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Determination of Assessment Scale of Selected Indicators in BEAS

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***Abstract*—The building environmental assessment systems and tools used over the world were the base of new system development for Slovak conditions. The proposed fields are site selection and project planning; building construction; indoor environment; energy performance; water management and waste management. The fields and indicators were proposed on the bases of available information analysis from particular fields of building environmental assessment and also on the base of our experimental experiences. The aim of this paper is presentation of Slovak building environmental assessment system and determination of assessment criteria of environmental indicators such as embodied energy (EE), embodied CO_{2eq} emissions (ECO_2) and embodied SO_{2eq} emissions (ESO_2) for the purpose of their implementation to BEAS.**

***Keywords*—sustainability, building materials, environmental assessment, indicators evaluation**

I. Introduction

According to study [1] buildings have great impact on the environment. Since early 1990s, the study of building sustainability has attracted more and more attention around the world. The increasing in public awareness of the environmental issues has led to the adoption of green labeling or eco-labeling schemes. Recently, the eco-labeling trends have also spread from the manufactured products the building assets [2]. The notion of Life-Cycle Assessment (LCA) has now been generally accepted within the environmental research community as the only legitimate basic on which to compare alternative materials, components, element, services and whole buildings [3].

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Developing the building environmental assessment systems is becoming necessary in the Developing World because of the considerable environmental, social and economic problems [4].

Green building rating and certification systems are intended to foster more sustainable building design, construction and operations by promoting and making possible a better integration of environmental concerns with cost and other traditional decision criteria. Different building assessment systems approach this task from somewhat different perspectives, but they have certain element in common [5].

Sustainability assessment of buildings can be defined as a specific complex of proceedings oriented towards systematic and objective evaluation of a building's performance. These processes lead to the design, construction and operation of buildings with respect to criteria for sustainable development. Many methodologies have been developed to establish the degree of accomplishment of environmental goals, guiding the planning and design processes. In these earlier stages of the construction process, planners can make decisions to improve building performance at very little or no cost, following the recommendations of the decision-making tool.

Separate environmental indicators were developed for the needs of relevant interest group. However, the first real attempt to "establish comprehensive means of simultaneously assessing a broad range of environmental considerations in buildings" was the Building Research Establishment Environmental Assessment Method (BREEAM) [6, 7]. After that, other methodologies, such as Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) from Japan [8], the Building and Environmental Performance Assessment Criteria (BEPAC) from Canada [9], the Building Environmental Assessment Method (BEAM) from Hong Kong [10], the National Australian Building Environmental Rating System (NABERS) from Australia [11] and the Leadership in Energy and Environmental Design (LEED) from the United States [12] were developed and are currently widely applied. Very comprehensive inventories of available tools for environmental assessment methods can be found in Ding [13] and Seo [14].

In recent years the evaluation of building performance in terms of environmental, social and economic aspects has become a topic of discussion in the Slovak Republic. A new Building Environmental Assessment System (BEAS) has been developed at the Institute of Environmental Engineering, Technical University of Košice. Systems and tools used in many other countries were the foundation of the new system, which was developed for application under Slovak conditions. The main fields and relevant indicators of BEAS were proposed on the basis of available information from particular fields of building performance in Slovakia and also according to our own experimental experience. BEAS as a multi-criteria system includes environmental, social and cultural aspects. The proposed fields and indicators respect and adhere to Slovak standards, rules, studies and experiments. The presented system was developed for use during the design stage of office buildings. This system for Slovakia contains 6 main fields and 52 indicators. The Slovak building environmental assessment system BEAS involves the evaluation of the following fields: site selection and project planning, building construction, the indoor environment, energy performance, water management and waste management [15].

Assessment of the environmental performances of building materials and products is a complex issue which requires the use of a set of comprehensive criteria [16]. The environmental impacts of these materials can be observed, in fact, at several levels: locally, if we look at the effects of activities such as quarrying or at the specific impact of the manufacturing processes (e.g. dust emissions, noise); globally, as a result of the greenhouse gas emissions linked to energy consumption or released during the manufacturing process; also internally, considering the effects of buildings on the health of the occupants [16, 17]. Therefore, a correct evaluation should adopt a life cycle perspective [18, 19], considering not only the impact of material production stage (raw material supply, transport, manufacturing of products and all upstream processes from cradle to gate), but also its contribution in the building construction process (transport to the building site and building installation/construction), use phase (energy losses, maintenance, repair and replacement, refurbishment), and finally end-of-life (recycling and disposal, including transport).

This study is focused on presentation of system BEAS and determination of assessment criteria of environmental indicators such as embodied energy (EE), embodied CO_{2eq} emissions (ECO_2) and embodied SO_{2eq} emissions (ESO_2) for the purpose of their implementation to BEAS. The criteria for the evaluation of mentioned environmental indicators are determined on the base of alternative material compositions of structures which are assessed in order to identifying the most optimal solutions in terms of environmental sustainability by LCA within system boundary "cradle to gate". The most of data were taken from the Austrian LCA database [20].

II. Environmental Building Assessment System in Slovakia

Table 1 presents the hierarchy structure of proposed building environmental assessment system. This system has six main fields: A – Site Selection and Project Planning, B – Building Construction, C – Indoor Environment, D – Energy Performance, E – Water Management and F – Waste Management. Some of main fields are divided into subfields, e.g. the field marked as A has two subfields: A1 - Site selection and A2 - Site development. Fields and subfields also contain determining indicators. The total number of the indicators is 52. Each main field has several indicators which have the intent of assessment and the scale of assessment. This scale is from negative (-1 point), acceptable practice (0 point), good practice (3 point) and best practice (5 point). Result of each indicator is obtained so that the point from scale is multiplying with weight of indicator [15, 21].

TABLE I. HIERARCHICAL STRUCTURE OF SYSTEM BEAS

A	A1	A1.1	A1.2	A1.3	A1.4	A1.5	A1.6	A1.7	A1.8	A1.9	A1.10	
	A2	A2.1	A2.2	A2.3	A2.4	A2.5	A2.6	A2.7				
B	B1	B2.1	B2.2	B2.3	B2.4	B2.5						Materials
	B2	B2.1	B2.2	B2.3								LCA
C	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10		
D	D1	D1.1	D1.2	D1.3	D1.4	D1.5						
	D2	D2.1	D2.2	D2.3								
	D3	D3.1	D3.2									
E	E1	E2	E3	E4								
F	F1	F2	F3									

III. CO_2 and SO_2 Emissions and Embodied Energy Versus U-value

By assessed different material compositions of building envelope which comply U-value of energy standard and near zero energy residential buildings is possible to compare impact of increasing insulation materials in structure compositions on embodied energy. The material compositions are divided into three groups A-C. The group A involves 100 designed conventional material solutions (20 floor construction, 60 exterior wall construction and 20 roof constructions) for Slovak energy standard residential buildings according to STN 730540, the group B involves 80 conventional material compositions (20 floor construction, 40 exterior wall construction and 20 roof constructions) for Slovak near zero energy residential buildings and the group C involves analyzed material compositions 164 alternative solutions for design of near zero energy residential buildings (50 floor construction, 60 exterior wall construction and 54 roof constructions). The resultant values of embodied energy and U-values of each evaluated building envelope indicate that alternatives of group C can achieve lower embodied energy than conventional energy standard solutions which consist of lower amount of building materials (mainly insulations). The most of alternatives from group C with higher embodied energy than value 900 MJ/m^2 consist of cross laminated wood panel with wood fibreboard insulation. The suitable material selection, especially using nature materials, is possible design near zero energy residential building with minimal environmental impacts [24]. The values of embodied energy and emissions determined for building envelope are presented in Table 2.

TABLE II. ENVIRONMENTAL AND ENERGY INDICATORS OF BUILDING ENVELOPE

	EE [MJ/m^2]	ECO₂ [kg $CO_{2\,eq.}/m^2$]	ESO₂ [kg $SO_{2\,eq.}/m^2$]
Floor - group A			
Average	1368,831	78,964	0,438
Maximum	1715,723	110,595	0,606
Minimum	1116,308	62,19	0,286
Coefficient of variation	599,414	48,405	0,32
Median	1325,428	78,468	0,421
Floor - group B			
Average	2010,541	98,256	0,572
Maximum	2510,97	139,505	0,763
Minimum	1329,647	56,478	0,337
Coefficient of variation	1181,322	83,027	0,426
Median	1994,478	97,621	0,565
Floor - group C			
Average	978,972	-115,193	0,463
Maximum	1407,927	-40,08	0,705
Minimum	478,127	-276,96	0,23
Coefficient of variation	929,8	236,88	0,476
Median	966,024	-84,626	0,446
External wall - group A			
Average	838,789	41,971	0,235
Maximum	1256,398	98,795	0,431
Minimum	465,986	-246,704	0,123
Coefficient of variation	790,413	345,499	0,308
Median	835,034	64,946	0,214
External wall - group B			
Average	1157,869	83,563	0,333
Maximum	1823,88	135,197	0,69
Minimum	737,45	54,078	0,162
Coefficient of variation	1086,431	81,119	0,528
Median	1104,963	73,306	0,249
External wall - group C			
Average	675,864	-100,302	0,294
Maximum	1292,347	-12,668	0,545
Minimum	338,808	-245,144	0,13
Coefficient of variation	953,539	232,476	0,416
Median	643,582	-81,615	0,268
Roof - group A			
Average	1313,689	34,877	0,446
Maximum	2031,635	137,23	0,741
Minimum	565,763	-55,871	0,215
Coefficient of variation	1465,872	193,102	0,527
Median	1256,841	28,495	0,434
Roof - group B			
Average	1787,6	50,614	0,627
Maximum	2822,91	172,403	0,893
Minimum	782,323	-74,312	0,341
Coefficient of variation	2040,587	246,714	0,551
Median	1791,885	49,906	0,637
Roof - group C			
Average	984,72	-99,862	0,415
Maximum	1484,245	-29,505	0,737
Minimum	544,073	-283,064	0,192
Coefficient of variation	940,172	253,559	0,545
Median	987,735	-80,049	0,416

A. *Results*

Figures (Fig. 1-3) illustrates the results of embodied energy and emissions for structures designed for buildings accomplished thermal requirement to year of 2012 (group A), low energy buildings (group B) and nearly-zero energy buildings (group C) in Slovakia. High value of embodied energy was achieved in group B of building envelope and least value was achieved in group C as well as in ECO_2 emissions and ESO_2 emissions. These results are implemented to evaluation of indicators proposed in the Slovak building environmental assessment system BEAS.

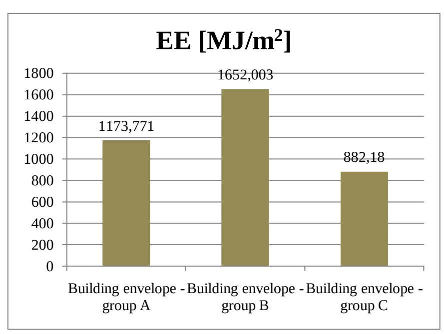

Figure 1. Embodied energy of building envelope

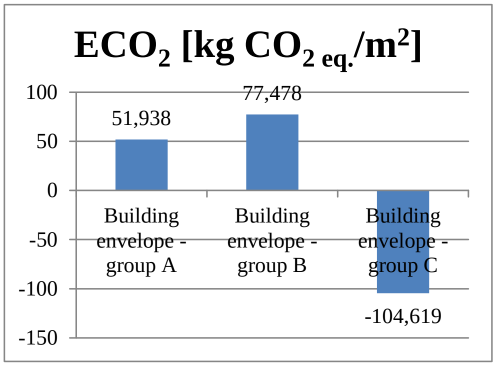

Figure 2. ECO_2 of building envelope

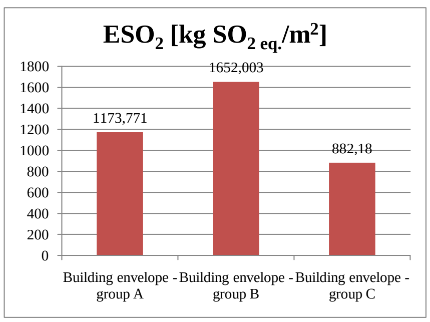

Figure 3. ESO_2 of building envelope

IV. Evaluation of Environmental Indicators in BEAS

Main field Building construction mark as B has two sub-field of assessment: Materials (B1) and LCA (B2). In the Table 3 are presented the evaluation of indicators in the sub-field LCA. This sub-field has three indicators of assessment. The criteria of indicators evaluation are determined according to study presented above. The weights of significance of indicators, sub-fields and fields are determined by Saaty method. Building materials in BEAS has a percentage weight of 20.59%. First sub-field of assessment Materials has a percentage weight of 75% and second sub-field of assessment LCA has a percentage weight 25%. The aim of this paper is introduces sub-field B2 – LCA. First indicator in this sub-field B2.1 Embodied energy has a percentage weight of 40%, second indicator B2.2 Global warning potential has a percentage weight of 20 % as well as third indicator B2.3 Acidification [21, 22, 23].

TABLE III. ASSESSMENT OF FIELD BUILDING CONSTRUCTION AND SUB-FIELD OF LCA

B2	**LCA**	**25%**	
B2.1	**Embodied energy**	**40.00%**	
Purpose	To ensure using of building materials with a lower value of embodied energy.	point	weight
Indicator	***The percentage of built-in building materials with lower value of embodied energy.***		
Negative practice	The predicted embodied energy of built-in building materials is:	> 1500 MJ/m^2	-1
Acceptable practice		1001-1500 MJ/m^2	0
Good practice		600-1000 MJ/m^2	3
Best practice		<600 MJ/m^2	5
B2.2	**Global warming potential**	**40.00%**	
Purpose	To minimize the production of atmospheric emissions of CO_2 from mining, manufacturing, transport and construction of building that may result in global warming potential.	point	weight
Indicator	***CO_2 equivalent in kg per unit net area.***		
Negative practice	The predicted emission from non-renewable sources of CO_2 equivalent in kg per unit area net:	> 100 kg/m^2	-1
Acceptable practice		51-100 kg/m^2	0
Good practice		10-50 kg/m^2	3
Best practice		<10 kg/m^2	5
B2.3	**Acidification potential**	**20.00%**	
Purpose	To minimize the production of atmospheric emissions of SO_2 from mining, manufacturing, transport and construction of building that may result in acidification.	point	weight
Indicator	***SO_2 equivalent in kg per unit net area.***		
Negative practice	The predicted emission from non-renewable sources of SO_2 equivalent in kg per unit area net:	>0.45 kg/m^2	-1
Acceptable practice		0.35-0.40 kg/m^2	0
Good practice		0.25-0.34 kg/m^2	3
Best practice		<0.25 kg/m^2	5

V. Conclusions

The selection of building materials for structures which has significant share of total environmental performance of building and the potential of improvement is analyzed in this paper. By evaluating of large quantity of different material compositions of conventional and alternative environmental suitable structures of building envelope were determined criteria for environmental indicators such as embodied energy, CO_{2eq} emissions and SO_{2eq} emissions. The criteria for the evaluation of mentioned environmental indicators are determined on the base of alternative material compositions of structures which are assessed in order to identifying the most optimal solutions in terms of environmental sustainability by LCA within system boundary "cradle to gate". The determined criteria of embodied energy, CO_{2eq} and SO_{2eq} emissions for their implementation to BEAS are presented in Table 3.

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[Nowadays the sustainability assessment of buildings during their whole life cycle is becoming necessary for sustainable development.]