ANALYSIS OF THE IMPACT OF LEED CERTIFICATION TECHNICAL REQUIREMENTS ON CALCULATED ENERGY PERFORMANCE OF AN OFFICE BUILDING

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Abstract

The article presents an analysis of the impact that meeting LEED certification criteria has on the calculated energy performance of a building based on Polish regulations regarding the methodology for determining the energy performance of a building, taking into account the technical modernization that affects the final result of the analysis. Calculations were carried out on the example of an office building. The analysis covered a scope that combines LEED certification and energy performance, such as water use and indoor lighting. The calculations were made in a program designed for energy performance calculations. The use of energy-saving lamps (46% lower energy use in relation to standard lamps) or fittings limiting the water flow from the tap (26% lower water use) did have a positive impact on the final calculation of post-modification energy performance, according to which the demand for primary energy was reduced by 36%. The static analysis was performed using commercial software for preparing energy performance certificates and on the basis of formal guidelines set out by the LEED certification.

Keywords: water saving, water fittings, energy, electricity, lighting, energy performance, passive building, energy efficient building

1. Introduction

The LEED (Leadership in Energy and Environmental Design) certificate (*USGBC: U.S. Green Building Council*, 2023) is an American building rating system created by the USGBC (United States Green Building Council) based on the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standard. The aim of LEED certification is to reduce the energy consumption (Scofield, 2013) of a facility by reducing energy consumption for lighting or

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ventilation (Newsham, Mancini, Birt, 2009), such as by using CO_2 concentration sensors. Another objective of the certification (Knapik, 2017) is to reduce the negative impact of a building by eliminating the "heat island" effect or by reducing water consumption. Water consumption and the amount of waste water can be reduced by using electromagnetic valves that cut off the water supply to a sanitary unit fitted with a presence sensor and by using water faucets fitted with an aerator or by limiting water flow rates (Knapik, 2022). Another important advantage of LEED certification is supporting pro-ecological initiatives such as subsidies for public transport, cycling or the installation of renewable energy sources. Points are awarded for implementing the above-mentioned initiatives during the certification process. Based on the collected points, the building receives an appropriate certificate. The LEED certificate promotes the principle of sustainable development (Knapik, 2014) and is commonly used as a marketing tool (Matisoff, Noonan, Mazzolini, 2014) to demonstrate the pro-environmental awareness of the owner (Walsman, Verma, Muthulingam, 2014).

Due to the fact that LEED certification directly affects and requires special design solutions to lower energy consumption for lighting and ventilation or reducing water consumption (Amiri, Ottelin, Sorvari, 2019). It also affects the calculation of energy performance – calculated, in this case, according to the Polish methodology (Regulation of the Minister of Development and Technology of 28 March 2023 amending the Regulation on the methodology of determining the energy performance of a building or part of a building and energy performance certificates, 2023), LEED certification process has an impact on the calculation of the Primary Energy (EP) index. EP is an indicator of a building's annual demand for non-renewable primary energy to meet its needs for heating, cooling, ventilation, hot water preparation, lighting and all other electrical devices. The essence of this article is to draw attention to the problem of minimalism in projects and strict adherence to the requirements of technical conditions.

1.1. Research objective

The analysis revealed points of commonality between LEED certification and energy performance calculations. The requirements of LEED include the scope of the installation of lighting, ventilation or water consumption, which are taken into account in the Polish methodology for calculating energy performance. The requirements set by LEED do not directly determine the calculation of primary energy demand. It should be mentioned that they may indirectly affect the final result, depending on the number of recommendations implemented and points awarded through certification.

The analysis significantly contributes to improving the current knowledge of energy savings and sustainability principles in relation to energy performance as calculated according to Polish regulations. In Polish conditions, architectural, construction and installation projects are required to meet minimum technical conditions relating to primary energy demand. In cases where no other external conditions are imposed, the investor will often benefit from taking a minimal approach to lower investment costs. Additional requirements, such as the LEED certification process, impose certain requirements on the investor and project teams that improve the building's energy efficiency. The awarded certificate can serve as a marketing tool promoting pro-ecological solutions. The solutions proposed by LEED contribute to reducing the building's operating costs and, consequently, increase the attractiveness of the building (Singh, Syal, Korkmaz, Grady, 2010).

Energy audits are performed (Hamoen, 1982) in office buildings (Hajduk-Stelmachowicz, 2018) to identify problems with energy consumption. Lower investment outlays on buildings worsen their technical efficiency, which directly affects higher operating costs of the facility. Energy audits often show irregularities in the preparation of energy characteristics, specially prepared to meet the technical requirements applicable at the time of building design. The use of certification such as LEED is an additional tool verifying the standard of project execution. A high-standard building generates lower operating costs.

The aim of the article is to analyse the impact that meeting the technical requirements of LEED certification has on the calculated energy performance of a building. An analysis means a comparison of two states of the building – a building not covered by LEED certification and a building in which LEED certification solutions have been introduced that affect the calculation of energy performance. The purpose of the analysis is to examine the indirect impact of the LEED certification recommendations on the calculation of energy performance and, consequently, the demand for primary energy. The anticipated conclusions should suggest a positive impact of LEED certification on energy performance calculations, which should result in a reduction in the building's primary energy demand. The primary energy demand parameter in a building not covered by certification and in a building with LEED certification recommendations will be assessed, together with a discussion of technical solutions that reduce energy demand. The article does not focus on an analysis of the costs of changes and the resultant operational savings. The analysis is intended to support the decision-making process of investors and designers regarding design solutions that will significantly reduce the building's energy demand, have a more favourable impact on the external environment and achieve a measurable marketing effect. The obtained results are intended to support new trends in office construction, consistent with the idea of sustainable development.

2. Materials and methods

2.1. Model, input data and calculations of the energy performance of the building

For the purpose of this analysis, the energy performance of a small office building was assessed using the Audytor OZC program based on Polish regulations (Regulation of the Minister of Development and Technology of 28 March 2023 amending the Regulation on the methodology of determining the energy performance of a building or part of a building and energy performance certificates, 2023; Notification by the Minister of Development and Technology of 15 April 2022 on the announcement of the consolidated text of the Regulation of the Minister of Infrastructure on the technical conditions to be met by buildings and their location, 2022). In the program, an appropriate office building model of 579 [m^2] usable area was drawn up (Fig. 1).

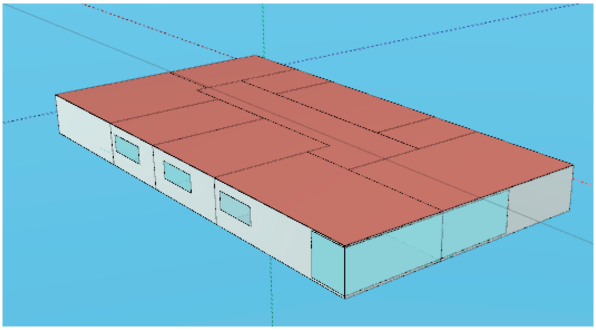

Figure 1. Model of a simple, single-storey office building

Calculations take into account the existing external partitions like walls, roof and windows. The energy demand for heating a building is determined by the quality of partitions (including windows and doors) (Knapik, 2018b), key dimensions, thermal bridges, and the balance of supply air and exhaust air (PN-83/B-03430, 1983). Table 1 lists the types of building partition with the area and heat transfer parameters of each, together with the limit U-coefficent values as set in the relevant regulations (Regulation of the Minister of Development and Technology of 28 March 2023 amending the Regulation on the methodology of determining the energy performance of a building or part of a building and energy performance certificates, 2023).

The baseline condition for the analysis was set using the default values suggested by the Polish regulation on energy performance calculations. Since the building has a mechanical ventilation system (PN-EN 13465:2006, 2006), the default heat recovery efficiency of η=70% suggested by the program was adopted (Kosieradzki, 2009). Only the value of supply air to the rooms was changed, where the default temperature of 8°C was changed to a supply air temperature of 18°C.

Table 1. Parameters of partitions of analysed building

Partition type	Heat transfer coefficient U [W/(m² K)]	Partition area [m²]	Heat transfer coefficient U_{max} technical conditions [W/(m² K)]
External Wall	0.187	304.88	0.2
Floor on the ground	0.181	592.19	0.3
Roof	0.122	626.41	0.15
Internal wall	2.405	304.55	n/a
Window	0.9	67.93	0.9
External door	1.3	4.60	1.3
Internal door	1.3	28.60	n/a

For the calculations, a reduction in ventilation airflows at night to 60% of the nominal value was used. In the subsequent step, default assumptions from the regulation were developed for a heating system supplied from a district heating network (coal or natural-gas-fired cogeneration heat). In the building, the heat source is a heat substation with a capacity of up to 100 kW. The rooms are heated with panel radiators. Building external walls are insulated with a 0.14 m thick layer of polystyrene - the thermal conductivity coefficient is $\lambda = 0.032$ [W/(m K)] (Knapik, 2020). The radiators are equipped with thermostatic valves. The heating system operates at 70/50°C and is equipped with a circulating pump. In rooms where mechanical ventilation is not provided, natural ventilation operates. The results of building model calculations performed in the Audytor OZC program are presented in Table 2, and include the areas, volumes and temperatures of rooms.

Table 2. Air balance (infiltration, supply and exhaust) for individual rooms in the building, taking into account room temperature

Room type	θint,H	A	V	Vinf	Vsup	Vex
	°C	[m²]	[m³]	[m³/h]	[m³/h]	[m³/h]
Social room	20.0	85.07	220.8	26.5	0.0	70.0
Office 1	20.0	76.73	199.1	15.9	50.0	50.0
Office 2	20.0	44.73	116.1	9.3	0.0	0.0
Reception	20.0	57.47	149.1	11.9	149.1	149.1
WC	20.0	22.71	58.9	4.7	0.0	70.0
Office 3	20.0	48.11	124.9	10.0	50.0	0.0
Office 4	20.0	60.40	156.7	12.5	60.0	0.0
Office 5	20.0	79.24	205.6	24.7	120.0	0.0
Technical room	20.0	19.92	51.7	0.0	0.0	30.0
Waiting room	20.0	84.38	219.0	0.0	0.0	90.0

Domestic hot water is heated in a heat substation. Since the facility is small, there are no circulation circuits for domestic hot water. A default value of water demand for office buildings of 0.35 [$dm^3/(m^{2}*day)$] was assumed. In the technical room, there is a domestic hot water tank supplied by a circulating pump.

Regarding lighting, default values from the regulation for Class-A offices were used for energy performance calculations (15 [W/m^2]), assuming typical usage time for office-type spaces and manual control of lighting without intensity control.

The building is supplied with electricity from the power grid. The building is equipped with photovoltaic cells on the roof, which are able to cover 25% of the electricity demand.

The most significant input data for energy performance calculations according to the Polish regulation are summarized in the Table 3.

Table 3. Summary of input data for energy performance calculations

Installation	**Final energy carrier**	**w_i factor**	**Average system efficiency [%]**	**Average power of devices [W/m^2]**	**Working time [h/year]**	**Primary energy demand EP [$kWh/m^2/year$]**
Heating	Cogenerated district heating	0.8	83	0.15	4500	5.9
Domestic hot water	Cogenerated district heating	0.8	50	0.25	270	7.6
Lighting	Electricity and Photovoltaic cells	2.5 (electricity) 0 (PV)	n/a	15	2250 (day) 250 (night)	70.3
Ventilation	n/a	n/a	n/a	0.5	8760	11.0

Notes: w_i – coefficient of non-renewable primary energy input for the generation and delivery of an energy carrier or energy for technical systems; average efficiency of system is the product of multiplying the partial efficiencies of individual parts of systems.

Based on the above data, energy calculations were carried out in the Audytor OZC program. The results are summarized in Table 4.

According to the calculations made in the program, the building meets the minimum requirements for primary energy demand. However, in accordance with Polish regulations, as an existing building it does not have to meet the requirements as to the EP value, but it must meet the requirements as to the insulation of partitions and the value of the heat transfer coefficient, *U*. It should be mentioned that as regards office buildings (public buildings), the partial values of the EP index for the needs of heating, ventilation and hot water preparation are 45 $kWh/m^2/year$; furthermore, the partial values of the EP index for lighting (including for office buildings) depending on the duration of lighting operation during the year is 50 $kWh/m^2/year$ if the duration exceeds 2500 hours per year. Consequently, for

Table 4. Summary of energy performance results, where EK – means final energy, EU – usable energy, and EP – primary energy

Energy performance indicator	**Building under evaluation**	**Requirements for the building according to Polish regulations**
Indicator of annual demand for usable energy	EU = 12.9 [kWh/m^2/year]	EP < 95 [kWh/m^2/year]
Indicator of annual demand for final energy	EK = 61.7 [kWh/m^2/year]	
Indicator of annual demand for primary energy	EP = 94.8 [kWh/m^2/year]	
Share of renewable installations in annual final energy demand	17.2 %	

the analysed building, the total limit demand for primary energy is the sum of two partial values and amounts to 95 kWh/m^2/year.

The energy performance prepared for the analysis provides a basis for further consideration of the impact of LEED certification on the energy performance score. LEED certification has implications regarding the building's water consumption, ventilation and lighting. These are areas that affect the final energy performance score (Seinre, Kurnitski, Voll, 2014).

2.1. LEED certification requirements and recommendations affecting the calculation of the building's energy performance

The LEED certification process is a multi-criterion evaluation of buildings and is one of the leading ways of evaluating buildings from an environmental perspective (Lee, 2011). It quantifies the extent to which facilities comply with the concept of sustainable architecture and construction. The certification system has the advantage of taking a holistic approach to various aspects of building occupant comfort and ecology (Cidell, 2009). For the purposes of the analysis, the scope was limited to water conservation and lighting issues, as the other areas do not affect energy performance calculations. The LEED certification process awards credits (points). Depending on the number of credits awarded, certification is granted at levels described as bronze, silver, gold or platinum.

One intent of LEED certification is to reduce indoor potable water consumption and preserve no- and low-cost potable water resources. LEED certification points for water-related improvements are awarded for the degree of reduction in water use relative to the designated baseline.

Water demand can be reduced (Hilaire et al., 2008) in office buildings by using water faucets with limited discharge. Another way is to protect bathrooms and other water hubs from leaks by providing appropriate solenoid valves. Another aspect is to educate employees and other users of the facility that water should be saved (Halilch, Stephenson, 2009).

In the analysed building there are 3 toilets, 2 urinals, 3 sinks (bathroom) and two kitchen sinks (social room). Hot water is used only in washbasins and sinks, and for the purposes of energy performance calculations these sanitary ware are included in the further analysis.

It can be noted that the reduction in water consumption from the LEED certification baseline for fixtures in sinks and faucets with limited water outflow time, the value exceeds 50%. Documenting the use of fixtures with flows as DELABIE fixtures (Armatura_sanitarna_budynków_użyteczności_publicznej, 2022) will allow the maximum number of LEED certification points to be earned for water efficiency (LEED requirements are for total reduction of water consumption - hot and cold). For energy performance calculations, it was assumed that domestic hot water consumption water demand for office buildings amounts 0.35 [dm^3/(m^2 * day)].

The usable area of the office building is 579 m^2, which results in 202 litres of domestic hot water consumed per day. For the purpose of analysing the water consumption in the building during the day (10 employees work in the building), a few additional assumptions were made, as summarized in Table 5.

Table 5. Additional assumptions for the analysis of daily water consumption in the office

Assumed daily uses of washbasins in bathroom	3 per employee
Daily uses of sink in social room	2 per employee

On the basis of the adopted assumptions, it was calculated that domestic hot water consumption in the office during the day would be 150 litres, which results in a water demand factor of 0.26 dm^3/(m^2*day). Based on the analysis and recalculation of energy performance after the installation of improved water fittings with limited water outflow time, a significant decrease in final energy demand for domestic hot water was observed (Fig. 3).

The demand for final energy in the basic variant was calculated on the basis of the energy performance methodology (Regulation of the Minister of Development and Technology of 28 March 2023 amending the Regulation on the methodology of determining the energy performance of a building or part of a building and energy performance certificates), where the annual demand for usable energy for domestic water heating is divided by the total efficiency of the domestic water heating system (Table 3). The demand for usable energy for the purposes of water heating, according to the regulation, is the product of the unit demand for hot water, the usable area of the building, the density and specific heat of the water, the temperature difference between tap water and the set water temperature, the correction factor related to the type of building and the time of use.

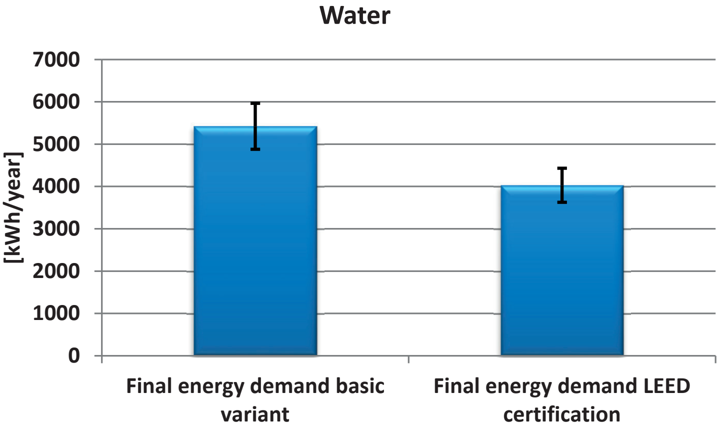

Figure 3. Comparison of final energy demand for baseline and post-LEED certification condition

LEED certification also highlights the scope of indoor lighting, where the intent is to promote occupants' productivity, comfort and well-being by providing high-quality lighting. In terms of interior lighting, two points can be obtained for offices. If the proposed solutions meet the requirements of one certification strategy, one point will be awarded. If three strategies are met, then two points will be awarded. In SI derived units, illuminance is measured in lux (lx) or lumens per square meter (1 [lx] = 1 lm/m^2 = 1 cd*sr/m^2). In capturing the necessary data necessary to further analyse the impact of LEED certification on energy performance, we convert lux to Watts. Watts per square centimetre at 555 nm (W/cm^2) is the derived SI unit of illuminance and luminous flux, expressing luminous flux per area, equal to 6,830,000 lux. The 555 nm wavelength, which is in the mid--point of the visible light spectrum, corresponds to a frequency of 540 terahertz. Converting the aforementioned value of 7000 candelas into Watts, we get the result 0.00102 W/cm^2 = 10.2 W/m^2. Therefore, in order to meet the requirements of one strategy, which is reflected in the energy performance calculations, lighting power of less than 10 W/m^2 should be adopted. In typical branch designs for offices, the illuminance is assumed to be 8 W/m^2 and this value is used for further calculations. In the analysis and recalculation of energy performance, a significant decrease in final energy demand for lighting was observed in relation to the condition of the building without the recommendation of LEED certification (Fig. 4).

A reduction in energy demand of almost 50% for lighting can be observed. The Polish regulation assumes a default value of 15 W/m^2, where the value of 8 [W/m^2] was assumed for the calculations.

The LEED certification requirements also relate to ventilation, where the intention is to promote occupants comfort, well-being and productivity by improving indoor air quality. In terms of LEED certification for ventilation, there are necessary conditions such as ASHRAE Standard.

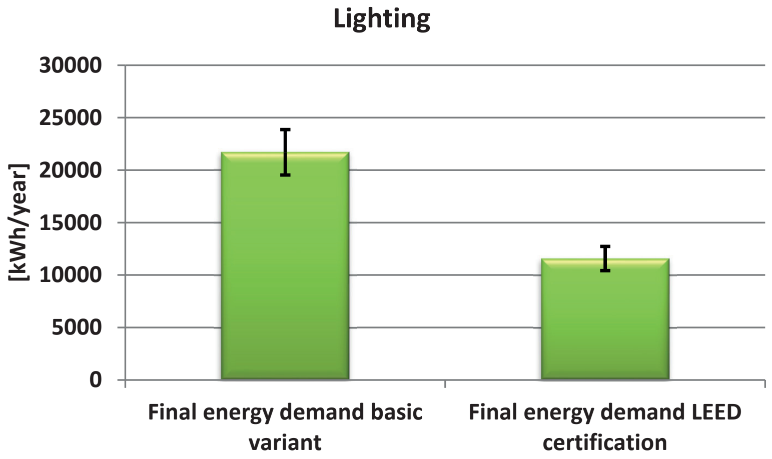

Figure 4. Comparison of final energy demand for the baseline and post-LEED certification condition

If meeting the outdoor airflow rates in ASHRAE Standard is not feasible because of the physical constraints of the existing ventilation system, an engineering assessment of the maximum outdoor air delivery rate of the system must be completed. The maximum possible airflow must be supplied to reach the minimum setpoint in ASHRAE Standard, and not less than 10 cubic feet per minute (5 litres per second) of outdoor air per person, and outdoor air monitors must be provided for all mechanical ventilation systems in the project scope of work for outdoor air intake flows exceeding 1000 cfm (472 l/s). Alternatively, for constant-volume systems comprised by the project scope of work, which do not employ demand-control ventilation, an indicator must be provided capable of confirming that the intake damper is open to the position needed to maintain the design minimum outdoor airflow as determined during the system startup and balancing. As these are necessary conditions, they do not affect the result of the building energy performance. One of the strategies proposed by LEED certification is the use of CO_2 sensors. Their use will reduce the amount of air supplied to the rooms and will have a positive effect on the energy balance of the building. However, without thorough research, it is impossible to estimate the results.

3. Results and discussion

On the basis of the analysis, the following results were received (Table 6). The calculations were again performed in the Audytor OZC program.

Usable energy demand remained practically unchanged, but final energy demand decreased by 31%, while primary energy demand decreased by 36%. For more details, refer to Fig. 5.

Table 6. Summary of energy performance results after considering LEED certification solutions

Energy performance indicator	The building under evaluation	Requirements for the building according to Polish regulations
Indicator of annual demand for usable energy	EU = 12.0 [kWh/m^2/year]	EP < 95 [kWh/m^2/year]
Indicator of annual demand for final energy	EK = 42.1 [kWh/m^2/year]	
Indicator of annual demand for primary energy	EP = 60.4 [kWh/m^2/year]	
Share of renewable installations in annual final energy demand	14.7 %	

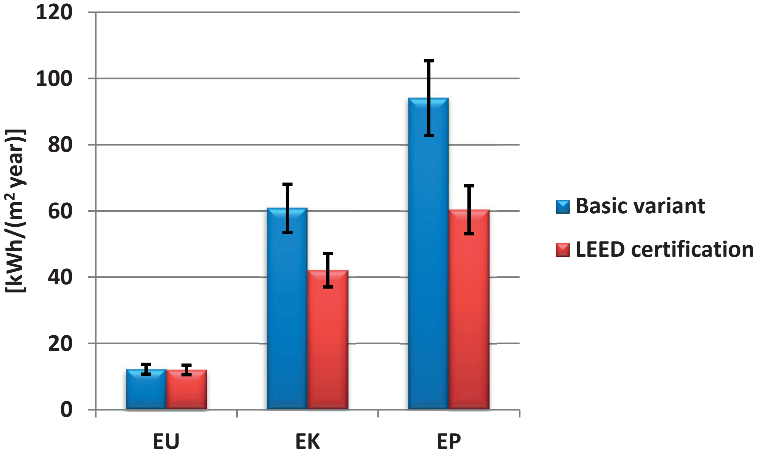

Figure 5. Comparison of energy performance results: basic variant and taking into account LEED certification requirements

Meeting LEED certification requirements reduced water demand by 26% through the use of limited-discharge fixtures and decreased the unit power of luminaires by 46%. Introducing even more energy-efficient lighting (with lower specific wattage), and including, for example, a lighting control system (DALI system) will also enhance the energy performance score and further reduce the energy demand for lighting. Increasing the use of daylight can reduce the operating time of lighting during the day even more. However, this scope was excluded from this analysis, as it was not part of LEED certification. In the case of water installations, the use of appropriate solenoid valves will prevent uncontrolled leakage from the installation, which can also have a positive effect on the balance of water used. The results obtained for the analysed office building confirm that applying the additional requirements of LEED certification in the design process has a significant beneficial impact on energy performance calculations. Certification indirectly forces the use of better solutions aimed at reducing energy demand. During the design work, the imposition of additional requirements causes minimalism to be abandoned in order to meet the technical conditions. Meeting the minimum technical requirements is a suboptimal solution. In the short term, it reduces investment during the construction or new arrangement of the building, yet in the long term it significantly increases the operating costs of the building. The increase in interest in energy audits (Robakiewicz, 2022) confirms that non-energy-efficient solutions were implemented at the design or construction stage of the buildings being audited. From a scientific point of view, the application of additional requirements, as it were, forces designers and contractors to introduce optimal solutions and to search for new ideas with high energy efficiency. Lower investment costs at the construction stage return to the investor in the form of increased operating costs, the cost of conducting an energy audit and the cost of implementing potential recommendations (Longo, Montana, Riva Sanseverino, 2019) such as replacing the heating source of the building with a more environmentally friendly one that uses renewable energy sources (Knapik, 2016). This applies to heating systems as well as water heating (Knapik, 2018a). The LEED certification process imposes additional requirements that are not mandatory, but that force project teams to take significant steps toward sustainability, as well as reducing operating costs in the future. The additional costs associated with implementing LEED requirements can be recouped in the form of increased marketing prominence and increased rental price for the space, due to the higher standard of the facility and lower environmental impact.

4. Conclusions

The article presents the results of an analysis of the impact of LEED certification on the calculation of building energy performance. The purpose of this article was to verify whether LEED certification has an impact on energy performance as calculated according to Polish regulations.

As building certification (e.g. by LEED or BREEAM) becomes the standard, it is important to establish whether this is reflected in energy performance calculations in Poland, where additional requirements are imposed by external regulations such as the American ASHRAE standard, which is the basis for LEED certification.

It was found that the energy performance calculations and the LEED certification requirements have two common points that have a real impact on the calculation result. These are water consumption and lighting.

The calculations of improvements made by adapting the building to LEED requirements showed two main positive impacts on the energy performance result: a 47% power reduction through the use of, among others, energy-saving lighting, and a 26% reduction in water consumption through the use of water fixtures that limit discharge.

For the analysed office building, after implementing the solutions required by LEED, the following results were achieved in relation to the initial state: usable energy demand remained practically unchanged, but final energy demand decreased by 31%, and primary energy demand decreased by 36%. From the scientific point of view, imposing additional requirements through certification eliminates the problem of minimalism that arises from Polish regulations. Higher requirements for buildings force design teams to come up with new solutions (Hui, 2001) – innovations intended to be energy efficient and reduce the demand for utilities such as water and electricity. At the design or construction stage, there are many possibilities for adopting simple recommendations that can be quite obvious, such as using LED lighting instead of fluorescent lamps. At the design stage, in Polish conditions, the investor often opts for low-cost solutions, which results in minimal solutions being selected that meet only the technical requirements. LEED certification imposes additional requirements and enforces the use of pro-ecological solutions. Due to poor decisions at the construction stage, after several years of operation, the investor asks the energy auditors what can be improved in the building to reduce the operating costs of the facility. These are often simple, low-cost solutions, such as changing the lighting schedule, using motion sensors, or turning off heating or air conditioning after working hours.

According to the definition of a passive building of the institute in Darmstadt (Feist, Schlagowski, Kołakowska, 2006) the renewable primary energy demand (EP), which is the total energy to be used for all domestic applications (heating, hot water and domestic electricity), must not exceed 60 kWh per square meter of treated floor area per year for Passive House Classic (Rylewski, 2002). Therefore, the adopted LEED modifications (Basińska, Koczyk, 2009) allowed the analysed building to almost obtain the status of a passive house (EP = 60.4 [kWh/m^2/year]).

The results of the performed analysis allow the presumption that the LEED certification process has a positive impact on energy performance calculations according to Polish regulations. This is due to the significant reduction in the demand for primary energy and the consequent decrease in the operating costs of the building and in its environmental impact. The LEED certification process increases the requirements for buildings and drives designers and contractors to adopt energy-efficient solutions (Chlela, Husaunndee, Inard, Riederer, 2009) and potential investors to obtain an environmentally friendly brand and associated prestige.

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ANALIZA ODDZIAŁYWANIA WYMAGAŃ TECHNICZNYCH CERTYFIKACJI LEED NA OBLICZENIA CHARAKTERYSTYKI ENERGETYCZNEJ BUDYNKU BIUROWEGO

Abstrakt

W artykule przedstawiono analizę wpływu certyfikacji LEED (Leadership in Energy and Environmental Design) na obliczenia charakterystyki energetycznej budynku w oparciu o polskie przepisy dotyczące metodologii wyznaczania charakterystyki energetycznej budynku z uwzględnieniem modernizacji technicznych, które mają wpływ na wynik końcowy analizy. Obliczenia przeprowadzono dla budynku biurowego. Analiza obejmowała zakres, który łączy certyfikację LEED, taki jak wykorzystanie wody i oświetlenie wewnętrzne, oraz charakterystykę energetyczną. Obliczenia wykonano w programie przeznaczonym do obliczeń charakterystyki energetycznej. Zastosowanie energooszczędnych lamp (redukcja zapotrzebowania na energię o 46% w odniesieniu do standardowych lamp) czy też armatury ograniczającej wypływ wody z baterii (redukcja o 26%) potrafi korzystnie wpłynąć na ostateczny wynik charakterystyki energetycznej, gdzie zapotrzebowanie na energię pierwotną po wprowadzeniu modyfikacji zmniejszyło się o 36%. Analizę statyczną wykonano za pomocą programu komercyjnego do sporządzania świadectw charakterystyki energetycznej oraz na podstawie wytycznych formalnych stawianych przez certyfikację LEED.

Słowa kluczowe: oszczędność wody, armatura wodna, energia, elektryczność, oświetlenie, charakterystyka energetyczna, budynek pasywny, budynek energooszczędny