Sustainable Design Building Evaluation Based on Multi-Criteria Methods

Lucjan W. Kamionka 3
1 Kielce University of Technology, 25-314 Kielce, Poland
luckam@tu.kielce.pl

Abstract. The article presents the objectives of sustainable development and the features of sustainable buildings executed within new urban structures. It presents various aspects of sustainable design, where energy-efficiency is the crucial building evaluation factor in multi-criteria LEED, BREEAM and Green Building methods. It points to the need for the application of a design solution multi-criteria evaluation method with the use of specialist software, within the sustainable design process. The process of evaluating and verifying applied solutions should involve a group of industry specialists, among others, from the field of building energy performance. The role of an architect in an inter-disciplinary design process is that of a leader in terms of coordinating the work, and a creator, where humanistic values are crucial. It also presents examples of buildings designed and constructed in Poland, which are characterized by high quality solutions in the field of sustainable design. These objects obtained LEED, BREEAM, Green Building and Passivhaus certificates.

1. Introduction
In a time of environmental hazard and power crises, sustainable development has become the major strategy for the activities in spatial development. Sustainable development was defined in 1987 in the Report “Our Common Future”, also called the Brundtland Report, prepared by the World Commission on Environment and Development. The meaning of “sustainable development” phrase was set out in the “Agenda 21” declaration, passed during the Earth Summit “Environment and Development” in Rio de Janeiro in 1992. This term was used to call the exploitation of declining natural resources and the maintained improvement of the quality of life of current and future generations. Sustainable development is a development possible to be continued over an extended period of time, without breaking ecological and social balance. In 2006, the European Council adopted a renewed strategy of sustainable development for the EU [1]. As per the strategy “Durable, sustainable development means that the needs of the contemporary generation should be satisfied without prejudice to the possibility of satisfying the needs for future generations. Construction is the largest economy sector in terms of commercial and resource flow. Most of the capital is invested in buildings both financial as well as natural. The role of construction, as well as architecture as a knowledge domain shaping the human surrounding is crucial in creating sustainable development, which is indicated by the theory of architectural-construction systems [2].

2. Aspects of sustainable design
A sustainable building has never been and is not understood and defined in a uniform manner. It was distinctly exhibited by a “Sustainable Building 2002” conference in Oslo [3], where attempts were
made at finding the best matching definitions in terms of the state-of-the-art and technical advancement of the subject. The OECD (Organization for Economic Cooperation and Development) Project identifies 5 features of sustainable buildings:

- efficient energy consumption,
- efficient consumption of resources,
- pollution prevention,
- harmonization with the environment,
- integrated and systemic troubleshooting.

The following aspects play an important role in the sustainable design process:

- the aspect of energy efficiency and environmental pollution,
- the aspect of user experience,
- the aspect of rational water consumption,
- the aspect of rational raw resources and construction material management,
- the aspect of eco-friendly land use and mitigating invasiveness,
- the social aspect,
- the regional and innovative aspects.

The energy-efficiency aspect, and in particular, energy-saving in architecture design, plays an important role in modern civilization conditions. Solar energy plays an important part in shaping an energy-efficient residential environment [4,5]. The arrangements of the European Community for 2020, expressed in the so-called “Green Paper on Energy Efficiency” [6] assume:

- achieving individual savings in buildings, in the scope of energy consumed for heating, air conditioning, hot water and lighting, at a level of 22%;
- doubling the share of renewable energy sources in the total electricity consumption, from 6% to 12%;
- increasing the share of green electricity from 14% to 22% of the total power consumption.

Architecture is an important element of environmental development, while maintaining the balance of nature and the durability of fundamental environmental processes. The construction of new buildings in the cities or modernization of the existing urban fabric is aimed at the implementation of specified sustainable development objectives [7]:

- decreasing the electricity and natural resource demand, through adopting a standard of energy-efficient construction, and passive construction in the future,
- intelligent application of technical systems, and exploitation of renewable energy sources,
- taking into account the basic climatic structure of a region, through relevant shaping and combinations of the buildings, terrain, technical infrastructure and green areas,
- maintaining a possibly low level of surface sealing,
- rational utilization of natural resources, and the use of eco-friendly materials,
- reducing the amount of air and water pollution, decreasing the volume of waste and waste water, as well as waste heat,
- developing the concept of logistics, which would lead to limiting transport during the construction and, later, building operation stages,

The idea of designing in harmony with the principles of sustainable development [8] is now in a stage of common embodiment. It is clearly discernible in designing high-rise buildings with varied functionalities [9]. Multi-criteria methods for evaluating buildings, codifying the standards of designing and construction, are being created. Designs in accordance with agreed standards are being developed, and then executed and awarded certificates, which enjoy an ever increasing prestige among the users. Coded standards, although they do not include a fully comprehensive sustainable design process in architecture, put the energy aspect in a leading place, appreciating the role of rational energy consumption.
3. Multi-criteria building evaluation method

Multi-criteria methods for the evaluation of buildings in terms of sustainable development were created in the 1990s. The most important ones include:

- Leadership in Energy and Environmental Design (LEED), USA,
- Building Research Establishment Environmental Assessment Method (BREEAM), Great Britain,
- Green Building – European Union
- Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), Germany.
- Building Environmental Performance Assessment Criteria (BEPAC), Canada,
- Green Building Challenge (GBC), European countries, Japan, Canada, USA.

The procedure of awarding a “Passivhaus” certificate to passive buildings deals with evaluating a building, solely in the energy aspect.

The author attempted to develop a method for evaluating sustainable architecture buildings. This method may be of significant application importance within the sustainable design process. It may be used in the process of designing various buildings and at each of its stages.

The evaluation of engineering solutions in a sustainable design process should be subjected to multi-criteria analysis.

The subject scope of codified standards in selected building evaluation methods, relative to sustainable design aspects is illustrated in figure 1.

![Figure 1](image)

**Figure 1.** The subject scope of codified standards in selected building evaluation methods, relative to sustainable design aspects

An ideogram of a method developed by the author is shown in figure 2.
Figure 2. An ideogram of a building evaluation method within a sustainable design process (author L. Kamionka)
Computer programs simulating building behaviour in various functional conditions are increasingly used in the conducted analyses. The programs have been constantly developed and are currently used as a significant tool in economic-energy analyses, like LCC (Life Cycle Cost), LCA (Life Cycle Assessment), LCCA (Life Cycle Cost Analysis).

The following software play an important role in LCC, LCA, LCCA analyses: BLAST, DOE-2, COMIS, ENERGY PLUS, TRNSYS, DEROB-LTH and CILECCTA [10].

CILECCTA is a project, which combines the efforts of scientists, industry associations and entrepreneurs, aimed at developing software supporting the decision-making process when designing sustainable buildings. The EC-supported program is adapted for analysing an entire building, as well as its elements. The Polish CERTO program, developed by the Lower Silesia Agency for Energy and the Environment should be noted, which can be successfully utilized for initial, conceptual analyses.

4. Examples of building constructed in Poland

It should be emphasized that an increasing number of architectural objects in accordance with codified standards of LEED, BREEAM, Green Building and defined passive building standards are being designed and constructed in Poland.

4.1. Building with a LEED certificate

2009 saw the opening of a plant belonging to an American Borg Warner concern in the Podkarpacie Research-Technical Park in Rzeszów. The plant manufactures turbochargers and components for air supply and harmful substances reduction systems in passenger and utility vehicles. The American concern constructed the building according to LEED standards. The facility was the first building in Poland to receive a certificate issued by the US Green Building Council. The outer wall and roof structure meet the highest insulation standard. The execution of the facility, used materials, as well as applied technologies, correspond to environmental conditions. Automatic energy management was used within the complex, and significantly impacts its energy balance.

In 2011, the Rondo 1 office building, as the first building in Poland to apply for certification after construction, was awarded a LEED golden level certificate. The building also included a conference centre, cafeterias, canteens, a supermarket, banks and a SPA. It has a structural height of 159 m and 40 overground storeys. Lighting in the building is controlled by “DALI” digital technology systems. The office building also uses 10% of the energy generated by a wind power plant. Water consumption was reduced by 30%. It should be noted that an office complex – the headquarters of Skanska-Property, located in Atrium City (Warsaw, Al. Jana Pawła II) was awarded a silver level LEED certificate in 2010.

4.2. Buildings with a BREEAM certificate

Three office-conference complexes, which received BREEAM certificates, were commissioned in Poland in 2010. They are Trinity Park III and Crown Square executed in Warsaw, and Business Point in Katowice. The buildings use energy-efficient HVAC and lighting systems, as well as energy-efficient elevators. The buildings have an extensive automatic management BMS system. The used materials were accurately selected in terms of ecology. The choice of the facade curtain was preceded by specialist analyses in the aspect of energy savings.

The Trinity Park III facility is located in Warsaw, at ul. Domaniewskia (arch. Jaspers & Eyers Partners) and has 6 overground and 3 underground storeys.

Crown-Square, an office-conference centre (arch. Ludwig Konior & Partners) is located in Warsaw, at ul. Przyokopowa, has 13 overground storeys and 3 underground storeys holding a parking for 227 vehicles. Katowice Business Point is an office-conference complex (arch. Jaspers & Eyers Partners, Czora&Czora) constructed near Silesia City Center in Katowice. The facility has 11 overground floors and 3 underground storeys with a garage holding ca. 200 parking spots.
4.3. Buildings with a “Green Building” certificate
In 2009, the Atrium City office building located in the centre of Warsaw, as the first building in Poland, received a Green Building certificate from the European Commission. The building has all the characteristic features for designs developed according to “Green Buildings” standards, i.e., increased energy-efficiency, high functional comfort and attention to architectonic qualities. (arch. Kazimierski & Ryba). Atrium City, located at Al. Jana Pawła II, in direct vicinity of the ONZ roundabout. Atrium City is a class A office building. The facility satisfies the highest standards both in terms of energy-efficiency as well as functional comfort, technical solutions and user safety. Raised floors, duct heaters, an air-conditioning system based on chilled beams, access control systems and 24/7 monitoring system were used. A half of the energy consumed during operation is used for the needs of internal building systems. The second half is the direct consumption of tenants and building users. The entire building is supervised by an Integrated Building Management System BMS. The building uses internal partitions with better parameters than the ones required by applicable standards and legal-technical regulations in Poland. The applied ventilation/air-con system utilizes air removed from the office area for heating the atrium and garage levels. The building integrates the insolation level with illuminating rooms. The lighting of building common areas is integrated with the Central Building Management System, thanks to which, its intensity adapts to external conditions (time of the day, cloud cover). Decreased energy costs are tangible economic benefits - starting from lower investment expenditure, through lower costs of servicing and technical equipment, to lower building operation costs.

4.4. Buildings with a “Passivhaus” certificate
The first design of a passive house in Poland was implemented in 2007 in Smolec near Wrocław (arch. Lipiński). Maximized solar heat gains were achieved thanks to appropriate arrangement of windows in the facade of the house. Large windows on the south-western side of the facade, apart from ensuring energy gains from solar radiation also determine the architectonic appearance of the building. The function of the house is similar to a traditional one, although with innovative elements imposed by large, glazed areas of the dining and living rooms. The general use area is comprised of a living room with a mezzanine, which binds the interior of the house. A compact character of the building is confirmed by an A/V of 0.75, and a garage with an independent structure, added from the western side play the role of a heat buffer. Calculated heat demand is 13.7 kWh/m² per year. A Platinum Plus polystyrene, 30-44 cm thick insulation layer was used for thermal insulation of the walls, which helped to achieve U = ca. 0.1 kWh/m². Walls are made from LECA blocks. An additional advantage of such a solution is their high accumulation mass. The rafter framing was made in a traditional manner of timber rafters with the use of thermal insulation. The heat transfer coefficient achieved a value of U=0.08 kWh/m². Certified windows and door woodwork was used, with a coefficient of U=0.7 kWh/m². Mechanical ventilation with heat recovery was designed and a counter-flow heat exchanger located under the ground freezing zone, at a depth of 1.5 - 2.0 m was used. During the winter, the temperature of air supplied to the building does not fall below zero, while during the summer, it is cooled down to pleasant temperatures.

A demonstration “autonomous house” with “passive building” standards was executed in Podzamcze Chęcińskie near Kielce. The autonomous house was built in 2015 by the Świętokrzyskie Centre for Innovation and Transfer of Technology in Podzamcze Chęcińskie near Kielce. L. Duda is the author of the design. The completed autonomous house, as per the assumptions of the Investor, is an example of a building of the nearest future and encourages consultations and new implementations.

A catalogue list of selected, architectural objects in Poland, which received the LEED, BREEA, GreenBuilding, Passivhaus certificates is shown in table 1.
| No | Building                        | Location  | Author                          | Basic parameters                                                                 | Photo | Certificate, year of award                          |
|----|---------------------------------|-----------|---------------------------------|----------------------------------------------------------------------------------|-------|---------------------------------------------------|
| 1  | Borg Warner edifice             | Rzeszów   | Predom arch. Michał Dąbrowski   | office area UFA - 841 m²; Cub. - 9453 m³; manuf. area UFA - 2911 m²; Cub. - 5270 m³; |       | LEED 2008/2010 (First building in Poland)         |
| 2  | Rondo-1 Office Building         | Warsaw    | AZO.Owings & Merrill            | UFA - 102.4k m²; stage I 3 undergr. storeys; Parking - 470 spots; stage II 15 overgr. storeys 16.5k m²; Parking - 490 spots; |       | LEED 2011 execution 2003-2006                     |
| 3  | Atrium South Office Building    | Warsaw    | arch.Kazimierski & Ryba        | stage I 3 undergr. storeys; Parking - 470 spots; stage II 42 overgr. storeys      |       | LEED Investment stage 2010-2012                   |
| 4  | Trinity Park III - office- conference building | Warsaw | Arch. Jaspers & Eyers Partners | 6 overgr. storeys 3 undergr. storeys UFA - 32.0k m² parking - 720 spots          |       | BREEAM 2010                                      |
| 5  | Crown Square-office-conference centre | Warsaw | Arch. Ludwik Konior & Partners | 13 overgr. storeys 3 undergr. storeys UFA - 16.2k m² parking - 227 spots          |       | BREEAM 2010                                      |
| 6  | Katowice Business Point - office-conference centre | Katowice | Arch. Jaspers & Eyers Partners, coop. Czora&Czora | 11 overgr. storeys 3 undergr. storeys UFA - 17.0k m² parking - 200 spots |       | BREEAM 2010                                      |
| 7  | Atrium City Office Building     | Warsaw    | Arch.Kazimierski & Ryba        | 15 overgr. storeys 3 undergr. storeys UFA - 20.0k m² parking - 218 spots          |       | „Green Building“ 2009                             |
| 8  | Passive dwelling house          | Smolec near Wroclaw | Arch. B.P. Lipiński-Domy | Single-family house                                                            |       | „Passivhaus“2007                                   |
| 9  | Passive dwelling house          | Podzamcze Chęcińskie near Kielce | Ludomir Duda with his team | Single-family house                                                            |       | „Dom autonomiczny“2015                            |
5. Conclusions

The evaluation of buildings in sustainable design is a crucial activity. Multi-criteria building evaluation methods such as LEED, BREEAM, Green Building determine ecological and energy standards for the functioning of large buildings, which are usually stricter than national standards, and the defined parameters of a passive building assume the use of a facility solely based on passive energy sources. The environmental and energy-efficient qualities of a building are impacted by specific aspects, which should be analysed within a sustainable design process:

- the aspect of energy efficiency and environmental pollution,
- the aspect of user experience,
- the aspect of rational water consumption,
- the aspect of rational raw resources and construction material management,
- the aspect of eco-friendly land use and mitigating invasiveness,
- the social aspect,
- the regional and innovative aspects.

In order to achieve the desired results, an integrated design process should be thoroughly prepared under the participation of specialist, i.a., in the field of building energy performance, subjecting the adopted design solution to multi-criteria analysis. Such a mode of action may guarantee the application of optimal solutions. The role of an architect in an inter-disciplinary design process is that of a leader in terms of coordinating the work, and a creator, where humanistic values are crucial.

The building evaluation method developed by the author may be of high application importance within the sustainable design process and is worth recommending.

Increasingly more buildings in Poland are being designed and executed as per the principles of sustainable development, and the energy aspect plays a leading role. More and more buildings have certificates confirming the quality of applied sustainable design.

References

[1] V. Abizov, Teoria rozwoju systemów architektoniczno-budowlanych [The theory of development of architectonic-construction systems]. Monograph, KNUKiM, Kiev. 2010.
[2] Biuletyn Polskiego Towarzystwa Certyfikacji Energii. No. 3 (p. 1-2). Poznań, September 2005.
[3] J. Gil-Mastalerczyk, Sustainable design in the contemporary architecture of tall buildings. E3S Web of Conferences 10.00125 (2016) SEED 2016.
[4] L. Kamionka, An architect as a creator and coordinator of sustainable architecture design – Design synergy. Architekt jako kreator i koordynator procesu projektowania architektury zrównoważonej- synergie projektowa. International Scientific Conference of the Institute of Architectural Design: Defining The Architectural Space. Architecture Now. Kraków, 19-20 XI. 2010, Czasopismo Techniczne t.II.
[5] L. Kamionka, Zagadnienia oceny i certyfikacji obiektów architektury zrównoważonej [The issues of evaluating and certifying sustainable architecture facilities]. Quarterly magazine Architektura I Urbanistyka. Polska Akademia Nauk. Zeszyt 3/2011.
[6] L. Kamionka, Architektura zrównoważona i jej standardy na przykładzie wybranych metod oceny [Sustainable architecture and its standards on the examples of selected evaluation methods]. Monografie, studia,rozprawy M30. Politechnika Świętokrzyska, Kielce 2012.
[7] E. Richter, K. Nowak, H. Krauze, H.A. Nowak, Modernizacja budynków mieszkalnych w Niemczech [Modernization of residential buildings in Germany]. Warszawa. Instytut Techniki Budowlanej 2001. Konferencja Naukowo-Techniczna” Energooszczędne budownictwo mieszkaniowe” [Scientific-Research Conference - Energy-efficient residential construction] – Mrągowo – 2001.
[8] T.D. Pettersen, Sustainable building 2002. 3-rd International Conference on Sustainable Building, 23-25 September 2002, Oslo. EcoBuild 2002.
[9] Rezolucja legislacyjna Parlamentu Europejskiego w sprawie zmienionej strategii zrównoważonego rozwoju [Legislative resolution of the European Parliament on amended
strategy of sustainable development] Dz.Urz.UE 300E P6 TA (2006/0272 of 15/6/2006).

[10] S. Wehle – Strzelecka, Architektura słoneczna w zrównoważonym środowisku mieszkaniowy [Solar architecture in a sustainable residential environment], Monografia, 312, PK , Kraków 2004.

[11] S. Wehle- Strzelecka, Energia słońca w kształtowaniu środowiska mieszkaniowego – ewolucja koncepcji na przestrzeni wieków [Solar energy in shaping a residential environment – the evolution of the concept throughout the ages], Wydawnictwa Politechniki Krakowskiej, Kraków 2014.