRef]
39. Bellia, L.; Bisegna, F.; Spada, G. Lighting in indoor environments: Visual and non-visual effects of light sources with different spectral power distributions. *Build. Environ.* **2011**, *46*, 1984–1992. [CrossRef]
40. Galasiu, A.D.; Veitch, J.A. Occupant preferences and satisfaction with the luminous environment and control systems in daylit offices: A literature review. *Energy Build.* **2006**, *38*, 728–742. [CrossRef]
41. WHO Global Recommendations on Physical Activity for Health. Available online: http://apps.who.int/iris/bitstream/10665/44399/1/9789241599979_eng.pdf (accessed on 2 December 2016).
42. Bullock, C.; Brereton, F.; Bailey, S. The economic contribution of public bike-share to the sustainability and efficient functioning of cities. *Sustain. Cities Soc.* **2017**, *28*, 76–87. [CrossRef]
43. Chan, I.Y.S.; Liu, A.M.M. Effects of neighborhood building density, height, greenspace, and cleanliness on indoor environment and health of building occupants. *Build. Environ.* **2018**, *145*, 213–222. [CrossRef]
44. Liang, H.; Chen, C.; Hwang, R.; Shih, W.; Lo, S. Satisfaction of occupants toward indoor environment quality of certified green office buildings in Taiwan. *Build. Environ.* **2014**, *72*, 232–242. [CrossRef]
45. Patiño, E.D.L.; Vakalis, D.; Touchie, M.; Tzekova, E.; Siegel, J.A. Thermal comfort in multi-unit social housing buildings. *Build. Environ.* **2018**, *144*, 230–237. [CrossRef]
46. Zhang, N.; Cao, B.; Zhu, Y. Indoor environment and sleep quality: A research based on online survey and field study. *Build. Environ.* **2018**, *137*, 198–207. [CrossRef]

