SUSTAINABILITY OF BUILDINGS: ENVIRONMENTAL, ECONOMIC AND SOCIAL PILLARS

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Abstract

Sustainability of buildings is not specified clearly in many of the Green Building Rating Systems, rather it is a long list of criteria without relation to each other. This creates misunderstandings about sustainability among the professionals in architecture and construction industry. The aim of this article is to define sustainability of buildings in a clear and comprehensive way and to list the aspects that influence it. The concept of three pillars of sustainability is taken as a basis of the sustainability definition and the article expands it specifically for buildings. The three pillars of sustainability are: environmental pillar, economic pillar and social pillar. Different sustainability criteria are collected from respected sources and Green Building Rating Systems (LEED, BREEAM, WELL, DGNB, SBToolCZ) and they are organized in the three pillars. The article concludes that a building cannot achieve the top results in all of the sustainability aspects, it has to be a balance of the economic, environmental and social criteria. Some of the criteria mutually reinforce each other, while trade-offs must be made among other criteria.

Keywords

Architecture; buildings; economic sustainability; environmental sustainability; social sustainability.

JEL Classification

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Introduction

Sustainability has become a trending topic in mainstream media and discussions in the last year and often it is linked to climate change. [1] However, the word sustainability itself does not have a generally accepted definition and each person can imagine a different concept behind the word. [2]

The situation is the same in the architecture and construction sector. The number of green buildings, both non-certified and certified by Green Building Rating Systems (GBRS), has been rising in the recent years. [3] However, the sustainability of buildings is not specified clearly in any of the systems, rather it is a long list of different aspects without a clear description how do they contribute to sustainability and what are the relations among them. Therefore, the understanding of sustainability among professionals in architecture, civil engineering and investors is not universal and creates problems in the process of designing and constructing buildings.

The aim of this article is to define sustainability of buildings in a clear and comprehensive way and to list the aspects that influence it. The concept of three pillars of sustainability [2] is taken as a basis of the sustainability definition and the article expands it specifically for buildings. Different criteria are listed for each pillar and they are briefly explained.

Methodology

Different sustainability criteria were collected from established sources of Green Building Rating Systems, international agreements from renowned institutions and scientific articles about buildings sustainability. In addition, other criteria from sources such as scientific articles and books about sustainability from different fields than architecture and building sector were included. All of these criteria were categorized in one of the three pillars, creating a synthesis of aspects for buildings sustainability. The main sources of sustainability criteria are:

- Sustainable Development Goals (SDGs) – United Nations [4]
- Level(s) – European Union framework for sustainable buildings [5]
- LEED – Green Building Rating System of building sustainability [6]
- BREEAM – Green Building Rating System of building sustainability [7]
- DGNB – Green Building Rating System of building sustainability [8]
- SBToolCZ – Green Building Rating System of building sustainability [9]
- WELL – Green Building Rating System of health and well-being [10]

UN Sustainable Development Goals define 17 goals and 169 partial targets for sustainable development [4], but none of the sections concentrates specifically on buildings. Therefore, only criteria relevant to buildings and its users have been selected. Criteria of sustainability from each of the pillars are included in SDGs. Level(s) is a common European framework of the sustainability of buildings, currently in the testing phase, so the criteria listed may not be final. LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Research Method) certifications were selected as the most frequent Green Building Rating Systems [11]. In Level(s), LEED and BREEAM mainly criteria from environmental pillar are included and some economic criteria, but the social pillar is only considered marginally. DGNB and SBToolCZ certifications were selected because they include criteria from all three pillars. WELL certification was selected as a representative of a rating system focusing on a partial aspect of sustainability: health and well-being of building users, with well-being representing only a small part of social sustainability. For complex definition of each pillars, more scientific literature was included with criteria from pillars that are underrepresented in the sources above.

Results

The three pillars of sustainability

The concept of three pillars of sustainability originated in the 1980s under different schools of thought, later institutionalized by the UN. [2] The three pillars of sustainability are the environmental pillar, the economic pillar and the social pillar (Figure 1). This concept can be applied to define sustainability of buildings. However, the literature is split between two approaches: whether the pillars reinforce each other or trade-offs between each pillar must be made. [2]

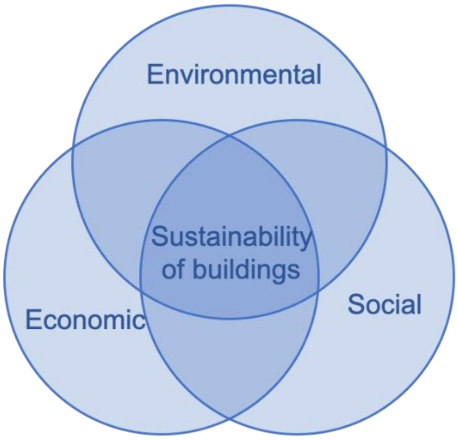

Figure 1: Three pillars of building sustainability (source: author)

Environmental sustainability of buildings

The environmental pillar criteria are briefly described in this chapter. The criteria are taken mainly from LEED, BREEAM, DGNB and SBToolCZ as these GBRS concentrate mainly on environmental sustainability.

Sustainable concept

The basis of environmental sustainability is a concept that is ecological. The ecological approach to resources is generally defined in Rs principle which appears in literature in different forms and with different number of Rs [12] [13]. The version of this principle applicable for use in construction and architecture would be 5R principle: Refuse, Reduce, Repair, Reuse, Recycle (Figure 2).

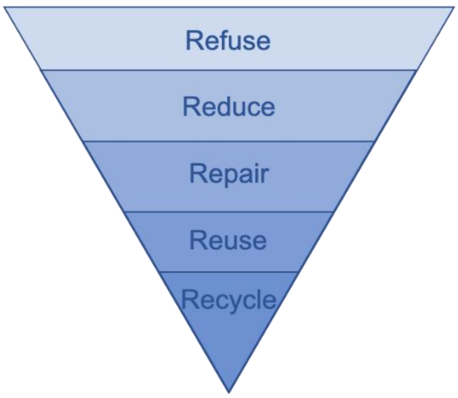

Figure 2: Scheme of 5R principle for construction and buildings (source: author)

- Refuse – do not build anything new and use existing buildings,
- Reduce – evaluate the needs for the size of an additional building and its facilities, then choose the minimal option,
- Repair – refurbish existing buildings of the same function,
- Reuse – reconstruct buildings of a different function to a new required function,
- Recycle – recycle old buildings and use recycled materials for construction of new buildings.

The steps are starting from the most sustainable (Refuse) to the least sustainable (Recycle). The most environmentally friendly approach is to do nothing. A building that is never built has no environmental impact. Unsustainable approaches (such as constructing new buildings from raw materials, demolition of buildings and landfilling the demolition waste) are not included in the 5R principle, even though these are the common approaches nowadays. It is evident from application of the 5R principle that construction of new buildings is inherently environmentally unfriendly. However, GBRS do not define it in their criteria, since their business interest is to build more and to certify more buildings. Even when developing a new building, the 5R concept is applicable for partial phases of construction and for the use of materials and waste management.

Sustainable site selection

The site selected for the buildings should be located on a site that has been developed before (brownfield). The site has to be easily accessible to its users and it should be located in a dense area with public amenities, so that the building generated the least traffic possible. The construction cannot destroy any important natural habitat, it should protect it or even restore it. Selection of site determines whether the building on it can be environmentally sustainable. [6] [7] [8] [9]

Carbon emissions

Reduction of emissions of CO2 and other greenhouse gases (GHG) is jointly referred to as carbon emissions reduction. It is an important factor that helps to slow down climate change. The carbon emissions should be assessed during the whole life cycle of a building and it should include all on-site and off-site sources necessary to develop, to operate and to demolish the building. Climate sustainability is directly linked to the carbon emissions. Buildings with zero carbon footprint are classified as net zero carbon buildings [15], zero emission buildings or climate neutral buildings. Building that absorb and compensate more GHG than they emit during the whole life cycle are called climate positive buildings. The carbon emissions reduction can be realized in the following categories: Energy, Materials and Waste, Water and Transportation.

Life cycle assessment (LCA) of a building is a method that evaluates the environmental impact of a building during the whole life cycle of a building. The results of the analysis can include carbon emissions, energy demand and other factors. [5] [6] [7] [8] [9]

Energy

Optimization of energy use is the key aspect of reducing carbon emissions of a buildings. The building envelope and systems have to be optimized to achieve the best energy efficiency possible which will lower the energy consumption. The necessary energy can be sourced from off-site renewable resources or by installing systems that produce renewable energy on-site. When the balance of energy needed for its operation and energy produced on-site is neutral, the building is classified as a net zero energy building. When the building produces surplus of energy on-site than it needs for its operation the building is classified as a net positive energy building.

The energy demand during the whole life cycle should be analyzed in LCA. [5] [6] [7] [8] [9]

Materials and Waste

The use of materials should be assessed in a whole life cycle of a building. This concept is referred to as circular use of materials or cradle to cradle. Recycled materials should be used for construction. If new materials have to be used, they should be sourced responsibly. The materials should not contain any harmful substances. Waste should be minimized during the whole life cycle and all of it should be recycled. [5] [6] [7] [8] [9]

Water

The water consumption should be minimized both indoor and outdoor. Grey water and rainwater should be used instead of potable when possible. Rainwater should be retained on the site. [5] [6] [7] [8] [9]

Transport

The site and the building should be easily accessible to its users by the most environmentally sustainable means of transport: walking, cycling, vehicles powered by renewable sources, public transport. The non-sustainable means of transport such as car transport should be limited. [6] [7] [8] [9]

Pollution

Pollution of the environment has to be minimized in all areas during the whole life cycle: dangerous chemical substances during the construction phase, substances such as refrigerants and NOX during the building operation, noise and light pollution. [6] [7] [9]

Health and indoor environmental quality

The aspects influencing the physical health of the building users are quality of air, thermal comfort, daylight and artificial light, acoustics, and potable water quality. Also, mental health is affected by aspects such as the amount of daylight, access to potable water and healthy food, possibility to perform physical movement, access to nature and relaxing spaces, and availability of quiet places for focus. Health is closely related to well-being and comfort as defined in social pillar. [5] [6] [7] [8] [9] [10]

Biodiversity and greenery

Biodiversity on the site should be supported. Sufficient greenery should be planted both on the site, on the building's facades and roof and in the building interior. Natural habitat for fauna and flora should be restored, suitable local plants should be planted and shelters for animals should be implemented. [6] [7] [8] [9] [10]

Adaptability

The building should be prepared for future climate change and extreme weather events such as rising temperature, floods, fires and other. The indoor environment and building systems should also be prepared for that. Heat island should be reduced. [5] [6] [7]

Food production

The site and the building should support sustainable food production. Food can be produced on site, on the building roof or in the building. The food production can cut off the carbon emissions of the food transportation and the carbon footprint of the production can offset the building carbon footprint. [4]

Possibility to behave ecologically

An environmentally sustainable building allows users to behave ecologically. It provides the necessary amenities for recycling waste, sustainable transportation, saving water, energies etc. [6] [7]

Economic sustainability of buildings

The economic pillar criteria and methods of assessment are listed in this chapter. Economic sustainability is the main factor which private developers and investor are aiming for and often it is considered as inherent. LEED and BREEAM do not include these criteria in their assessment, DGNB and SBToolCZ include it. However, the investors usually only consider a limited part of building life cycle when evaluating economic sustainability. There are many other stakeholders such as building owners, users, municipality and fellow citizen who are also affected by the economic sustainability of a building, but that often happens in a different life cycle phase. Therefore, it is necessary to assess the economic sustainability in all of the phases and as a whole.

Life cycle costing and whole life cost

Life cycle costing (LCC) is a method that represents the costs that are spent during the building life cycle: investment cost, maintenance and renovation cost, operating cost and end of life cost. [15] According to some literature this method can be also called Whole Life Cycle Costing (WLCC). [16] This method only calculates costs and does not include revenues, so it is suitable for comparison of options of buildings which do not generate any revenue. However, it is not possible to assess economic sustainability only with this indicator when the building investor have to assess revenues.

Whole life cost (WLC) is a method that takes into account life cycle cost plus all other business costs, revenues, and both negative and positive externalities. [15] An example of externality are carbon emissions which can be either negative externality (a building produces carbon emissions) or positive externality (a building absorbs carbon emissions). A universally accepted methodology for calculation of externalities is yet to be established.

Net present value

Net Present Value (NPV) is an economic indicator where the discounted present value of cash inflow is subtracted from the discounted present value of cash outflows. This metric indicates the net value of the investment in the building in today's money. [16]

Return on investment, Return on capital employed

Return on investment (ROI) and Return on capital employed (ROCE) are economic indicators used by private investors to assess the profitability of an investment. ROI is measured as a ratio of profit to cost of investment, whereas ROCE determines the percentage of net profit before income and taxes to total capital employed. [16]

During the life cycle of a building ROI and ROCE are usually assessed by different stakeholders in different phases as illustrated in following examples. The developer calculates the return ratios in the development stage until the sale of the building. Then the building owner calculates the ratios at the beginning of the operation stage when the owner buys the building from the developer and the return ratios are estimated for a limited time of expected operation by the owner. The return indicators of both of the developer and the owner are completely different numbers with different inputs. ROI and ROCE are rarely calculated for the building's end of life and for the whole life cycle. The costs associated with the building's disposal can be included in the return indicators of a new developer who buys a building at the end of its life cycle, plans to demolish it and then build a new building on the site. It can also happen that the disposal of a private building has to be done by the municipality and then the costs associated with the building's disposal are pure loss.

Lifetime ROI is an indicator that can assess economic profitability of the whole life cycle of the building. Literature suggests that continuous refurbishment of a building can lead to lifetime ROI optimization. [17]

Internal rate of return

Internal rate of return (IRR) is defined as the rate of discount that would potentially produce a zero NPV when applied to project cash flows. It serves for the investor as a decision-making basis: only projects with a greater rate than a limit set by the investor should be accepted. The limit is usually the market rate of interest. [16]

Management and monitoring

Continuous monitoring of costs and revenues is necessary in the whole life cycle of a building to ensure optimized economic performance of the building. [9] Building Integrated Modeling (BIM) can be an effective tool to track the costs together with the environmental impact.

Commercial viability

An empty building is not economically sustainable, nor it is environmentally sustainable because the resources in the building are not used effectively. The building capacities should be used effectively during the whole life cycle. [8]

Social sustainability of buildings

Social sustainability of buildings is a topic that has not been generally adopted by GBRS in all of the width of the topic, but rather in partial aspects. The social pillar criteria based on scientific literature review and SDGs are listed in this chapter.

Management and integrated process

Sustainable management practices should be used during the whole life cycle of the building. All stakeholders should be consulted when making decisions. A survey among building users should be performed and the suggestions should be implemented to improve the building performance. [6] [7] [8]

Participation

Participation means including as many social groups as possible in the decision-making process. [18] In the design phase fellow citizens and municipality should participate in an open discussion to present their needs in the location. The results of the participative planning process should be implemented in the building project. During the operations of the building users should have an opportunity to express their needs and problems in a regularly conducted survey. The participation process should also be implemented when a new purpose of a building or demolition are proposed.

Function and usability

The building function is the reason why the building exists: to fulfill the needs of the owner and the building users. Therefore, it is not always possible to achieve an absolute environmental sustainability as defined in the criteria Sustainable concept with 5R principle starting with Refuse: it is not possible to refuse the building existence when a demand for function is inevitable. An example is a need for housing: the most environmentally sustainable solution would be to live outside, but the socially sustainable solution is to use a building for living.

Usability of a building can be measured, and it assesses how well the building fulfills the goals of its users. In other words, how well the building fulfills its function. [19] Usability is defined by three factors: effectiveness, efficiency and satisfaction. Effectiveness assess whether the users can achieve the intended result. Efficiency assess how long it takes to achieve the result and if the use of resources is efficient. Satisfaction assesses users' emotions and experiences when using the building. [19]

Functional mix

The functions in the building or in the cluster of buildings should be diversified to fulfill the needs of the building users and other citizens. The diverse mix supports diversity of social contacts. [20]

Flexibility

The building design should be flexible and adaptable, so that the building can accommodate different functions in the future. Flexibility will ensure longer lifespan of the building and lower economic investments needed when the owner or the building owners are changed. Flexibility reinforces economic sustainability in the whole life cycle. [8] [9]

Comfort and well-being

Comfort and well-being are closely connected to physical and mental health as defined in environmental sustainability. Both are subjective criteria of individual building users and can be enhanced by various measures: incorporating more greenery inside of a building, creating calm relaxing areas both indoor and outdoor and other measures. Criteria of Comfort and Health mutually reinforce each other. [10]

Education

The building itself should educate the users about benefits of environmental aspects, sustainability, health and well-being. It is related to mental health and well-being of the users. [10]

Aesthetics

The aesthetic quality of building exterior and interior has an impact on its users and neighbors. In addition, the aesthetic quality has an impact on the lifespan of the building: the more aesthetic the building is, the higher the probability that no-one will want to demolish it before its end of life. [9]

Using exterior space

Building a quality exterior spaces for the building users support their comfort and well-being. It also encourages more social interactions. [9] [10]

Safety

Safety refers to criminality in the location and safety of the building and its systems. Measures to increase safety should be implemented in both cases. [9]

Inclusivity and accessibility

The building should be open and accessible to all social groups regardless of their disabilities. Needs of minorities and families should be taken into account and supportive measures should be implemented. All social groups should be taken into account even if the building is not designed for them nowadays – it can change in the future because of the building flexibility. [8]

Equity and affordability

All people should have equal opportunity to fulfill their development and should not be discriminated. [18] In relation to buildings it means for example that all social groups should be allowed to buy the building or part of it provided they have the resources. It is important to consider affordability of buildings which is related to commercial viability.

Definition of sustainability of buildings

Sustainability of buildings is a synthesis of the three pillars of sustainability: environmental, economic and social. A building cannot achieve the top results in all of the sustainability aspects, it has to be a balance of the economic, environmental and social criteria. Some of the criteria mutually reinforce each other, while trade-offs must be made among other criteria.

Conclusion and discussion

Building sustainability should be evaluated in all three pillars to be comprehensive. It is not possible to fulfill all the criteria of all pillars to the maximum, but a balance should be achieved with no pillar being significantly stronger than the other two pillars.

Public investors should consider all aspects of sustainability, because all of them are beneficial for the state and for the society. Regulations can be issued to make all 3 pillars mandatory for both public and private investments. The private investors usually try to achieve the best economic sustainability possible at the expense of environmental and social sustainability. Therefore, there has to be other motivation for them to also consider the environmental and social pillars.

GBRS that do not include all three pillars should be updated or they should transparently state that they only assess one of the pillars (usually the environmental pillar).

The research can continue with assessing importance of the individual criteria based on opinions of experts, architects, investors, building users, municipal representatives and other stakeholders. Also, deeper investigation of the synergies and trade-offs between the individual aspects of the pillars can be conducted. A methodology that takes into account all of these pillars should be established. This method should calculate the overall sustainability of a building and it should be comparable among buildings. Criteria from environmental and social pillars that can be quantified in monetary value should be included in the calculations of economic sustainability.

The list of sustainability criteria in this article cannot be exhaustive because a new aspect can always be added based on a personal opinion of any stakeholder which is a weakness of the research. However, the presented criteria were selected from many respected sources and this article summarizes it briefly. The most important mission of this article is the definition of many sustainability aspects of buildings which can be used among professionals to unify their understanding of sustainability of buildings.

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