CHEMICAL ENGINEERING TRANSACTIONS

VOL. 39, 2014

A publication of AIDIC
The Italian Association of Chemical Engineering
www.aidic.it/cet

Guest Editors: Petar Sabev Varbanov, Jiří Jaromír Klemeš, Peng Yen Liew, Jun Yow Yong

ISBN 978-88-95608-30-3; **ISSN** 2283-9216

DOI: 10.3303/CET1439178

Evaluation of Energy Aspects in Residential Buildings

Eva Krídlová Burdová, Silvia Vilčeková*

Institute of Environmental Engineering, Faculty of Civil Engineering, Technical University of Košice, Vysokoškolská 4, 042 00 Košice, Slovakia
silvia.vilcekova@tuke.sk

Integrated assessment of buildings involving environmental, social and economic dimensions should be incorporated in sustainability assessment of buildings. Systems and tools used in many countries were based on the Slovak system development. Building environmental assessment system (BEAS) applicable in Slovakia has been developed for evaluation of building performance. BEAS is a multi-criteria system contains fields: site selection and project planning; building construction; indoor environment; energy performance; water management and waste management. Significance weight of proposed six main fields and 52 indicators was determined by mathematical method. Mathematical mechanism for evaluation processes in field of environmental engineering is extensive. There are many methods for determination of significance criteria, significance parameters, control of dependency, tests of sensitivity, etc. For example: Multi-criteria analysis, Analytical hierarchy process, Saaty's method, Pairwise comparison method - Fuller method, etc. These methods were analyzed and evaluated in the context of environmental assessment requirements and respect to qualitative and quantitative characteristics of determining indicators ranking. Analysis of mentioned methods for criteria weights estimation was performed. Saaty's method has been used for determining the significance weights of indicators, sub-fields and fields of buildings environmental assessment and seems to be the most appropriate of them. This paper summarizes the analysis of significance weights of energy performance indicators for evaluation of residential buildings. It uses multi-criteria analysis to measure the quality of buildings in Slovak Republic. The presented energy indicators and their evaluations are proposed for the phase of building design. The significance weights of proposed indicators were determined by Saaty's method of multi-criteria analysis. For the purpose of system verification, a statistically significant set of buildings is required to be evaluated.

1. Introduction

The concerns about the climate change effects, the increasing demand and the price fluctuation of fossil fuels have become more present on the international policy agenda. The use of renewable energy sources is often suggested to be a possible solution to lower the contribution to climate change and the dependency from fossil fuels. In parallel, wastes and wastewater generated from various industries should be avoided or converted to energy more in the future in order to reduce environmental problems and provide additional sources of energy. (Papong et al., 2014). The Energy Performance Buildings Directive (EPBD) was issued to provide a common strategy for all European countries and to implement several actions for improving energy efficiency of buildings, responsible for 40 % of energy consumption. Energy Performance Certificates are provided as a tool to evaluate the energy performance of buildings; however, costly and time-consuming controls are necessary to verify the accuracy of the set and declared data. Many studies in Europe highlighted how buildings are responsible for 40 % of the total energy consumptions, due both to building envelope and heating systems. In order to provide a common strategy for all European countries, the Energy Performance Building Directive (EPBD, 2010), provides the guidelines on which national regulations must be based on (Burrati et al., 2014). In order to quantify the effect of energy-saving measures in the built environment, different methodologies with accompanying indicators have been, and still are being developed. Because of the European EPBD (Míguez et al, 2006), many indicators have been developed to express the energy performance of European buildings through use of an energy label with a classification system with grades from A to G. Now that Energy Performance

Please cite this article as: Krídlová Burdová E., Vilčeková S., 2014, Evaluation of energy aspects in residential buildings, Chemical Engineering Transactions, 39, 1063-1068 DOI:10.3303/CET1439178

Certification is compulsory within the European Union, it might be useful to relate the value of real estate objects to the life-cycle costs of energy-saving measures (Hoesen and Letendre, 2010). In order to reduce energy consumptions for sustainable and energy-efficient manufacturing, continuous energy audit and process tracking of industrial machines are essential. Compared to other non-residential buildings that have been widely researched, industrial buildings are generally characterized by larger thermal loads, ventilation losses and pollution control requirements (Dongellini, 2014). According to study (Kiraly et al., 2012), improving energy efficiency and thus reducing energy waste, on the one hand, and the use of renewable resources, on the other hand, have become two of the more important issues over recent years due to concerns regarding increasing energy costs, and sustainability (Nemet et al., 2014).

2. Environmental building assessment system in Slovakia

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 this new system developed for application in 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 residential buildings. Figure 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 (Vilčeková et al., 2013).
Hierarchy structure allowed using Multi-criteria decision analysis (MCDA) for weight significance determination. MCDA is a tool for effective evaluation and decision support. Analytic hierarchy process (AHP) is one of the Multi-criteria analysis methods. AHP is a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales. It is these scales that measure intangibles in relative terms. The comparisons are made using a scale of absolute judgments that show how much one element dominates another with respect to a given attribute (Saaty, 2008). The multi-criteria framework incorporates the consideration of environmental issues in a development and it will play an important role in the evaluation approach. The methodology for the derivation of the assessment indicators in BEAS was elaborated according to a study (Yang, 2010) and the list of indicators derived through a three-step process (Figure 2). In order to establish a comprehensive set of indicators for this method of building environmental assessment for residential buildings, existing methods of building environmental assessment used worldwide were combined with valid Slovak standards and codes and an

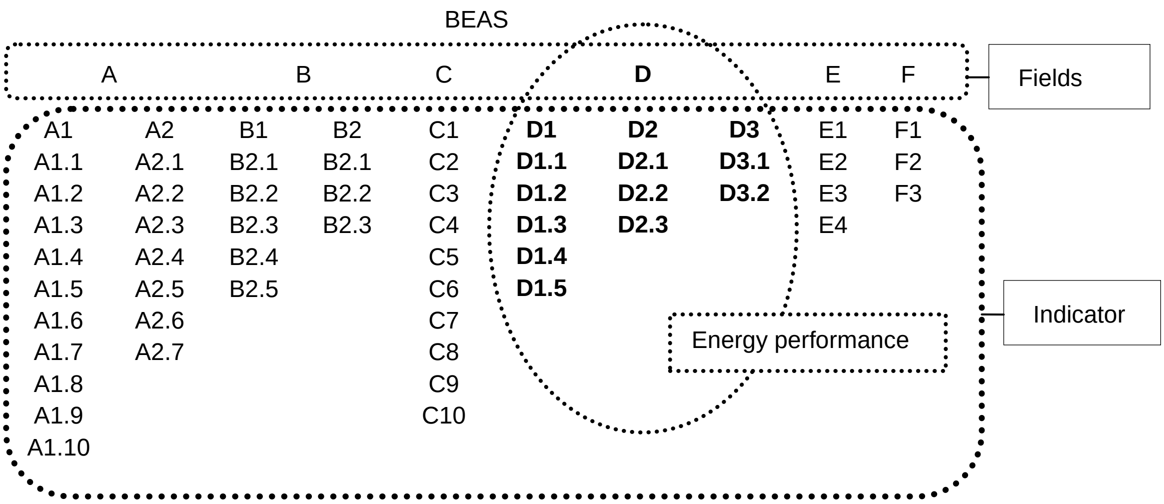

Figure 1: Hierarchical structure of system BEAS

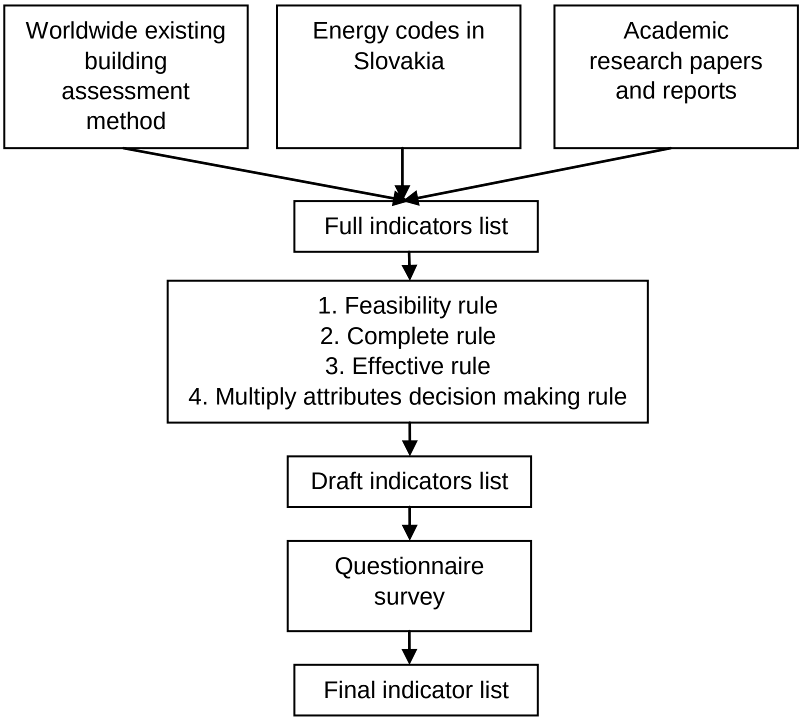

Figure 2: Method for indicators identification (Yang, 2010)

academic research paper. A three-step process was carried out. In the first step a full range of indicators relating to sustainable building efficiency were collected through an extensive review of the literature. In step two, a draft indicator list was selected from the full indicator list based on an in-depth analysis, and in step three, a survey was conducted to gather comments from experts in order to refine the selected draft indicators. As a result, a final indicator list was then proposed. This list is presented for the field of energy performance in the following sections of this paper.

3. Methods of significance weighting

The next step was determining the weights of significance of final indicators list. Questionnaire survey aimed at determining the importance of indicators by point method for the evaluation of energy performance was attended by 25 respondents. Four questionnaires were withdrawn because of the incompleteness of the questionnaire. Based on the results of the questionnaire was processed statistical evaluation by using MCDA. Methods such as multi-criteria decision analysis, analytic hierarchy process, Saaty’s method, Pairwise comparison method - Fuller method were analyzed and evaluated in the context of environmental assessment requirements respect to qualitative and quantitative characteristics of determining indicators ranking. Consequent analysis of methods for criteria weights estimation was performed. The Saaty’s method was used for determination of percentage weight of indicators. Strategies and approaches to environmental assessment of buildings affected by varying degrees of exactness are more or less comprehensive and take into account the principles of uniformity and independence.
The significance weights of the energy performance field and indicators were determined using the mathematical analytic hierarchy process (AHP), the Saaty method and the pairwise comparison method (the Fuller method). Determined weights of significance were analyzed and compared with weights of significance determined in various other systems used around the world. On the basis of comparison and consistent analysis of several variants the most suitable variant was determined by the Saaty method. The procedure of weighting determination of subfields and indicators of energy performance is presented in study (Vilčeková et al., 2014).

4. Proposal of energy performance indicators assessment

The proposed subfields and indicators related to energy performance of buildings and the means of assessment are presented in the Table 1(a) and (b).

Table 1(a): Way of energy performance assessment

D	Energy performance	26.45 %
D1	Operation Energy	22.51 %
D1.1	Energy needs for heating	11.51 %
Intent	To determine energy needs for heating	Weight
Indicator	Class of energy for heating according to Energy Performance of Buildings Directive (EPBD) and related standards.	
Negative	Energy for heating is in a class lower than C.	-1
Acceptable	Energy for heating is in class C.	0
Good practice	Energy for heating is in class B.	3
Best practice	Energy for heating is in class A.	5
D1.2	Energy needs for domestic hot water	15.41 %
Intent	To determine energy needs for domestic hot water.	Weight
Indicator	Class of energy for domestic hot water according to standards about energy performance of buildings.	
Negative	Energy for domestic hot water is in a class lower than C.	-1
Acceptable	Energy for domestic hot water is in class C.	0
Good practice	Energy for domestic hot water is in class B.	3
Best practice	Energy for domestic hot water is in class A.	5
D1.3	Energy needs for mechanical ventilation and cooling	31.42 %
Intent	To determine energy needs for mechanical ventilation and cooling.	Weight
Indicator	Class of energy for mechanical ventilation and cooling according to standards for energy performance of buildings.	
Negative	Energy for mechanical ventilation and cooling is in a class lower than C.	-1
Acceptable	Energy for mechanical ventilation and cooling is in class C.	0
Good practice	Energy for mechanical ventilation and cooling is in class B.	3
Best practice	Energy for mechanical ventilation and cooling is in class A.	5
D1.4	Energy needs for lighting	21.61 %
Intent	To determine energy needs for lighting.	Weight
Indicator	Class of energy for lighting according to standards for energy performance of buildings.	
Negative	Energy for lighting is in a class lower than C.	-1
Acceptable	Energy for lighting is in class C.	0
Good practice	Energy for lighting is in class B.	3
Best practice	Energy for lighting is in class A.	5
D1.5	Energy needs for appliances	20.23 %
Intent	To minimize energy needs for appliances.	Weight
Indicator	Using electric appliances with low consumption of electric energy, which is determined by energy class.	
Negative	At least one electric appliance is in energy class lower than A or B.	-1
Acceptable	Fewer than 2/3 of electrical appliances are in energy class A, the others are in B.	0
Good practice	At least 2/3 of electrical appliances are in energy class A and 1/3 is in B.	3
Best practice	All electrical appliances are in energy class A.	5
D2	Active systems using renewable energy sources	36.22 %
D2.1	Solar system and/or photovoltaic technology	34.05 %
Intent	To minimize energy consumption using active solar components or photovoltaic technology.	Weight
Indicator	Using a solar energy for domestic hot water and heating or transformation to electric energy.	
Negative	Solar system and/or photovoltaic technology is not installed.	-1

Table 1(b): Way of energy performance assessment (Continued)

Acceptable	Energy generated by solar system and/or photovoltaic technology covers < 30 % of energy consumption.	0
Good practice	Energy generated by solar system and/or photovoltaic technology 30 - 60 % of energy consumption.	3
Best practice	Energy generated by solar system and/or photovoltaic technology covers > 60% of energy consumption.	5
D2.2	Technology for renewable energy other than solar energy	37.66 %
Intent	To minimize energy consumption using technology for renewable energy sources other than solar energy.	Weight
Indicator	Using renewable energy other than solar energy for domestic hot water and heating/cooling or transformation to electric energy.	
Negative	Technology for renewable energy is not installed.	-1
Acceptable practice	Renewable energy other than solar energy for domestic hot water and heating/cooling or transformation to electric energy covers < 30 % of consumption energy.	0
Good practice	Renewable energy other than solar energy for domestic hot water and heating/cooling or transformation to electric energy covers 30 – 60 % of consumption energy.	3
Best practice	Renewable energy other than solar energy for domestic hot water and heating/cooling or transformation to electric energy covers > 60 % of consumption energy.	5
D2.3	Heat recuperation	28.28 %
Intent	To utilize recovery heat.	Weight
Indicator	Using a barrier-layer photocell.	
Negative	Heat recuperation is not utilized.	-1
Acceptable practice	Under 30 % of recovery heat is utilized for heat recuperation.	0
Good practice	30 - 60 % of recovery heat is utilized for heat recuperation.	3
Best practice	Above 60 % of recovery heat is utilized for heat recuperation.	5
D3	Energy management	41.27 %
D3.1	Energy management system	60.87 %
Intent	To improve energy performance of building.	Weight
Indicator	Utilizing energy management system according to ISO 50001.	
Negative	Energy management system is not established for the building.	-1
Acceptable practice	Requirements specified in standard about energy management system are met in 50 %.	0
Good practice	Requirements specified in standard about energy management system are met in 75 %.	3
Best practice	Requirements specified in standard about energy management system are met in 100 %.	5
D3.2	Facility management	39.13 %
Intent	To improve performance of systems in the building.	Weight
Indicator	Utilizing facility management system according to series of standards EN 15221.	
Negative	System of facility management is not established for the building.	-1
Acceptable practice	Requirements specified in standard about facility management are met in 50 %.	0
Good practice	Requirements specified in standard about facility management are met in 75 %.	3
Best practice	Requirements specified in standard about facility management are met in 100 %.	5

5. Conclusion

The developed building environmental assessment system applicable in the conditions of Slovakia consists of 6 main fields and 52 indicators and incorporates systems and methods used in many other countries. In this paper the indicators related to the field of energy performance and method for determining the significance weight of this field in BEAS are presented. The field of energy performance in BEAS consists of 3 subfields and 11 indicators. Within this field the subfield, D1 - Operational energy has a weight of 22.51 %, the second subfield, D2 - Active systems using renewable energy sources has 36.22 % and the third subfield, D3 - Energy management has 41.27 %. Our future research work will then be an implementation of aspects and indicators given in European standards for the sustainability assessment of buildings to the BEAS applicable in Slovakia.

Acknowledgement

This study was supported by European Union Structural Funds (Grant code: ITMS 26220120037, ITMS 197 26220220064) and the Grant Agency of Slovak Republic for the support of projects no. 1/0405/13 and 052TUKE-4/2013, on the bases of which these results are presented.

References

Burrati C., Barbanera M., Palladino D., 2014, An original tool for checking energy performance and certification of buildings by means of Artificial Neural Networks, Applied Energy, 120, 125-132.

Čuláková M., Vilčeková S., Krídlová Burdová E., Katunská J., 2012, Reduction of Carbon Footprint of Building Structures, Chemical Engineering Transactions, 29, 199-204.

Dongellin M., Marinosci C., Morini G.L., 2014, Energy audit of an industrial site: a case study. Energy procedia 45, 424-433.

European Parliament, 2010, Council of the European Union: Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, Off. J. Eur. Union, 53, 13-35.

Hoesen J., Letendre S., 2010, Evaluating potential renewable energy resources in Poultney, Vermont: A GIS-based approach to supporting rural community energy planning, Renewable Energy, 35, 2114-2122.

Kiraly A., Pahor B., Kravanja Z., 2012, Integration of Renewables for Improving Companies' Energy-Supplies within Regional Supply Networks, Chemical Engineering Transactions, 29, 469-474.

Míguez J.L., Porteiro J., López-González L.M., Vicuña J.E., Murillo S., Morán J.C., Granada E., 2006, Review of the energy rating of dwellings in the European Union as a mechanism for sustainable energy, Renewable and Sustainable Energy Reviews, 10, 24–45.

Nemet A., Čuček L., Varbanov P.S., Klemeš J.J., Kravanja Z., 2012, The Potential of Total Site Process Integration and Optimisation for Energy Saving and Pollution Reduction, 7th Conference on Sustainable Development of Energy, Water and Environment Systems - SDEWES2012, Ohrid, Republic of Macedonia, SDEWES12-0555.

Papong S., Rotwiroon P., Ghatchupong T., Malakul P., 2014, Life cycle energy and environmental assessment of bio-CNG utilization from cassava starch wastewater treatment plants in Thailand, Renewable Energy, 65, 64-69.

Saaty T.L., 2008, Decision making with the analytic hierarchy process, International Journal of Services Sciences, 1(1), 83-98.

Vilčeková S., Sedláková A., Krídlová Burdová E., Čuláková M., Geletka V., Kapalo P., 2013, Analysis of environmental aspects in high energy performance family house - Case study, Chemical Engineering Transactions, 35, 385-390.

Vilčeková S., Krídlová Burdová E., 2014, Multi-criteria analysis of building assessment regarding energy performance using a life-cycle approach. International Journal of Energy and Environmental Engineering, April 2014, 5:83, Open Access

Yang Y., Li B., Yao R., 2010, A method of identifying and weighting indicators of energy efficiency assessment in Chinese residential buildings, Energy Policy, 38, 7687-7697.