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# ENVIRONMENTAL, ECONOMIC AND SOCIAL ASPECTS AND INDICATORS IN RELATION TO ENERGY PERFORMANCE OF BUILDINGS

# ASPEKTY I WSKAŹNIKI ŚRODOWISKOWE, EKONOMICZNE ORAZ SPOŁECZNE W ODNIESIENIU DO ENERGETYCZNEJ WYDAJNOŚCI BUDYNKÓW

A b s t r a c t

The new approach of sustainability assessment of buildings requires the quantification of impacts and aspects for the environmental, social and economic performance of buildings using quantitative and qualitative indicators. These indicators are included in building environmental assessment systems and tools used in different countries for evaluating the integrated building performance. The building environmental assessment system (BEAS) has been developed in Slovakia as well through the last years. BEAS as a multi-criteria system includes environmental, social and cultural aspects which are incorporated in proposed main fields: site selection and project planning; building construction; indoor environment; energy performance; water management and waste management. The aim of paper is the identification and determination of weights of fields in BEAS. Eleven experts participated in the study. Consequently the order and weights of significance of main assessment fields was determined.

*Keywords: environmental aspects, economic aspects, social aspects, energy performance*

S t r e s z c z e n i e

Nowe podejście do oceny zrównoważonego charakteru budynków wymaga obliczenia wpływów i aspektów środowiskowej, społecznej i ekonomicznej wydajności budynków z zastosowaniem wskaźników ilościowych oraz jakościowych. Zostają one włączone w systemy i narzędzia środowiskowej oceny budynków wykorzystywane w różnych krajach dla oceny zintegrowanej wydajności budynków. W ostatnich latach system środowiskowej oceny budynków (ang. BEAS) opracowywano również na Słowacji. BEAS jako system wielokryterialny obejmuje aspekty środowiskowe, społeczne i kulturowe włączane do proponowanych domen głównych, takich jak: wybór terenu budowy, planowanie projektu, konstrukcja budynku, środowisko wewnętrzne, wydajność energetyczna, zarządzanie wodą oraz odpadami. Celem niniejszego artykułu jest identyfikacja i określenie znaczenia poszczególnych czynników BEAS. W opracowaniu udział wzięło jedenastu ekspertów. W rezultacie ustalono porządek i znaczenie głównych dziedzin oceny.

*Słowa kluczowe: aspekty środowiskowe, aspekty ekonomiczne, aspekty społeczne, wydajność energetyczna*

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# 1. Building environmental assessment

## 1.1. Building environmental assessment in the world

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. The first of such tools was the Building Research Establishment Environmental Assessment Method (BREEAM) [2]. After that, other methodologies, such as Green Star from Australia [3], the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) from Japan [4], the Building and Environmental Performance Assessment Criteria (BEPAC) from Canada [5], the Building Environmental Assessment Method (BEAM) from Hong Kong [6], the Green Building Rating System (SABA) from Jordan [7], Estidama from Emirate [8] and the Leadership in Energy and Environmental Design (LEED) from the United States [9] were developed and are currently widely applied. Very comprehensive inventories of available tools for environmental assessment methods can be found in Ding [10], in Seo [11], the Whole Building Design Guide [12], and the World Green Building Council [13, 14].

## 1.2. New European standards for sustainable assessment of buildings

The aim of this paper is also to present the new European standard for sustainable assessment of buildings. New European Standards (EN 15643-1, 2; prEN 15643-3, 4; EN 15978; EN15804) provide the principals and requirements for the assessment of building performance. This series of standards allow the sustainability assessment, i.e. the assessment of environmental, social and economic performance of a building, to be made concurrently and on an equal footing, on the basis of the same technical characteristics and functionality of the object of assessment. The sustainability assessment quantifies impacts and aspects for the environmental, social and economic performance of buildings using quantitative and qualitative indicators. These standards do not set benchmarks or levels of performance. Although the evaluation of technical and functional performance is beyond the scope of this series of standards, the technical and functional characteristics are considered within this framework by reference to the functional equivalent. The functional equivalent forms the basis for comparisons of the results of the assessment. The framework applies to all types of buildings and it is relevant for the assessment of new buildings over their entire life cycle, and of existing buildings over their remaining service life and end of life stage. The standards developed under this framework do not set the rules for how the different building assessment schemes may provide valuation methods. Nor do they prescribe levels, classes or benchmarks for measuring performance.

### 1.2.1. The assessment of environmental performance of a building

Indicators included in the current versions of standards focused on resource use (environmental aspects): use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; use of renewable primary energy excluding renewable primary energy resources used as raw materials; use of non-renewable primary energy resources used as raw materials; use of renewable primary energy resources used as raw materials; use of secondary materials; use of non-renewable secondary fuels; use of renewable secondary fuels; use of freshwater resources. Further indicators used in the current practice focused on resource use: use of non-renewable resources other than primary energy; use of renewable resources other than primary energy [15].

### 1.2.2. The assessment of social performance of a building

The following categories shall be used to describe the social performance aspects and impacts of buildings: accessibility; adaptability; health and comfort; loadings on the neighbourhood; maintenance; safety/security; sourcing of materials and services; stakeholder involvement [16].

### 1.2.3. The assessment of economic performance of a building

The assessment of the economic performance of a building shall incorporate all relevant information, which may include the following: economic aspects and impacts at the Before Use Stage; economic aspects and impacts excluding the building in operation at the Use Stage (Energy costs); economic aspects and impacts of the building operational use; economic aspects and impacts at the End of Life (Costs from re-use, recycling and energy recovery at end of life) [17].

### 1.3. Building environmental assessment in the Slovak Republic

The building environmental assessment system (BEAS) has been developed in Slovakia as well through the last years. This topic is very discussed between architects, designers and developers in Slovakia. The main fields and determining indicators of BEAS are proposed on the base of available information analysis from particular fields and also on the base of our experimental experiences. The proposed indicators respect Slovak standards and rules and with respect of environmental, social and economic aspect of environmental performance of buildings. The background of BEAS development was mainly SBTool.

## 2. Energy performance

Buildings account for a large part of the annual energy consumption in modern societies. Within the European Union (EU) the energy use by the built environment is more than 40% of the total energy consumption [18, 19]. In order to quantify the effect of energy saving measures in the built environment different methodologies with accompanying indicators were and still are being developed. Because of the European Energy Performance of Buildings Directive (EPBD) [20], many indicators have been developed to express the energy performance of European buildings by an energy label with a classification of A to G. Now that Energy Performance Certification is compulsory within the European Union, it might be useful to relate the value of real estate objects with the life cycle costs of energy saving measures [19]. Promotion of energy efficiency is one of the main goals of energy policies since it improves resource management and reduces energy use and its environmental impact. Today most of the developed nations include a section on energy efficiency within their energy planning policies, usually implemented by means of a variety of laws, codes, strategies, regulations and certification schemes [21]. In this paper we focus on the proposal of system BEAS for building environmental assessment system especially on the assessment of energy performance of buildings in the Slovakia.

## 3. The methodology of the derivation of assessment field in BEAS

The methodology of the derivation of assessment field in BEAS has been performed according to a study [22]. A field list has been derived by a three-step process. In order to establish a comprehensive set of fields of the building environmental assessment method for office buildings, a combination of reviewing existing methods of building environmental assessment used worldwide, valid Slovak standards and codes, and an academic research paper has been conducted. A three-step process has been conducted in this method. The first step, a full range of fields relating to the sustainable building efficiency, has been collected through a wide-ranging literature review. In step 2, a draft indicator list has been selected from the full indicator list based on an in-depth analysis. In step 3, a questionnaire survey has been conducted in order to get the comment from the experts to refine the draft indicators. As a result, a final indicator list has been proposed. The final indicators list is presented for "Energy performance" main field of assessment in the next sections of this paper.

### 3.1. Literature review

The field of building environmental assessment has matured remarkably quickly since the introduction of BREEAM, and the past thirteen years have witnessed a rapid increase in the number of building environmental assessment methods in use world-wide In the Table 1 are shown the most significant building environmental assessment system [2-12] with their main field of energy assessment used over the world.

Table 1

**Energy performance field in the most significant building environmental assessment systems**

| System | Energy performance field | Weight | Indicators |
|---|---|---|---|
| BREEAM | Energy | 19 [%] | Reduction of $CO_2$ emissions<br>Energy monitoring<br>Energy efficient external lighting<br>Low or zero carbon technologies<br>Energy efficient cold storage<br>Energy efficient transportation systems<br>Energy efficient laboratory systems<br>Energy efficient equipment (process)<br>Drying space |

| | | | |
|---|---|---|---|
| Green Globes | Energy | 38 [%] | Energy performance<br>Reduced energy demand<br>Integration of energy efficient systems<br>Renewable energy sources<br>Energy-efficient transportation |
| SBTool | Energy and Resource Consumption | 22,5 [%] | Total Life Cycle Non-Renewable Energy<br>Electrical peak demand for facility operations<br>Renewable Energy<br>Materials<br>Potable Water |
| LEED | Energy and Atmosphere | 36,4 [%] | Regional Materials<br>Rapidly Renewable Materials<br>Certified Wood |
| CASBEE | Energy | 20 [%] | Building Thermal Load<br>Natural Energy Utilization<br>Efficiency in Building Service System<br>Efficient Operation |
| BEAM | Energy use | 41,3 [%] | Annual Energy Use<br>Energy Efficient Systems<br>Energy Efficient Equipment<br>Provisions for Energy Management<br>Building Design for Energy Efficiency |
| SABA | Energy efficiency | 23,1 [%] | Building envelope performance<br>Renewable energy<br>Natural lighting/lighting<br>Energy-efficient heating/cooling system<br>Mechanic systems<br>Greenhouse gases emission<br>Machines/appliances |
| Estidama | Resourceful Energy | 26,4 [%] | Community Energy Strategy<br>Building Guidelines<br>Energy Monitoring and Reporting<br>Community Strategies for Passive Cooling<br>Urban Heat Reduction<br>Efficient Infrastructure<br>Renewable Energy: Onsite, Offsite<br>Energy Efficient Buildings |

### 3.2. System BEAS

In the table (Table 2) is shown draft indicator list in field of energy performance which has been selected from the full indicator list based on an in-depth analysis.

Table 2

**Energy performance main field and subfields of system BEAS**

| Main field | Subfields | Indicators |
|---|---|---|
| D Energy performance | D1 Operation Energy | D1.1 Energy needs for heating |
| | | D1.2 Energy needs for domestic hot water |
| | | D1.3 Energy needs for mechanic ventilation and cooling |
| | | D1.4 Energy needs for lighting |
| | | D1.5 Energy needs for appliances |
| | D2 Active systems using renewable energy sources | D2.1 Active solar design |
| | | D2.2 Heat pump |
| | | D2.3 Photovoltaic technology and heat recuperation |
| | D3 Energy management | D3.1 System of energy management |
| | | D3.2 Operation and maintenance |

### 3.3. Questionnaire survey

A questionnaire survey which aims to weight the final fields in BEAS has been conducted with the experts. Eleven experts participated in the study. Their task was the determination of significance intensity of main fields according nine-point scale of relative importance. Consequently the order and weights of significance of main assessment fields was determined. According AHP method, the numerical value of fields in a comparison matrix is determined by the Saaty's nine-point scale of relative importance for pairwise comparison [23]. On the base of intensity expression of significance has been assigned the order of fields. The significance weight for Energy performance field was determinate using Saaty matrix and the results is 26,47 %, In the table (Table 3) is shown identification of significance of assessment subfields and indicators in Energy performance field determined by experts. The number 1 means the most important field; number 2 means the second important field, etc.

Table 3

**Expert identification of significance of Energy performance assessment subfields and indicators**

| Expert | D1 | D1.1 | D1.2 | D1.3 | D1.4 | D1.5 | D2 | D2.1 | D2.2 | D2.3 | D3 | D3.1 | D3.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 4 | 5 | 2 | 1 | 1 | 3 | 3 | 1 | 1 |
| 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 3 | 1 | 1 |
| 3 | 2 | 1 | 1 | 4 | 4 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | 1 | 1 | 1 | 1 | 5 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 1 |
| 6 | 1 | 1 | 1 | 5 | 1 | 1 | 3 | 1 | 2 | 2 | 1 | 2 | 1 |
| 7 | 1 | 1 | 4 | 1 | 3 | 4 | 1 | 1 | 3 | 1 | 1 | 1 | 1 |
| 8 | 1 | 1 | 3 | 1 | 3 | 3 | 2 | 1 | 2 | 2 | 3 | 2 | 1 |
| 9 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 3 | 1 | 1 | 2 | 1 |
| 10 | 1 | 1 | 1 | 3 | 3 | 3 | 1 | 1 | 3 | 1 | 3 | 1 | 1 |
| 11 | 1 | 1 | 1 | 3 | 5 | 3 | 2 | 1 | 2 | 3 | 2 | 1 | 1 |

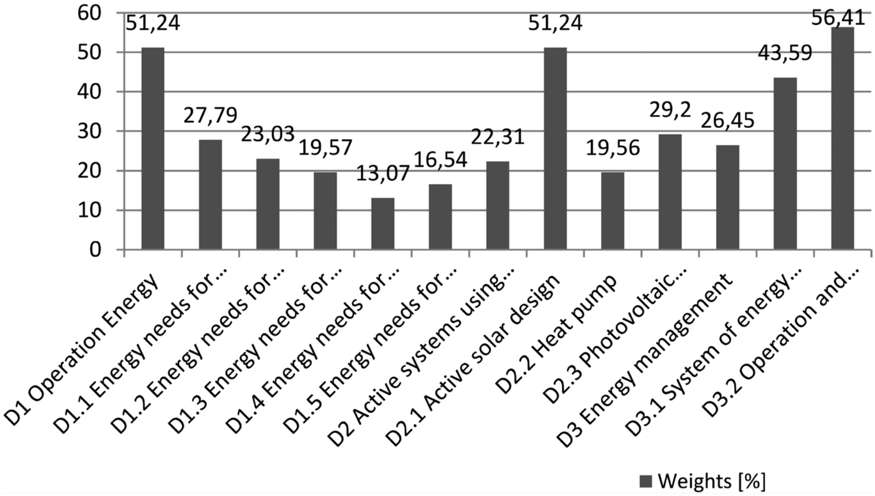


Fig. 1. Results of significance determination.

Rys. 1. Znaczenie poszczególnych czynników

In the figure (Fig, 1) is shown result of significance determination of subfield and indicators in energy performance main field of assessment.

## 4. Conclusions

The aim of paper was the identification and determination of weights of energy performance fields in BEAS. Eleven experts participated in the study. Their task was the determination of significance intensity of main fields according nine-point scale of relative importance. Consequently the order and weights of significance of main assessment fields was determined. The field of energy performance was determined as the most significant field with the weight of 27.84 %. The first sub-field of assessment D1 – Operation Energy has weight 51,24 %, second sub-field of assessment D2 - Active systems using renewable energy sources has weight 22,31 % and third sub-field of assessment D3 – Energy Management has weight 26,45 %.

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