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Analysis of influence of LEED certification process to achieve the passive house standard

Analiza wpływu procesu certyfikacji LEED na uzyskanie standardu budynku pasywnego

Abstract

The article presents an analysis of influence of the LEED certification process to achieve the passive house standard of the building. The purpose of LEED certification is to reduce building energy consumption, water consumption and to reduce building impact on the environment. The passive building is characterized by low energy demand of 15 kWh/(m^2*year). Passive buildings are the result of introducing new ideas in the design process of buildings. This article presents the results of the analysis based on example objects. The results show that the LEED certification significantly influences the achievement of the passive building standard.

Keywords: LEED certification, energy consumption of the building, passive house

Streszczenie

Artykuł przedstawia analizę wpływu procesu certyfikacji LEED na osiągnięcie przez budynek standardu budynku pasywnego. Celem certyfikacji LEED jest zmniejszenie energochłonności obiektu, zużycia wody oraz zmniejszenie jego wpływu na otoczenie. Budynek pasywny charakteryzuje się niskim zapotrzebowaniem na energię wynoszącym 15 kWh/(m^2*rok). Budynki pasywne są wynikiem wprowadzenia nowych idei w procesie projektowania budynków. Artykuł przedstawia wyniki analizy na podstawie przykładowych obiektów. Wyniki pokazują, że certyfikat LEED w znaczny sposób wpływa na uzyskanie standardu budynku pasywnego.

Słowa kluczowe: certyfikat LEED, energochłonność budynku, budynek pasywny

1. Introduction

The passive house standard has been set by Dr. Wolfgang Feist from the Institute of Passive Houses, Passivhaus Institut in Darmstadt. Dr. Feist said that a passive house is a building with a very low energy demand for interior heating like 15 kWh/(m^2*year), in which thermal comfort is ensured by passive heat sources (like residents, electrical devices, solar heat, heat recovered from the ventilation), so that the building does not need a separate active heating system. Heating demand is realized by heat recovery and reheating the air ventilating the building [1].

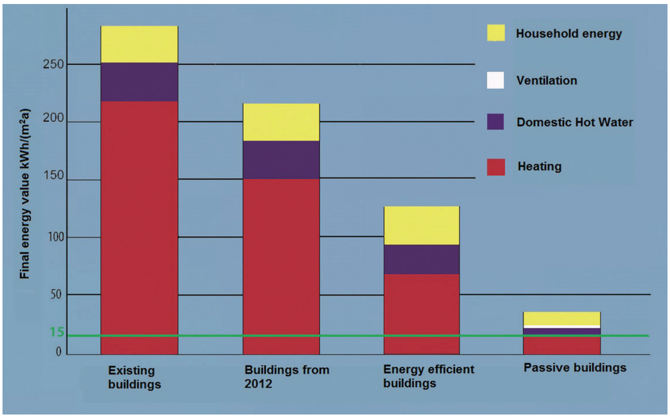

Fig. 1. Energy demands for buildings (source: [2])

By definition passive houses are environmentally friendly. Other buildings can also be environmentally friendly in case of pro-ecological certification, for example, such as LEED certification.

LEED certification – Leadership in Energy and Environmental Design is a rating system devised by the United States Green Building Council (USGBC) to evaluate the environmental performance of a building and encourage market transformation towards sustainable design, which is based on ASHRAE Standard 90.1–2010 [3]. The system is credit-based, allowing projects to earn points for environmentally friendly actions taken during construction and use of a building [4].

Of all the available types of LEED certification, we can specify LEED for Homes. LEED for Homes – is a standard for the design and construction of high performance "green" homes. A green home uses less energy, water, and natural resources; creates less waste; and is healthier and more comfortable for the occupants. The process of the LEED for Homes Rating System, available in the USA, Canada and Sweden is significantly different from the LEED New Constructions rating system. LEED for Homes projects are low rise residential and are required to work with either an American Provider Organization or a Canadian Provider Organization and a Green Rater. Green Raters are individuals that conduct the two mandatory LEED for Homes site inspections: the Thermal Bypass Inspection and the Final Inspection [5, 6].

2. Passive constructions

Passive constructions are characterized by low energy demand for heating purposes. Lower energy demand is a result of better parameters of the building envelopes. For example, heat losses can be reduced through the use of appropriate technology wall insulation, where the heat transfer coefficient U for the exterior wall of the passive building should be less than $0.15\ \mathrm{W/(m^2 \cdot K)}$.

Passive building is also characterized by better standards of thermal comfort. As noted, the measured temperature difference in different room locations are not higher than 0.8 [°C] and the difference in temperature distribution between the head and the feet of the sitting person does not exceed 2 [°C].

An important aspect of thermal comfort is the ventilation. Effective ventilation provides a feeling of comfort in the winter and allows cooling the incoming fresh air during the summer.

As a result of the lower energy demand, passive buildings are characterized by lower consumption of fossil fuels, which reduces the environmental impact.

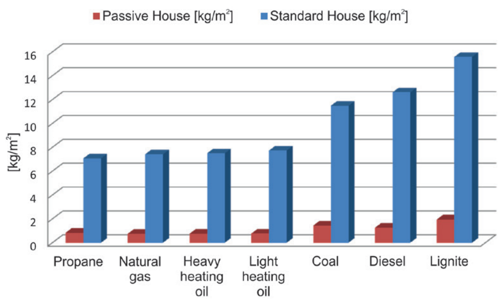

Fig. 2. Comparison of fuel requirements for passive and house, built in 2012 (own study)

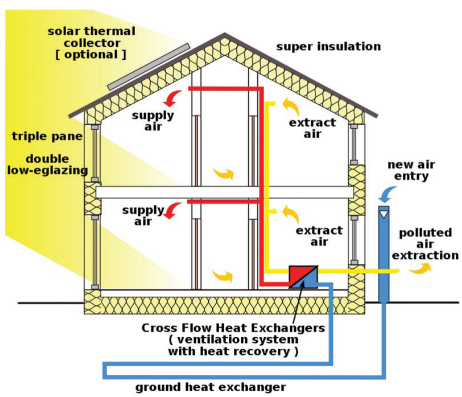

Fig. 3. The use of solar energy (source: [8])

Passive buildings try to use the heat gains from the sun in the maximum way. One of the ways to use heat gains from the sun is heating the ventilation air.

First of all, fresh air is heated up in a ground heat exchanger, afterwards this air is heated up in a heat exchanger in the air handling unit. The air supply from the air handling unit is supplied to the rooms from the southern part of the building, where this air is heated up the air is heated up by the sun's rays passing through the triple-glazed windows. The heated air is transported to rooms on the north side of building and from there extracted through the heat exchanger and it is removed outside [7].

3. Sample of single family house – basic heat losses calculations

For analysis purposes basic calculations of the heat losses and energy demand for a standard single-family building from 2012 have been prepared. All calculations were performed in the program OZC to the heat loss calculations based on PN-EN 12831 [9].

Table 1. Basic results of heat losses and annual heat demand for heating calculations (own study)

Basic heat losses calculations		
Heated area of the building Ah:	174.8	m^2
Design heat load of the building ΦHL:	13 598	W
Indicators and coefficients heat losses:		
Indicator ΦHL related to area φHL, A:	77.8	W/m^2
Indicator ΦHL related to cubature φHL, V:	28.5	W/m^3
The results of calculations of seasonal demand for energy E:		
Weather station:	Kraków	
Annual heat demand for heating Qh:	71	$kWh/(m^2 \cdot year)$

According to the calculations of the annual energy demand for heating, the building is in the scope of energy efficient building, but this is already the upper limit. In order to achieve the passive house standard, the designer should introduce some innovations that will reduce the demand for heat.

It should be remembered that the above calculations relate to the building in the design phase, because the LEED certification process starts with the design phase, when it should make some decisions regarding the further design development. It should also be remembered that the start of the LEED certification process after the design phase does not close the way to receive a certificate, but significantly reduces the possibility of obtaining a higher point result.

In the design phase important decisions are made regarding future investments, improvements or innovations in the scope of LEED certification. Also in this phase the main goal – what kind of certificate will be achieved – is established.

4. LEED for Homes Scoreboard [4]

Scoring in the LEED certification process is divided into several sections. Each section focuses on a different scope, but each of them has the same goal –making the building more environmentally friendly.

The maximum number of points in the LEED certification process is 110, as shown in Table 3. In order to bring the building to the passive house standard, the highest number of points from the section Energy&Atmosphere should be achieved.

In the simple statistics, compared to the other sections Energy & Atmosphere section is the most expensive for investments, which will be significant in the further analysis.

The main task of **Integrative Processes** is to maximize opportunities for cost-effective adoption of integrative green design and construction strategies. This can be achieved easily and cheaply by hiring the appropriate team and organizing the appropriate workshops to integrate green strategies across all aspects of design.

Points in the Location and Transportation section depend on the location of the building and whether the building has access to public transportation or public buildings. A well-located facility will be able to obtain LEED points easily.

Sustainable Sites are focused on design solutions for limitation of the heat island effect, rainwater management or reduction of activity of pests. There are also known inexpensive ways to obtain LEED points in this section.

The **Water Efficiency** section is focused on reducing water consumption. There are many reasonably priced solutions reducing water consumption, such as electromagnetic valves or the appropriate metering of water supply points.

The main task of Materials and Resources are to make building more environmentally friendly by using materials important for sustainable homebuilding because of the extraction, processing, and transportation they require. An important aspect of this section is the construction waste management during the construction to find another use for this waste, for example in another construction. Environmentally friendly materials are more expensive, but still not as expensive as investments related to section Energy&Atmosphere.

Indoor Environmental Quality applies to comfort in the broad sense. Comfort means here an increased ventilation and supply of fresh air, control of air quality, proper management of heating and cooling or garages protection against air pollution with increased ventilation to remove these contaminants.

Innovation and **Regional Priority** relate to the introduction of innovative design solutions and use of materials from local producers.

5. LEED Energy&Atmosphere [4]

The Energy & Atmosphere section applies to all aspects in order to reduce the energy consumption in the building.

Table 2. Energy & Atmosphere Scoreboard (source: [4])

	ENERGY & ATMOSPHERE	POSSIBLE: 38
Prereq	Minimum energy performance	REQUIRED
Prereq	Energy metering	REQUIRED
Prereq	Education of homeowner, tenant, or building manager	REQUIRED
Prereq	Home size	REQUIRED
Credit	Annual energy use	29
Credit	Efficient hot water distribution system	5
Credit	Advanced utility tracking	2
Credit	Active solar-ready design	1
Credit	HVAC Start-up credentialing	1
Credit	Building orientation for passive solar	3
Credit	Air infiltration	2
Credit	Envelope Insulation	2
Credit	Windows	3
Credit	Space heating and cooling equipment	4
Credit	Heating and cooling distribution systems	3
Credit	Efficient domestic hot water equipment	3
Credit	Lighting	2
Credit	High-efficiency appliances	2
Credit	Renewable energy	4

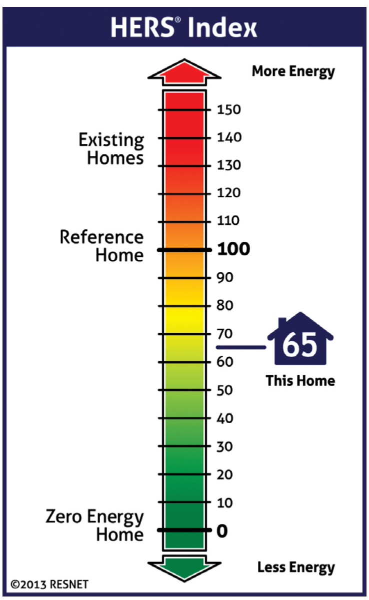

Fig. 4. HERS index (source: [19])

This section has two paths: Performance path and Prescriptive path. The Performance path is less specific and is based on the energy performance of the building. In the case of LEED certification it is a HERS [10, 11] index.

From the other side, the Prescriptive path is more detailed and more accurately describes what LEED points can be awarded for. This method gives specific guidance on how to proceed in the design phase. However, the Performance path is more easy to execute because it does not impose design solutions. It focuses on the final result of energy performance. A crucial indicator is the above mentioned HERS index.

How to understand the HERS index? This can be described with a simple example house whose index is 70. This means that the building is 30% more energy efficient than the reference building RESNET. For the building whose HERS index is 130, it is less energy efficient than the reference building RESNET by 30%. (RESNET – Residental Energy Services Network) [11].

If a sample family house, for which calculations have been made, will be considered as the reference home with the received results of the annual heat demand for heating which amounts 71 kWh/(m^2*year), in order to achieve the passive house standard, design solutions should allow a HERS index of 20to be achieved. Each 1-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the HERS Reference

Home. In order to achieve the passive standard (15 kWh/(m^2 · year)), annual heat demand for heating in the analysed case should be reduced by 80%. Reduction of annual heat demand for heating from 71 to 15 kWh/(m^2 · year), amounts to 80%. The number of LEED points depending on the achieved HERS index is shown in Figure 5. The first points can be obtained for an index value of 70, and the maximum number of points, that is 29, for a HERS index of 0.

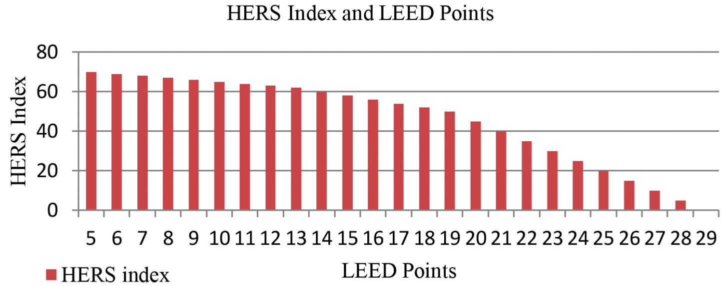

Fig. 5. HERS Index & LEED points (own study)

6. Design solutions

What should be implemented to make a building more energy efficient [12]? First of all, a highly efficient mechanical ventilation with heat recovery and the use of heat gains from the sun should be designed. In order to illustrate the scheme of mechanical ventilation in the passive building, please refer to illustration 1. The design of mechanical ventilation reduces energy demand for heating by 20–30%.

The use of high quality insulation and triple glazed windows reduces the energy demand for heating by10 to 15% counting from the existing state. The main goal of this is to minimize the heat transfer coefficient U for each building envelope. The more this coefficient is reduced the better this effect will be. Figure 6 shows a cross section through a typical external wall of a passive building [7].

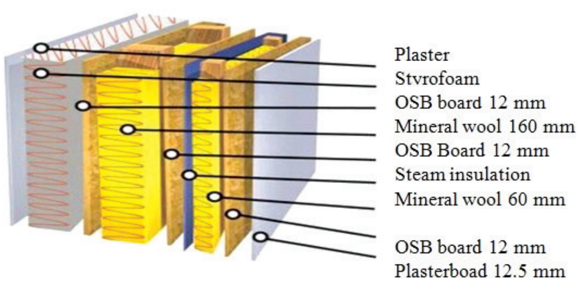

Fig. 6. Typical external wall cross section for passive building (source: [20])

Another important aspect of the improvement of energy performance of the building is to minimize the effect of thermal bridges. A thermal bridge, also called a cold bridge or heat bridge, is an area of an object (frequently a building) which has a significantly higher heat transfer than the surrounding materials resulting in an overall reduction in thermal insulation of the object or building [13]. Thermal bridges occur in three ways, through: materials with higher thermal conductivity than the surrounding materials [14],penetrations of the thermal envelope, and discontinuities or gaps in the insulation material.

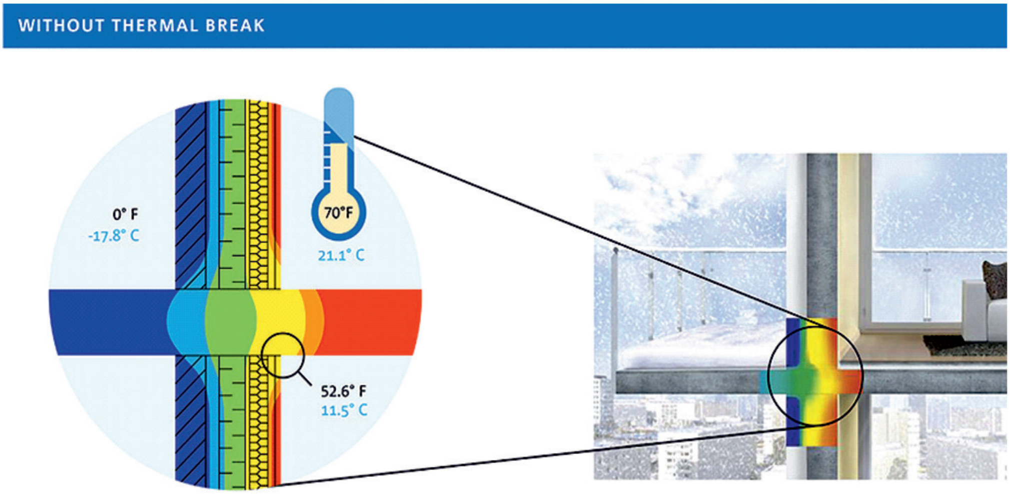

Fig. 7. Influence of thermal bridges at room temperature (source: [15])

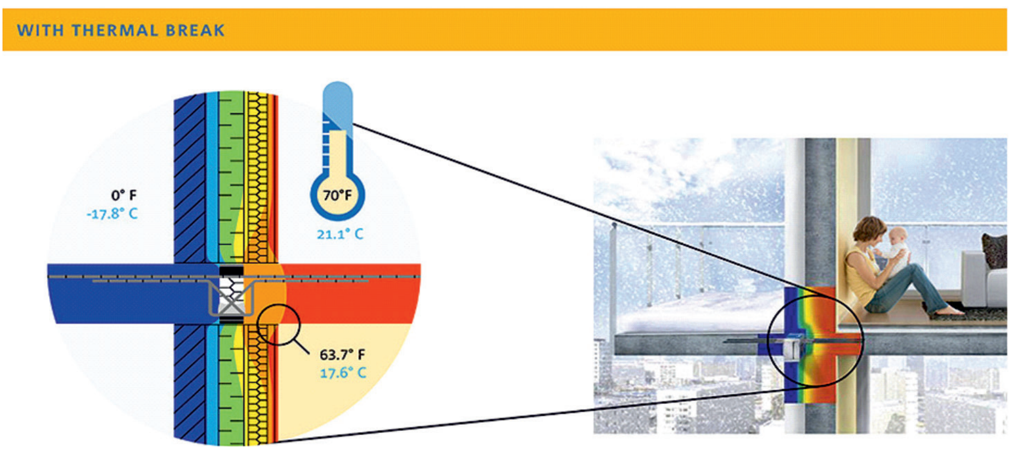

Fig. 8. Influence of thermal bridges at room temperature after use of thermal breaks (source: [15])

Designers in order to limit the influence of thermal bridges should design Thermal breaks. A thermal break is an element of low thermal conductivity placed in an assembly to reduce or prevent the flow of thermal energy between conductive materials [16].

As shown in Figure 1, in passive and energy efficient buildings, can be seen an increased energy demand for domestic hot water in relation to the energy needed for heating. In this case, the designer needs to provide solutions to reduce the energy demand for domestic hot water through the use of renewable energy sources. An example of the use of renewable sources of energy is the cooperation of the small wind turbines and photovoltaic cells. This system is mono energetic, it means that there is only one source of energy, electricity, which is converted into thermal energy by warmer in the domestic hot water tank. In the months in which the energy production exceeds the demand, energy can be partly stored in batteries or used to power fans of mechanical ventilation. For example using water solar collectors do not have the possibility of a longer heat storage in summer and there is an increased risk of overheating the water in the water tank. A system based on electricity is more preferable. It should also be noted that the production of energy from wind turbines and photovoltaic cells is determined by the weather. In the winter months it is windier, but the winter months are characterized by lower solar radiation, thus the wind turbines produces more power compared to the photovoltaic cells. In the summer months it is the opposite. There is no wind, and the solar radiation is the highest throughout the year.

In this case, in the summer months, the production of energy from photovoltaic cells is much higher than the production of energy from wind turbines.

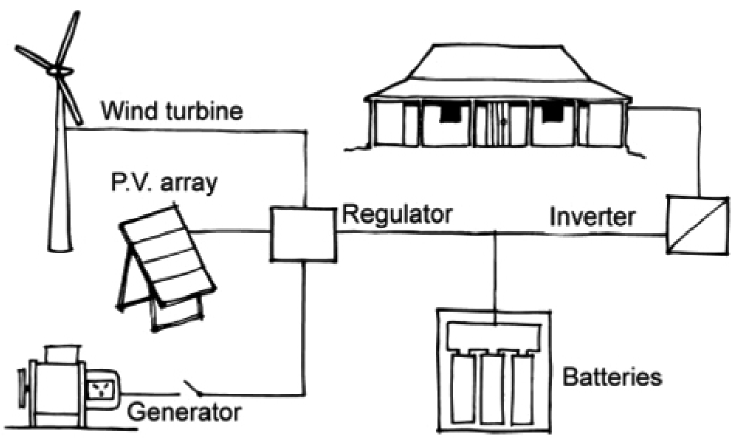

Fig. 9. Example of system generating electricity using a wind turbine and a photovoltaic cell (source: [17])

An important element in energy saving is the BMS –Building Management System, which is the central nervous system of the energy efficient building. The BMS is a fully automatic system, which controls energy consumption in the building. The tasks of the BMS are the optimization of all systems so that energy consumption is adequate for current needs. For example, BMS controls the lighting so that the lighting intensity is adjusted to current external conditions and in rooms using motion sensors. Mechanical ventilation is based on CO_2 sensors, so that if there are no users in the home, the ventilation is running at a minimum level or is completely switched off. Energy from renewable energy sources is stored, used for hot water needs or household appliances, all depending on building needs will be controlled by the BMS, which will optimize the use of energy.

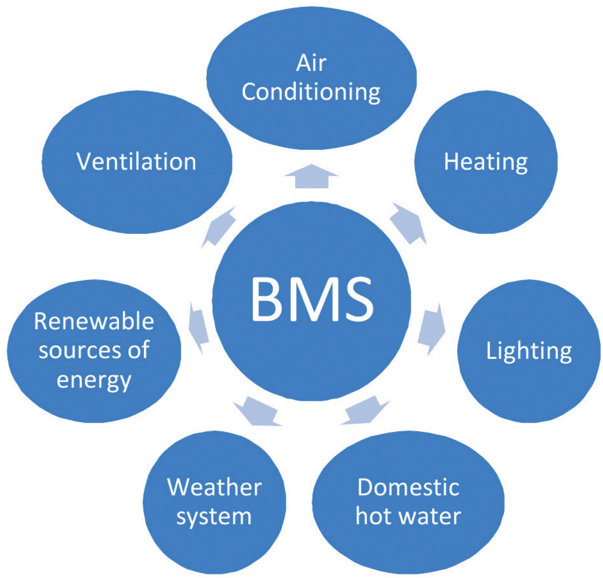

Fig. 10. BMS controls all building systems (own study)

7. LEED implementation costs

All environmentally friendly solutions are associated with higher investment costs, but in the long term investment brings tangible benefits to our environment.

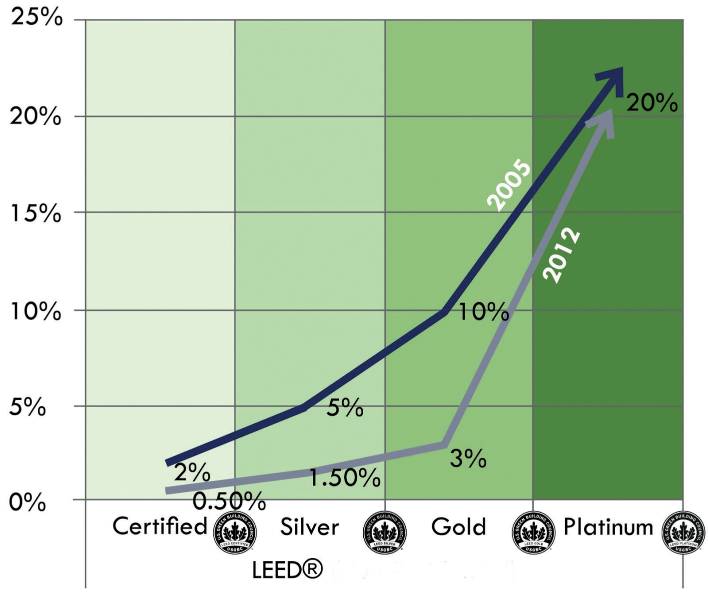

Fig. 11. The increase in investment costs, depending on the LEED certification, in 2005 and 2012 (source: [18])

On the example of LEED certification and analysis of the costs of execution of several projects, a chart was prepared that shows how much on average the basic cost of the project increases without innovation, depending on the introduced certificate.

Figure 10 applies only to small residential buildings (LEED for Homes), this does not relates to larger developments like offices or other commercial buildings, because the costs of LEED implementation in other buildings than homes is relatively higher. Investing about 20% more, we have a chance to receive LEED Platinum, and also increase your chances of achieving the passive house standard. The most expensive section of LEED for Homes is the above-mentioned section Energy & Atmosphere. Building can be of course certified by LEED Platinum without major investment in this section, but then it will significantly limit the ability to achieve the passive house standard.

Analysis of the influence of the Energy & Atmosphere section (and in total LEED certification process) to achieve passive house standard will be presented in the next section.

8. Analysis of influence of LEED certification process in achieving the passive house standard

Table 3. LEED for Homes Scoreboard (source: [4])

Credit		Points
Integrative Process		2
Location and Transportation		15
Sustainable Sites		7
Water Efficiency		12
Energy and Atmosphere		38
Materials and Resources		10
Indoor Environmental Quality		16
Innovation		6
Regional Priority		4
TOTAL	Possible Points:	110
Certified: 40 to 49 points, Silver: 50 to 59 points, Gold: 60 to 79 points, Platinum: 80 to 110		

The point of the baseline analysis was to determine the probability of obtaining a point in the section. The probability of obtaining a point was created on the basis of several projects that have received LEED certification. The probability changes depending on the kind of LEED certificate. The results obtained are summarized in table 4. To clarify – **Prob**. means the probability of obtaining a point (It depends on the design, the investment costs, materials used, the project execution phase and the type of certificate. The probability increases with the type of certificate because it requires more complex design solutions, which will reduce energy consumption).**P.** represents the probable amount of LEED points obtained in each Section and **HERS** is a HERS Index, which shows much energy efficient the building is.

Table 4. Probability of obtaining a LEED points (own study)

Prob.	P.	HERS	Prob.	P.	HERS	Prob.	P.	HERS	Prob.	P.	HERS
1	2	30 % More energy efficient building	1	2	31 % More energy efficient building	1	2	35 % More energy efficient building	1	2	70 % More energy efficient building
0.33	5		0.5	8		0.6	9		0.7	11	
0.33	3		0.55	4		0.6	5		0.7	5	
0.33	4		0.55	7		0.6	8		0.7	9	
0.13	5		0.15	6		0.25	10		0.6	23	
0.5	5		0.55	6		0.6	6		0.75	8	
0.33	6		0.4	7		0.6	10		0.7	12	
1	6		1	6		1	6		1	6	
1	4		1	4		1	4		1	4	
LEED Certified	40		LEED Silver	50		LEED Gold	60		LEED Platinum	80	
40				50			60			80	

As shown in the table, the lowest probability is characterized by section Energy & Atmosphere due to higher investment costs. How do the results impact on achieving the passive building standard?

The results of the probable amount of points obtained from the section Energy & Atmosphere and using the HERS Index allow to determine the probable chance of receiving passive house standard, comparing the amount of obtained LEED points to the maximum number of points from the Performance Path.

The results of probability of obtaining passive house standard, depending on the type of LEED are presented in Figure 11.

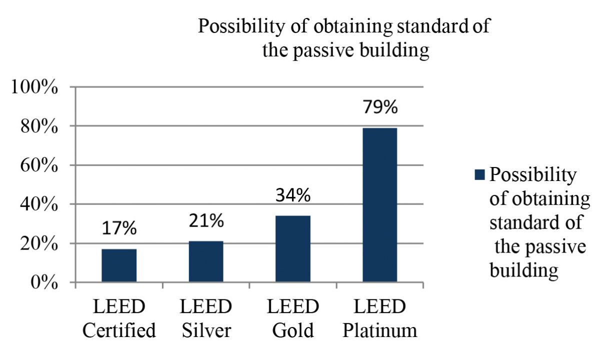

Fig. 12. Probability of obtaining passive house standard (own study)

9. Summary and Conclusions

Passive and low energy buildings are characterized by a lower consumption of fossil fuels, which causes lower emissions to the environment. These buildings are friendlier for the environment by using for example renewable sources of energy and heat gains from the sun. However, the standard of these buildings could not easily be achieved without proper funding. The incentive for this type of investment is LEED certification.

LEED certification significantly helps new constructions, to become more environmentally friendly. LEED certification is responsible for the reduction of energy consumption which is submitted that the building could become the passive building.

The type of certificate which a building will receive depends on the investor and his financial investment, because as demonstrated by the analysis of costs, the basic investment costs could increase by 20%.

Increased investment costs primarily come from the section Energy & Atmosphere, and it is this section that has the largest impact on reducing energy consumption and passivity of the building.

The small demand for points in this section has been confirmed by probability of obtaining LEED points during the certification.

The reasons for increase in investment costs are better insulating properties of partitions, installation of mechanical ventilation, and a complex BMS.

The analysis also showed that the better the kind of certificate, the higher the probability that the building will achieve the passive house standard.

The passive standard of the building depends on many variables, even LEED Platinum certificate does not guarantee passive standard, but it definitely helps to achieve this standard.

The analysis shows that the minimum level to achieve a LEED Platinum, give the probability of obtaining the standard of the passive house at 79%, where the LEED certified probability is 17%.

Even without achieving a passive building standard LEED certification makes the building more environmentally friendly, the more so the higher the certificate type awarded, and it should be also noted that a LEED certificate promotes renewable sources of energy and Building Management Systems, reducing energy consumption.

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