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Sustainability assessment of family house

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Abstract

Sustainable construction of buildings provides an ethical and practical response to issues of environmental impact and resource consumption. Sustainability assumptions include the entire life cycle of the building and its significant components, from resource extraction through disposal at the end of the materials' useful life. Sustainable building design relies on renewable resources for energy systems, recycling and reuse of water and materials, minimal intervention for landscaping, passive heating, cooling, and ventilation; and other approaches that minimize environmental impact and resource consumption. At present, sustainable buildings are defined by the assessment systems, that rate and certify them. Building assessment systems simply score or rate the effects of a building's design, construction, and operation, among them environmental impacts, resource consumption, and occupant health. Health in building can be deduced by the presence or absence of chemical and biological substances within circulating air, as well as the relative health and wellbeing of the building occupants. Building assessment systems used in the world evaluates various types' buildings (office, hotels, government buildings, educations, institutional, industrial facilities, facilities of health-care, residential buildings). Assessment systems evaluate new buildings, major renovations or existing buildings. The aim of this paper is to highlight the evaluation of the selected family houses in various categories aimed at location and site, building constructions, energy efficiency, water efficiency and waste.

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Keywords: environmental assessment buildings, certify, environmental impact, resource consumption, occupant health

1. Introduction

Sustainable construction refers to both a structure and the using of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from site to design, construction, operation, maintenance, renovation and deconstruction. In other words, sustainable construction involves finding the balance between

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homebuilding and the sustainable environment. This requires close cooperation of the design team, the architects, the engineers, and the client at all project stages. New technologies are constantly being developed to complement current practices in creating greener structures. The common objective of green buildings is to reduce the overall impact of the built environment on human health and the natural environment by: efficiently using energy, water, and other resources, protecting occupant health and improving occupant productivity and reducing waste, pollution and environmental degradation. The built environment has a vast impact on the natural environment, human health, and the economy [1]. By adopting sustainable construction or green building strategies, we can maximize the environmental, social and economic performance. Sustainable building methods can be integrated into buildings at any stage, from design and construction, to renovation and deconstruction. However, the most significant benefits can be obtained, if the design and construction team takes an integrated approach from the earliest stages of a building project [1].

2. Sustainability Assessment of Buildings

At present, high-performance green buildings are defined by the assessment systems that rate and certify them. Building assessment systems simply score a building project on how well it lines up with the general philosophical approach developed by the designers of the assessment system. One advantage of relying on building assessment systems for this purpose is that it standardizes the boundaries of what constitutes a high performance green building, what are its important attributes, and how the performance of the project across a wide variety of categories is measured [1]. Sustainable building brings together a vast array of practices, techniques, and skills to reduce and ultimately eliminate the impacts of buildings on the environment and human health. For sustainable building it is often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic equipment, and using plants and trees through green roofs, rain gardens, and reduction of rainwater run-off. Many other techniques are used, such as using low-impact building materials or using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of ground water. While the practices or technologies employed in sustainable building are constantly evolving and may differ from region to region in the world, fundamental principles persist from which the method is derived: siting and structure design efficiency, energy efficiency, water efficiency, materials efficiency, indoor environmental quality enhancement, operations and maintenance optimization and waste and toxics reduction [3]. Environmental assessment of buildings, green building construction is becoming increasingly important for building owners, builders and developers all over the world. Building assessment systems rate the effects of a building’s design, construction, and operation, among them environmental impacts, resource consumption, and occupant health. Environmental effects can be evaluated at local, regional, national, and global scales. Resource impacts are measured in terms of mass, energy, volume, parts per million (ppm), density, and area. Building health can be inferred by the presence or absence of chemical and biological substances within circulating air, as well as the relative health and well-being of the occupants [1]. There are several significant building assessment systems that are used in other countries and provide other perspectives on how to approach the problem of determining how environmentally friendly a given building design may be. The effort to build a sustainable buildings establish of building assessment systems. The first building rating system in the 1990s in the U.K was Building Research Establishment's Environmental Assessment Method (BREEAM). In 2000, the U.S. Green Building Council (USGBC) followed suit and developed and released criteria also aimed at improving the environmental performance of buildings through its Leadership in Energy and Environmental Design (LEED) rating system for new construction. Green Globes is a building assessment system used in Canada which is supported by the Green Building Initiative (GBI). CASBEE is the Japanese building assessment system, which was developed as comprehensive green building rating tools for many markets and building types. Green Star is the major Australian green building assessment scheme and is similar in many respects to BREEAM and LEED in its approach and structure [1]. Many building assessment systems used in the world evaluates various type buildings, for example office, government buildings, commercial interiors, educations, institutional and industrial facilities, facilities of health-care, residential buildings, neighborhood development. Buildings are evaluated in state pre-design, new buildings, existing buildings, major renovations, operations and maintenance of building. Building assessment systems are structured to provide evaluation in several categories: Sustainable Sites, Land Use & Ecology, Water Efficiency, Energy Efficiency and Atmosphere, Materials and Resources, Indoor Environmental Quality and Emissions, Innovation in Design, Regional Priority, and Environmental Management [1, 4].

3. Materials and methods of assessment of family house

The assessment systems and their tools used in the world served as a basis for developing and creating of new building assessment system for Slovak conditions. Building environmental assessment system (BEAS) has been developed at the Institute of Environmental Engineering at the Technical University of Kosice. The main fields and indicators of building environmental assessment were proposed on the basis of available information analysis from particular fields of the building performance, Slovak standards and requirements and also according to our experimental experiences. The proposed fields and indicators respect and adhere to Slovak standards, rules and studies. This building assessment system is developed for stage of new construction of buildings. BEAS for Slovakia contains 6 main fields, which are: A–Site Selection and Project Planning, B–Building Construction, C–Indoor Environment, D–Energy Performance, E–Water Management, F–Waste Management. Some of main fields have subfields and determining indicators. The main fields and their subfields are shown in following Tables 1, 2, and 3 [2, 5]. The theoretical level of knowledge of building environmental assessment which is completely analyzed, were these knowledge implemented to construction practice.

Table 1. Assessment fields A and B and indicators of BEAS.

A	Site Selection and Project Planning	B	Building Construction
A1	Selection of location for the construction	B1	Materials
A2	Selection of location vulnerable to flooding	B1.1	Product environmental labeling
A3	Selection of location nearby recipient	B1.2	Use of local materials
A4	Selection of Brownfield areas	B1.3	Use of recycled materials
A5	Distance of construction site to road-traffic infrastructure	B1.4	Use of substitutes in concrete
A6	Distance to commercial and cultural facilities	B1.5	Radioactivity of building materials
A7	Distance to sport and active recreation	B2	Life-cycle of materials
A8	Distance to public or natural green space	B2.1	Primary energy embodied in building materials
A9	Possibility of connection to engineering networks	B2.2	Global warming potential
A10	Possibilities exploitation of renewable energy sources	B2.3	Acidification potential
A11	Possibility to maximize passive solar gains by orientation of building		
A12	Compatibility of urban design with local cultural values		
A13	The occurrence of transport infrastructure in construction site		
A14	The share of green spaces in construction site		

Table 2. Assessment fields C and D and indicators of BEAS.

C	Indoor Environment	D	Energy Performance
C1	Thermal comfort during the heating season	D1	Operation energy
C2	Thermal comfort during the cooling season	D1.1	Energy for heating
C3	Natural ventilation and mechanical ventilation	D1.2	Energy for domestic hot water
C4	Noise attenuation through the exterior envelope	D1.3	Energy for mechanical ventilation and cooling
C5	Noise isolation between primary occupancy areas	D1.4	Energy for lighting
C6	Day-lighting	D1.5	Energy for appliances
C7	Shading and blinds	D2	Active systems used renewable energy sources
C8	Artificial lighting	D2.1	Solar system/heat pump
C9	The materials used in the building	D2.2	Photovoltaic technology
C10	Transfer of pollutants from the garage space into user space of the house	D2.3	Heat recuperation
		D3	Energy management
		D3.1	System of energy management

Table 3. Assessment fields E and F and indicators of BEAS.

E	Water Management	F	Waste Management
E1	Reduction and regulation of water flow in water systems	F1	Plan of waste disposal originated in construction process
E2	The water management of surface runoff	F2	Measures to minimize waste resulting from building operation
E3	Drinking water supply	F3	Measures to minimize emission resulting from air pollution sources
E4	System of grey water		

For this paper the BEAS was used for evaluation of a new building – family house in various fields and subfields aimed at location and site, building constructions, indoor environment, energy, water and waste. Assessed family house is located in the northwest part of the town of Kosice in Slovak Republic. Mentioned area is built-up and according to urban city plan of Kosice this locality is intended for construction of residential buildings. The building is located in a slightly sloping terrain, in dense built-up area with cramped conditions for further construction, see Fig.1.

Fig. 1. Situation placement of family house.

Family house is two-storey building, consisting of 1st floor embedded in a slope and 2st floor, with flat vegetation roof, see Fig.2 and Fig.3. The total built-up area of the building is 296 m^2. Support system of constructions are designed from ceramic blocks in combination with reinforced concrete walls with thickness of 250-300 mm. Interior walls are designed as sandwich constructions plasterboard with thickness of 150 mm with sound and thermal insulation. The flat roof is designed as vegetation, with double thermal insulation made from extruded polystyrene with thickness of 200 mm, with vapor barrier and waterproofing PVC films, drainage studded film, coating the substrate with vegetation mats. Foundation structures are made of B20 concrete. Substructure construction is being protected from PVC insulated against radon. Insulation cladding the façade thermal insulating materials based on mineral wool with thickness of 200 mm. The core element of the ceiling and the roof is reinforced concrete structures reinforced plate with thickness of 200 mm stored in the load-bearing walls. Interior finishing floors are designed as wood flooring, ceramic tiles, linoleum and concrete paving. Interior walls surfaces are covered by plaster, ceramic and stone tiles. Ceilings are designed as plasterboard and architectural concrete. Window structures are designed as aluminum, multi-chamber system Schüco, vacuum with triple glazing, with horizontal aluminum blinds. The building is connected to engineering networks by water and sewage connection and electricity connection. Drainage of rainwater from the building is ensured downpipes into the sewage connection. Heating in the building is ensured by hot water with radiators and floor heating. Building has installed heat pump for heating and preparing of hot water, the type of ground-water with an integrated additional electric boiler. In the building there is also proposed ceiling cooling [6].

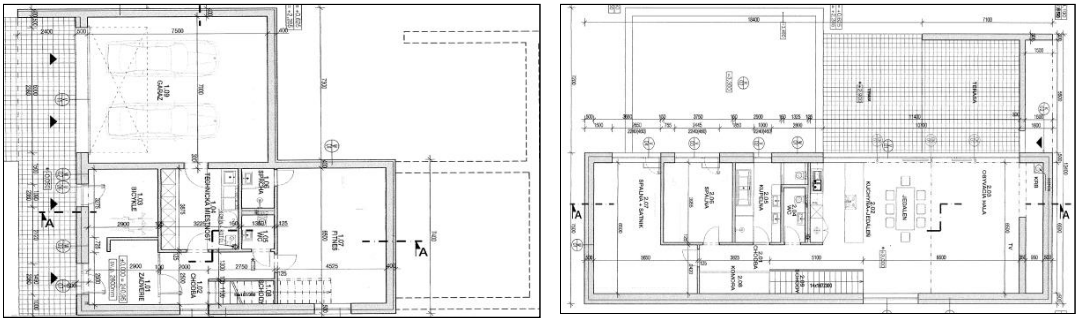

Fig. 2. Ground plans 1st floor and 2st floor of family house.

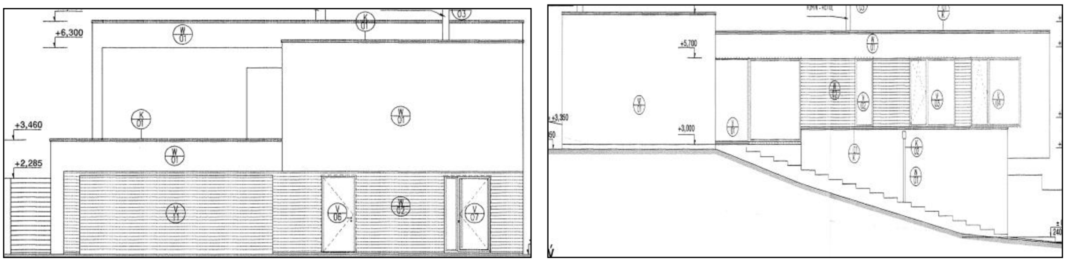

Fig. 3. South and west views of family house.

4. Results of family house assessment

Family house was assessed according to Building environmental assessment system (BEAS) in 6 main fields and their subfields. The field A–Site Selection and Project Planning was assessed in subfields: A1 Selection of location for the construction, A2 Selection of location vulnerable to flooding, A3 Selection of location nearby recipient, A4 Selection of Brownfield areas, A5 Distance of construction site to road-traffic infrastructure, A6 Distance to commercial and cultural facilities, A 7 Distance to sport and active recreation, A8 Distance to public or natural green space, A9 Possibility of connection to engineering networks, A10 Possibilities exploitation of renewable energy sources, A11 Possibility to maximize passive solar gains by orientation of building, A12 Compatibility of urban design with local cultural values, A13 The occurrence of transport infrastructure in construction site, A14 The share of green spaces in construction site. In term of the evaluation of this field, building is situated in the territory with soft disturbed environment based on Environmental regionalization of Slovakia [7]. Location of building is not in the floodplain town of Kosice; building is located in distance of 120 m from the recipient. Building site not used Brownfield area. The building is accessible from the local road; distance of building to road-traffic infrastructure is 750 m. In this location there are not situated commercial and cultural facilities as well as sport and active recreation. The nearest facilities are located in distance of 2.0 km. Building site is located nearby natural green spaces. Site of building has possibility of connection to engineering networks as water and sewage connection, electricity and gas connection [7]. Site of building has possibility uses three renewable energy sources (solar panels, photovoltaic panels, heat pumps). Possibility to maximize passive solar gains by orientation of building is ensured the percentage area of the building (60.1%) oriented east – west. Compatibility urban design with local cultural values is ensured, building is designed in accordance with the concept of urban design and architecture at this location. Significant transport infrastructure (highway, road of 1st, 2nd and 3rd class) not occurs in building site. The share of green spaces (37.04 %) in construction site is featured the percentage of green spaces of the total land area [6].

The field B-Building Construction, was assessed in subfields: B1 Materials - B1.1 Product environmental labeling, B1.2 Use of local materials, B1.3 Use of recycled materials, B1.4 Use of substitutes in concrete, B1.5 Radioactivity of building materials, and B2 Life cycle of materials – B2.1 Primary energy embodied in building materials, B2.2 Global warming potential, B2.3 Acidification potential.

Evaluated family house has built-in construction products which has been awarded Eco friendly (interior finishing floors are designed as wood flooring; window structures are designed as aluminum, multi-chamber system Schüco) [9]. Distance manufacturing materials from construction site, which are used in construction, is a distance in the range of 250-500 km. Recyclable share in building materials is more than the 50%, building uses of recycled materials (building materials used in intensive vegetation roof as recycling HDPE and artificial fibres). The percentage weight of the replaced cement in concrete is less than the 20%, building not use of substitutes in concrete. Mass 226Ra activity in the construction products is < 100 Bq/kg. Primary energy embodied in building materials of assessing building is > 1500 MJ/m^2, global warming potential is > 100 kg/m^2 and acidification potential is > 0.45 kg/m^2 [6].

The field C–Indoor Environment, was assessed family house in subfields: C1 Thermal comfort during the heating season, C2 Thermal comfort during the cooling season, C3 Natural ventilation and mechanical ventilation, C4 Noise attenuation through the exterior envelope, C5 Noise isolation between primary occupancy areas, C6 Daylighting, C7 Shading and blinds, C8 Artificial lighting, C9 The materials used in the building, C10 Transfer of pollutants from the garage space into user space of the house.

Evaluated family house in this field and subfields indicated that an operative temperature in 95-ies % of buildings during the heating season is range of $18 \leqslant \theta o < 20°$ C. The value of operational temperature in some rooms of building is below the requirements according to EN 15251: 2007. The building has provided natural ventilation. The total area of the openings in exterior envelope is at least 10% of the total floor area and more than 90% of the ventilation space from the top down. The building has not provided mechanical ventilation but in the building is ensured ceiling cooling. Noise attenuation through the exterior envelope in residential areas of cities according to the legislative regulations is provided 4 quality class sound insulation for windows. Noise attenuation between rooms of building is provided that airborne sound insulation meets the minimum requirements of the standard. Daylighting factor of 100% of the space is at least the value of the planned tasks according to requirements of the standard. In space of the building are designed best shading and blinds elements which are the most appropriate measures to ensure brightness (are designed horizontal aluminium blinds). Artificial lighting is sufficient for the task every 10 m^2 work area. More than 75% of interior materials of building (including paints, sealants, adhesives, carpets, furniture and composite wood products) are collected as materials with low-level release of VOC emissions and are not used in composite wood products containing urea formaldehyde resins. Space of garage in house which produces harmful chemicals is separately ventilated and isolated garage door from other user space [6].

The field D–Energy Performance, was assessed family house in subfields: D1 Operation energy, D1.1 Energy for heating, D1.2 Energy for domestic hot water, D1.3 Energy for mechanical ventilation and cooling, D1.4 Energy for lighting, D1.5 Energy for appliances, D2 Active systems used renewable energy sources, D2.1 Solar system/heat pump, D2.2 Photovoltaic technology, D2.3 Heat recuperation and D3.1 System of energy management.

Evaluated family house in this field and subfields indicated, that class of energy for heating and domestic hot water of family house according to Slovak standards is class A. Class of energy for mechanical ventilation and cooling and for lighting of family house according to Slovak standards is class A. All electrical appliances in the building are energy class A. In term of the active systems used renewable energy sources, building has installed heat pump for heating and hot water, the type of ground-water with an integrated additional electric boiler. The heat pump for hot water production and additional heating cover more than 75 % of energy consumption. The building has not installed solar system, photovoltaic technology not even heat recuperation. The building has a system of energy management into three components (heating, cooling, lighting and shielding) [6].

The field E-Water Management, was assessed family house in subfields: E1 Reduction and regulation of water flow in water systems, E2 The water management of surface runoff, E3 Drinking water supply and E4 System of grey water.

In term of the evaluation of building in this field and subfields, family house has designed equipments to reduce and control the water flow in the armature and flush toilet. Building has introduced water management of surface runoff. Water from surface runoff is collected in a single sewage and section of surface runoff is collected in vegetation roof. Building is supplied with a sufficient amount of fresh water with high quality but building is not designed split potable and gray water [6]. The field F-Waste Management was assessed family house in subfields: F1 Plan of waste disposal originated in construction process, F2 Measures to minimize waste resulting from building operation and F3 Measures to minimize emission resulting from air pollution sources.

Evaluated family house in this field indicated, that was prepared general waste management plan for building in the construction process. Family house has ensured the separate collection of the four components of municipal waste (paper, plastic, glass and metal). In terms of minimizing emissions from air pollution sources, the building has built-in a small source of air pollution (fireplace with solid fuel) [6]. The evaluation results of individual fields and a key to the overall assessment of buildings is shown in the following Tables 4 and 5 and Fig. 4.

Table 4. Fields assessment, score assessment and total score building.

Fields assessment	Assessment	Weight [%]
A-Site Selection and Project Planning	2.18	14,71
B-Building Construction	1.07	20,59
C-Indoor Environment	2.80	23,56
D-Energy Performance	2.99	26,47
E-Water Management	1.85	8,88
F-Waste Management	1.64	5,88
Total score Building	2.25	Environmentally friendly building

Table 5. The key to the overall assessment of buildings.

	The key to the overall assessment of buildings	Type of final assessment building
-1	building unacceptable	Environmentally unacceptable building
0	acceptable building	Environmentally acceptable building
3	good building	Environmentally friendly building
5	best building	Sustainable building

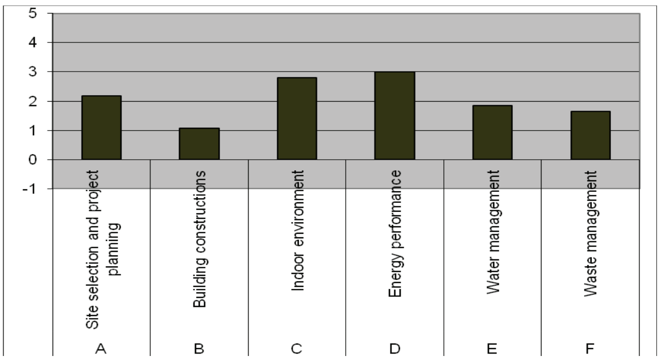

Fig. 4. Score assessment in individual fields.

The results of the assessment shows that, evaluated family house according to environmental assessment system (BEAS) is classified as environmental friendly building with 2.25 total score for building. The highest ratings 2.99 and 2.80 within the assessment fields have been achieved in fields D - Energy Performance and C - Indoor

Environment. In field Energy Performance is family house designed such that in accordance with the requirements of the Slovak standard is class of energy of family house for heating and domestic hot water, for mechanical ventilation and cooling and for lighting of family house is class A. In term of the active systems used renewable energy sources, building has installed heat pump for heating and hot water, the type of ground-water with an integrated additional electric boiler. The heat pump for hot water production and additional heating cover more than 75 % of energy consumption. Within system of energy management, the building has secures a monitoring the operation of technical building systems (heating, cooling, lighting and shielding). In field Indoor Environment is family house designed in accordance with the minimum requirements of the Slovak standard and the legislative regulations. Family house has provided favorable conditions for thermal comfort, sufficient air exchange, daylighting and shielding and acoustic comfort. The interior materials used in the building are mostly low-level release of materials. Space of garage in the building not produced harmful chemicals into other user space because it is separately ventilated and isolated.

Relatively suitable and acceptable values have been achieved in field A - Site Selection and Project Planning with rating 2.18, in field E - Water Management with rating 1.85 and in field F-Waste Management with rating 1.64. In the assessment field Site Selection and Project Planning with, family house is situated in the territory with soft disturbed environment and is not in the floodplain town of Kosice. Building site not used Brownfield area. In this location there are not situated commercial and cultural facilities as well as sport and active recreation. Significant transport infrastructure not occurs in building site. Site of building has possibility of connection to engineering networks and has possibility to use three renewable energy sources. In fields Water Management and Waste Management, family house economical use of water but building is not designed split potable and gray water. Family house has ensured the separate collection of the waste but in terms of minimizing emissions from air pollution sources, the building has built-in a small source of air pollution. The lowest rating 1.07 has been achieved in field B - Building Construction. Although family house has built-in products with environmental label and recycled materials, building not uses local materials. Construction materials reached high levels of primary energy embodied in building materials, global warming potential and acidification potential.

5. Conclusion

The high-performance building movement worldwide is being propelled by the success of building assessment methods. Assessment methods addresses wide ranging environmental and sustainability issues and enables developers, designers, architects and engineers to prove the environmental credentials of buildings for their users. Assessment methods provide quantitative performance indicators for design, construction, operation, maintenance of buildings and a rating score for the whole assessment of building. In this paper were presented results of environmental assessment of selected family house according to Building environmental assessment system (BEAS). House was classified as environmental friendly building. To increase the assessment score, building should has built-in more natural materials or recycled materials respectively products with environmental label. Building should maximize passive solar gains by suitable orientation of building and to increase the share of green spaces. Building should be has implemented better water management and waste management.

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