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Concept of Near-Autonomous Passive House

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1. Introduction

The definition of passive house was created in 1988 by Wolfgang Feist (the founder of the Passive House Institute). According to Feist, passive house is a building with extremely low energy requirements for interior heating (15 kWh/m^2 per year), for which thermal comfort can be achieved solely through passive heat sources (e.g. residents, electrical appliances, solar heat, heat recovered from ventilation) and by post-heating or post-cooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions – without the need for active heating system (Feist 1988).

The definition above is just the basis for what a passive house is – it's not a trademark or brand name, but an idea, a construction concept. A building standard that is truly energy efficient, comfortable, affordable and ecological at the same time. Research and development of passive housing is led by The Passive House Institute (ger. *Passivhaus Institut*). The Institute's tasks include setting standards and assigning certificates to passive houses. In order to obtain a certificate, the building must meet a number of criteria for energy consumption. The basis is to obtain the aforementioned energy demand for heating the interior of the building at 15 kWh/m^2 per year, Which corresponds to the consumption of 1.5 l of fuel oil per square meter per year. Demand for primary energy used for all home appliances (electrical appliances, heating, hot water heating) cannot exceed 120 kWh/m^2 per year. Another condition is air tightness n_{50} of the building – by using a constant output pressure, the software calculates the amount of air exchange at a pressure difference in one hour. At a pressure of 50 Pa, the object can reach a maximum of 0.6 air changes per hour. The tightness of passive building must go hand in hand with excellent thermal insulation, in moderate climate, the heat transfer coefficient (U-value) of a building cannot exceed 0.15 W/m^{2}K. The ultimate condition is to achieve thermal comfort both in summer and in winter, throughout the usable area of the building, by achieving a temperature not higher than 25ºC for 90% of the year (*www.passivehouse.com*, 2017.05.07).

2. Methodology

Due to the data validity (being the key aspect), the basis of a cost analysis of necessary installations and additional elements of the project was information included in the websites of the companies dealing with passive and energy-efficient buildings, operating in Poland. Characteristics of installations increasing the autonomy of an exemplary passive house and the criteria for the construction of passive houses were backed up by a thorough analysis of the subject literature. Based on the literature, nine design criteria are presented, seven of which are necessary. Ultimately, on the basis of the existing project, a model passive house was created, supplemented by the latest energy-efficient technologies. In order to estimate the general average solar conditions of Poland, Photovoltaic Geographical Information System was used. The gathered information allowed to assess usability of the concept of near-autonomous passive house.

3. Passive house criteria and use of renewable energy sources

Passive houses effectively use solar energy, internal heat sources and ventilation with heat recovery, so conventional heating systems are no longer necessary even during winter frosts. Ventilation system, the basis of the passive house, unobtrusively ensures constant access to fresh air without drafts. The use of an efficient ventilation system allows to give up the standard, uncontrolled way of building ventilation – opening windows (or involuntary ventilation due to leaks). Passive house criteria are achieved through smart building design and a number of rules (Feist 2006, Wnuk 2007, Piotrowski 2009, Costa Duran 2012, Piotrowski, Dominiak 2012, Wnuk 2012, Steinmüller 2014, Stram 2016).

Building setting in relation to the directions of the world – for optimal passive use of sunlight to warm the interior, the back of the building should be oriented south. By designing large windows on the southern façade of the building, solar thermal energy will become the passive heating system of the building (unlike active systems, which require mechanical circulation of heat). During the day, sunlight is absorbed through uncovered windows by the inner walls, the ceiling and floor, thus accumulating heat in the building. Absorption capacity can be further increased by painting it to dark colour (up to 75%). A greenhouse effect is created – the room is heated by the sunlight retained by the glass.

Simplicity of structure – energy efficient architecture is characterized by the guarantee of thermal comfort without any additional heating systems. Compact construction requires less energy to heat, therefore it is necessary to minimize the length of walls and the number of corners – each of them threatens with the occurrence of thermal bridges.

Avoiding thermal bridges – the thermal bridge is an element of building construction with a higher thermal conductivity than the surroundings. It consists of any structural break through the insulation coating, as well as corners of the building and connections or contacts of materials with different thermal conductivity. Incorrect window placement or door fit can also lead to the formation of thermal bridges, and as a result cause heat loss and reduce the energy balance, by creating the temperature difference inside and outside of the building. In order to limit the occurrence of thermal bridges, it is essential not to break the insulation layer of the building.

Proper layout of the utility and residential rooms – proper setting of rooms is an important part of designing a passive house, the building location requirements and the way the sunlight is used must be reflected in the planning of the rooms. For this reason, living rooms should be located on the south side of the building. Well-isolated northern part of the building (with a small number of window openings) should be distributed with bathroom and utility room. Bedrooms should be located in the east or west of the building.

Air tightness of the building structure – passive building envelopes are characterized by exceptionally high thermal insulation. For this reason, traditional foundations cannot be used in construction. Instead, the building must be placed on a well-isolated plate, and all insulating elements should be made continuously (preferably prepared in one piece). Thermally insulated bearing walls are an important element of the structure, omission in insulation continuity can cause thermal bridges and thus allow heat to escape. Thick and heavy construction components constitute as an additional energy store, and contribute to the accumulation of heat in the building. Quality of exterior windows and doors are an important element of a passive house. It must meet high insulation requirements, it is therefore important to use doors and window frames made of materials with good thermal performance (e.g. pine wood) and reduce heat loss through windows (e.g. by using insulated glazing). All means of achieving adequate thermal insulation are designed to achieve nearly full tightness of the building, which is a key element of passive house construction. Achieving almost full tightness prevents heat loss by air convection and it is necessary for proper operation of heat recovery ventilation.

Heat recovery ventilation – the heart of the passive house. Properly designed ventilation system continuously removes contaminated and „used" air (from kitchen or bathroom), replacing it with fresh air coming from the outside. Standard ventilation system causes energy losses by also removing heated air, therefore the passive house ventilation system is supplemented with a heat recovery system. Heat exchanger (recuperator) absorbs heat from removed, warm air, and then returns it to the fresh air. To improve the performance of the recuperator (the efficiency right now is 75-95%) and to minimize the consumption of electricity, the system can be supplemented by a ground heat exchanger. Through a tube network buried in the ground (usually at a depth of 2 m) the air can be heated up to 20 degrees or cooled down by 10 degrees. This is possible due to the relatively constant temperature at this depth (which is no more than 10°C during the summer and no less than 4°C during the winter). An additional antibacterial layer prevents unpleasant odours. It is possible to use an integrated heating system with a recuperator, a ground heat exchanger and an electric heater powered by solar collectors.

Use of renewable energy sources – necessary factor for the use of passive houses. Sunlight can be used in passive manner (as explained previously) and in active manner – by using photovoltaic cells. Solar energy can be used: to improve the performance of the recuperator (by charging additional immersion heater for warming fresh air), to heat up utility water and to supply power to the lighting system and other electrical equipment in the passive house. The construction of a wind farm is associated with high investment costs and its power definitely exceeds the energy requirements of a single building – therefore, in order to supply the passive house with electricity the so-called small wind turbines (with rated power up to 100 kW) can be used. Low investment costs, simple construction and setup, as well as low wind power requirements, makes it available for individual customers. The use of solar and wind power is not determined by exceptional spatial conditions (only the lack of high structures in the vicinity is required, due to the sunlight blocking and wind-insulation). In case of using hydropower requirements are higher – the building plot must adjacent to the river. Small hydropower plant (with rated power up to 500 kW), as in the case of a small wind power plant, does not require a lot of investment costs, therefore it can be an alternative source of electricity in passive house placed in the immediate vicinity of the river. Regardless of the origin, the energy that drives electrical appliances from renewable sources, is a necessary complement to the environmentally friendly passive house. In an ecologically designed home (beyond the requirements of a passive house) in order to save utility water, home water supply system can be complemented with rainwater tank and household sewage treatment plant. The first system collects rainwater from the gutter network, purifies it with the filtering system and transmits it to the sanitary appliances. And the second system, after cleaning, distributes used water for reuse, e.g. in the garden or in the toilet.

Proper arrangement of the building plot – an aspect helpful but not necessary for passive house building. Due to the different behavior of different types of trees during different seasons, deciduous trees should be located on the southern side of the passive house, while coniferous trees on the north side. Deciduous trees protect the south façade of the house from intense sunlight in the summer and during winter lose leaves and do not block the sunrays, necessary to operate the passive heating system. Conifers, while preserving their form throughout the year, provide good insulation against the wind.

Use of energy efficient household appliances – to meet the energy requirements of the building with renewable energy sources, it's necessary to minimize its consumption as much as possible without limiting the usability. For this purpose, despite higher initial investment costs, passive house should be equipped with energy-efficient electrical appliances, to reduce electricity consumption by up to 60%.

4. Passive housing in the world

Passive House Database is an official register and review of existing passive houses (investments confirmed with Passive House Institute Certificate) and energy efficient buildings with the attributes of passive house. The database is the result of cooperation of Passive House Institute, Passivhaus Service Ltd. (*ger. Passivhaus Dienstleistung GmbH*), German Passive Buildings Information Society (*ger. IG Passivhaus Deutschland*) and International Passive House Association. At the moment of writing this article, Passive House Database contained information on 4 149 buildings built up to year 2017 (of which 1 147 is a certified passive house), however there are certainly more uncertified passive houses worldwide. The database also contained information about 55 energy efficient buildings with the attributes of passive house and 16 certified passive houses built already in 2017. However, due to the time remaining until the end of the year, these investments will not be included in the analysis. In addition, some entries contain no information about the year of investment (this applies to 87 buildings). Data from Passive House Database were used to create Table 1, portraying the development of energy efficient buildings with the attributes of passive house and passive houses in the world (Passive House Database, *www.passivhausprojekte.de*, 2017.09.20).

Based on the data, graphs showing number of energy efficient buildings with the attributes of passive house and certified passive houses were created (Figure 1 and Figure 2).

Figure 1 shows an almost constant upward trend in the number of energy efficient buildings with the attributes of passive house build in the years 1996-2011, with periods of slight decline in 2001, 2006 and 2010, and Figure 2 shows a dramatic increase in the number of passive houses built between 2006 and 2012. Increased interest in passive houses from 2006 may be related to the release of the first version of computer Passive House Planning Package – toolset to help designers create, verify and optimize passive house projects. Passive House Planning Package by Passive House Institute has created the possibility of more accurate analysis of the construction project and opened the way to passive construction for a wider number of designers. A growth in 2006 may also be the result of the launch of annual International Passive House Days, held by International Passive House

Association, in 2004. This initiative once a year brings together experts, owners and residents of passive houses and ecological building enthusiasts. Passive House Association, in cooperation with its national subsidiaries, creates the basis for the development of an energy sustainable future, promoting new ideas and technical solutions for the construction of passive houses. International Passive House Days are held continuously every year, raising awareness of the public in the field of environmentally friendly but affordable construction solutions (*www.passivehouse.com*, 2017.09.14, *www.passivehouse-international.org*, 2017.09.14).

Table 1. Number of energy efficient buildings with the attributes of passive house and passive houses in the world (years 1991-2016)

Year	Number of energy efficient buildings with the attributes of passive house	Number of passive houses
1991	1	1
1992	0	0
1993	0	0
1994	0	0
1995	0	0
1996	1	0
1997	11	0
1998	39	9
1999	75	12
2000	128	32
2001	101	22
2002	140	17
2003	178	27
2004	228	32
2005	229	32
2006	213	19
2007	233	32
2008	262	47
2009	329	58
2010	285	83
2011	340	121
2012	325	145
2013	288	122
2014	269	130
2015	220	115
2016	167	70
Overall	4062	1126

Source: own elaboration, based on Passive House Database

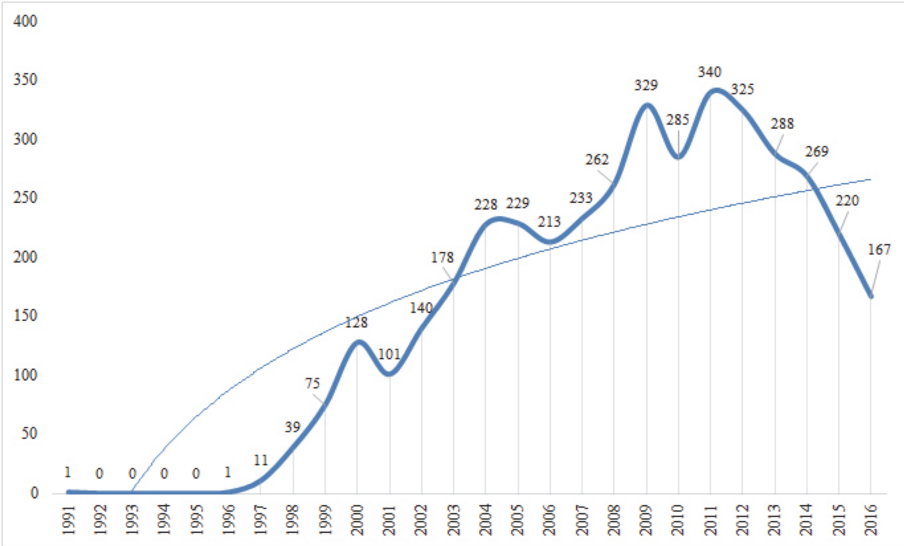

Fig. 1. Number of energy efficient buildings with the attributes of passive house in the world (years 1991-2016)
Source: own elaboration, based on Passive House Database

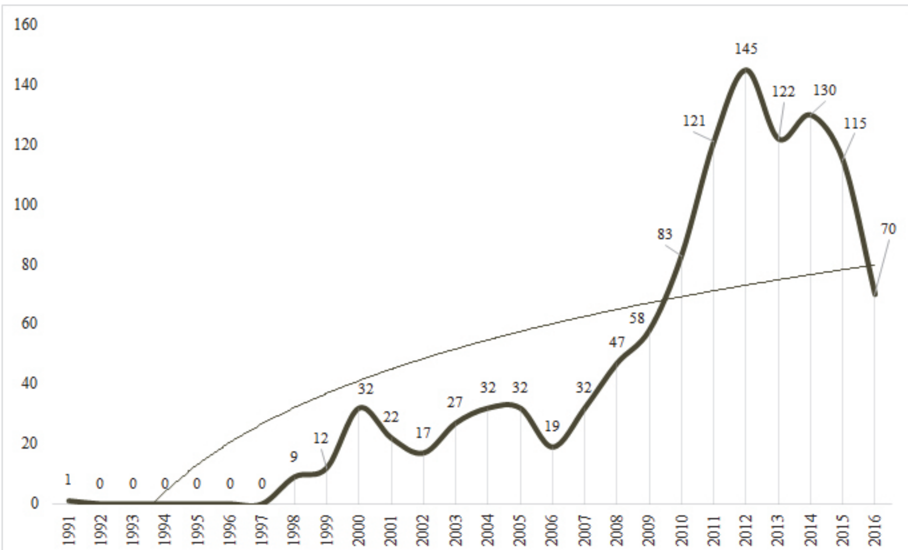

Fig. 2. Number of certified passive houses in the world (years 1991-2016)
Source: own elaboration, based on Passive House Database

The Passive House Database grows slowly, but constantly – the theoretical downward trend may be due to the detail of the certification process, and in the next few years, the upward trend will stabilize. Despite the downward trend in the number of passive houses being built since 2012, this type of construction is still developing, just as people's awareness of the need to save energy in every area of their lives.

5. Exemplary passive house model

Requirements for land development for passive housing differs from requirements for standard construction. By setting the goal for the highest energy autonomy of the object, additional requirements appear – for example, space should be allocated for equipment using renewable energy sources. The exemplary model was based on the 163 P2 project by design agency "Bravo Passive Houses" (pol. Brawo Domy Pasywne) located in Stawiguda, Poland (Bravo Passive Houses, project 163 P2, www.grupabrawo.pl/domy/6/brawo-163-p2, 2017.05.07). The model house is a single-family detached house, with attic and without basement, with a total usable floor area of 178.36 m^2 (of which 94 m^2 on the ground floor and 84.36 m^2 on the first floor) and 8 m high. The horizontal projection (plan view) of the building has a rectangular shape, measuring 12.24 x 9.86 m, with a protruding southern part of the living room, measuring 4.76 x 1.20 m, and the total built-up area equals 126.40 m^2. The model provides the following layout of rooms on the ground floor of the building: anteroom of 16.97 m^2 area, kitchen of 15.24 m^2 area, dining / living room of 35.22 m^2 area, office room of 13.23 m^2 area, bathroom of 2.98 m^2 area and utility room of 10.36 m^2 area. Fan-shaped stairs lead from the anteroom on the first floor, which includes: corridor of 8.45 m^2 area, two bedrooms of 15.12 m^2 area each, main bathroom of 15.13 m^2 area and main bedroom of 30.54 m^2 area. The base project was complemented with a detached garage with a usable area of 42 m^2. Figure 3 is a visualization of a passive house model, with the area of every room.

The foundations of the house consist of a compacted aggregate layer, 100 mm concrete C12/15 plate, PE insulation film, 300 mm thick Styrofoam with thermal conductivity (k-value) of 0,031 W/mK and screed of 80 mm thickness. For the floor, used insulating elements made possible to reach the heat transfer coefficient (U-value) of 0,1 W/m^2K. The exterior walls of the building were made of 12.5 mm thick plasterboard, Insulating mineral wool of 50 mm thickness, vapour barrier film, 12 mm MFP construction board, mineral wool layer of 180 mm thickness and thermal conductivity (k-value) of 0,036 W/mK, wooden poles 45 mm thick, another 12 mm MFP construction board, windproof film, façade wool layer of 250 mm thickness and thermal conductivity (k-value) of 0,036 W/mK, metal grate and "Ceresit" CT 174 silicate-silicone plaster. The total thickness of the outer baffle equals 600 mm, and heat transfer coefficient (U-value) equals 0.073 W/m^{2}K.

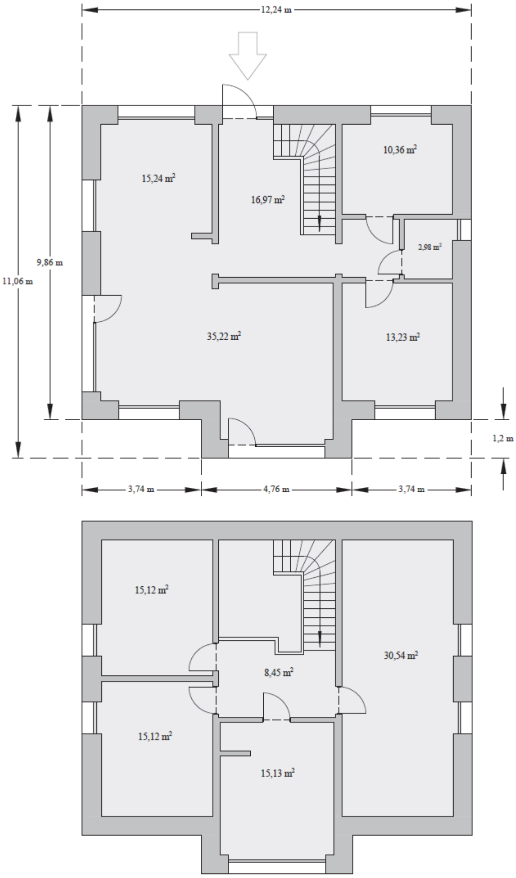

Fig. 3. Passive house model
Source: own elaboration based on project 163 P2

Figure 4 shows the cross section of the external wall of the model passive house, detailing the materials used.

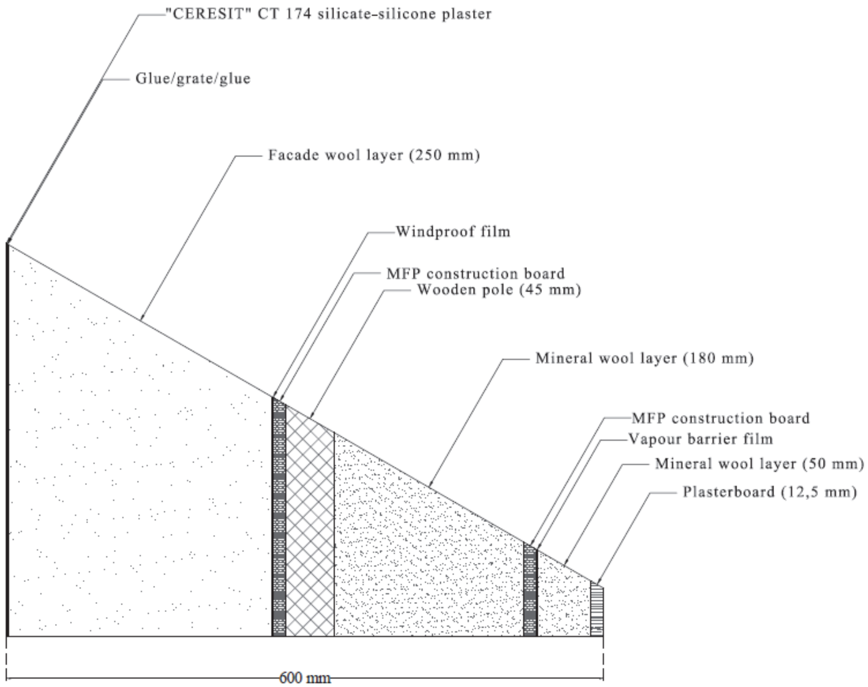

Fig. 4. External wall cross section
Source: own elaboration

The building has a gable roof with a 40º angle, which is covered with tile and made of: 12.5 mm thick plasterboard, vapour barrier film, metal grate, mineral wool layer of 550 mm thickness and thermal conductivity (k-value) of 0,033 W/mK, 60 x 180 mm rafters, 15 mm MFP construction board and waterproof roofing film with a density of 160 g/m^2. Heat transfer coefficient (U-value) of the roof equals 0,059 W/m^{2}K.

The model passive house was equipped with an exterior door from the company “Cal”, from the “Alaska” collection, with a thickness of 90 mm and heat transfer coefficient (U-value) of 0,71 W/m^{2}K; and insulated glazing “IDEAL 8000” from the “Aluplast” company with a thickness of 85 mm and heat transfer coefficient (U-value) of 0,50 W/m^{2}K (*www.drzwi-cal.pl*, 2017.05.07, *www.aluplast.com.pl*, 2017.05.07).

An exemplary passive house model was equipped in the central ventilation unit with heat recovery “Zehnder ComfoAir 550 Luxe VV ERV R”. A compact unit consists of: recuperator with automatic by-pass system (workaround for exhaust air, bypassing the heat exchanger and not heating up the fresh air) and integrated electric preheater. The cross-flow exchanger allows for 95% heat recovery, with the use of DC motors, low power consumption was achieved (13-350 W). Airflow volume stream is in the range of 50-550 m^3/h, at a noise level of 28-35 dB (comfortable for the human ear). The system is controlled with touch panels and its operation is simple and easy. The price of the system is 16 800 PLN (*www.zehnder.pl*, 2017.05.07).

The ComfoAir 550 Luxe system can be directly connected to the ground heat exchanger – in exemplary passive house "GEOSTRONG 1400" from the company "GLOBAL-TECH" was used. Almost 100% efficiency of heat exchange can be achieved, which is unusual in other types of ground heat exchangers. Because of the exceptional endurance of the system (460 t/m^2) the "GEOSTRONG 1400" can be placed at a greater depth than other models. During winter measurements (at air temperature -20°C), air at the outlet of the exchanger never exceeded 0°C. Meanwhile, during the summer measurements (air temperature to 35°C) system reached 17°C. Used humidity reduction system in summer and humidifying the air in winter definitely improves thermal comfort inside the building. Model 1400 placed in the ground at a depth of 5 m, requires an area of 7.10 x 10.80 m. Due to complete synchronization with the "ComfoAir" ventilation system "GEOSTRONG" ground heat exchanger does not require any additional electricity. The cost of purchasing this installation is 19 200 PLN (*www.gruntowe-wymienniki.pl/geostrong*, 2017.05.07).

"ComfoAir" electricity demand can be fully covered by the use of renewable energy sources. Wind energy can be converted into electricity using a small VAWT (Vertical Axis Wind Turbine) wind farm. The use of vertical Darrieus turbines reduces the noise and vibration level, at the expense of reduced capacity of the power plant (estimated at 40%). Additional advantages of vertical wind turbines are less sensitivity to swirling and change of the wind direction. In exemplary passive house model the use of solar home power plant "VAWT-2kW Solta" was established – it allows to generate 1 800-15 600 kWh of electricity per year with a minimum level of momentary power of 353 W (for wind speed at 4 m/s). The cost of this installation is 24 000 PLN. In the case of investment in a more powerful power plant with power of 20 kW (price - 50 000 PLN), 6 600-133 200 kWh of power can be generated per year (www.solta.info.pl, 2017.05.07, Tytko 2011).

Planned "Selfa SV60P-240 PVCWU-10" photovoltaic modules consists of an autonomous system of using solar energy to heat up utility water in the tank, the system does not require connection to the power grid. Comprised of 10 photovoltaic modules, it can reach power of 3 400 watts (depending on the sun exposure). The system completely covers the needs of a family of four in hot water, its cost is 6,800 PLN. The installation of additional modules can support the operation of the hot water heating system or can be used to power home electrical appliances (*www.selfa-pv.com*, 2017.05.07).

In order to make passive house independent of the supply of running water, rainwater harvesting system was used – complete Professional Set with “Diamant 4800” underground tank with “GRAF Minimax” internal filter kit. This set is a comprehensive and professional solution for home and garden. Rainwater harvesting systems reduce the consumption of drinking water by replacing it with rainwater, e.g. for garden watering, washing, toilet flushing or floor cleaning. In total, it saves about 60% of drinking water. Rainwater is collected from the roof through a set of gutters and transported to an underground tank. A 4 800 l tank provides the optimum volume for a family of four. The filter unit (with 95% efficiency) is integrated into the tank and acts in a self-cleaning manner. The cost of the set is 13 000 PLN. Additionally, the rainwater harvesting system can be complemented by the household sewage treatment plant – “SEDYMENT BIO 2000 OB3K” was used in exemplary passive house. It is characterized by approximately 96% reduction of contamination, with a power consumption of only 29 W. Waste generated in the purification process is discharged into the soil, therefore a distance of at least 3 m from the building, 2 m from the boundary of land plot and 30 m from the drinking water intake is required. The household sewage treatment plant has a capacity of 2 300 l and its price is 8 500 PLN (*www.powode.pl*, 2017.05.07., *www.sedyment.com.pl*, 2017.05.07).

The base 163 P2 project was characterized by tightness n_{50} of 0.6/h, primary energy demand of 101 kWh/m^2 per year and energy requirements for interior heating of 14 kWh/m^2 per year. Due to the use of more modern components and materials, the energy performance of the building should be even lower. In total, the cost of installations that helps to achieve partial autonomy and the cost of ventilation to reduce the energy demand for heating the building, amounted to 88 300 PLN (approximately 19 000 £, 21 000 € or 25 000 $). The amount of extra investment costs is high, but it allows you to forget the monthly home use fees. Table 2 shows the total cost list for additional installations (currency rates from *www.bankier.pl*, 2017.08.30).

All controls for additional technical installations will be placed on the ground floor in the utility room. The main element in the utility room will be Central ventilation unit with heat recovery “ComfoAir 550 Luxe” measuring 0.73 x 0.57 m and an area of 0.41 m^2. At a distance of 1 m to the outside wall at the utility room “Diamant” rainwater tank will be located, measuring 1.70 x 1.70 m and an area of 2.89 m^2. Ground heat exchanger “GEOSTRONG 1400” measuring 7.10 x 10.80 m and an area of 76.68 m^2 has sufficient load capacity, therefore a detached garage with an area of 53 m^2 was designed in the place over it. The ground heat exchanger will be located at a maximum distance of 7 m from the building. On the roof of the building, 10 photovoltaic modules will be installed, of 1.69 m^2 area each. In the further part of the building plot, in order to avoid possible energy losses, the location of the VAWT wind farm is planned, measuring 9.00 x 9.00 m and an area of 81 m^2. A small wind farm should be placed at least 20 m from the building. Due to the disposal of waste from "SEDYMENT BIO" sewage treatment plant to the soil, it should be located at a considerable distance from the building. Sewage treatment plant measuring 1.80 x 1.60 m and an area of 2.88 m^2 is planned approximately 35 m from the house.

Table 2. Cost of additional installations

Installation type	Cost [PLN]	Cost [GBP]	Cost [EUR]	Cost [USD]
Central ventilation unit with heat recovery	16 800	3 645,44	3 942,74	4 708,78
Ground heat exchanger	19 200	4 166,21	4 505,98	5 381,47
Small wind turbine	24 000	5 207,77	5 632,48	6 726,83
Photovoltaic modules	6 800	1 475,53	1 595,87	1 905,94
Rainwater harvesting system	13 000	2 820,87	3 050,93	3 643,70
Household sewage treatment plant	8 500	1 844,42	1 994,84	2 382,42
Sum	88 300	19 160,25	20 722,84	24 749,15

Source: own elaboration

According to earlier guidelines, the passive house was located in the north-south line. To maximize the passive use of sunlight, eliminating all possibilities of shading by neighbouring buildings, the side boundaries of the plot have been determined at a distance of 19 m from the exterior walls, and southern border – 49 m. Front of the building is planned 11 m from the border of the plot. Ultimately, the example building plot has dimensions of 70.00 x 50.00 m and area of 3,500 m^2.

6. Achievement of partial energy autonomy of the building

Photovoltaic Geographical Information System (PVGIS) may be the source of information on the levels of sunlight. It is part of the SOLAREC action, contributing to the efficient use of renewable energy in the European Union. The system itself operates at the Institute for Energy and Transport from Joint Research Centre under the authority of the European Commission. To determine country's energy potential interactive map can be used – after selecting the location and entering basic data (e.g. power and angle of installed photovoltaic cells) the system provides, e.g.: estimated losses due to temperature and low irradiance (using local ambient temperature), estimated loss due to angular reflectance effects, other losses (cables, inverter etc.) and combined PV system losses. Additionally, gives information about optimal angle of the photovoltaic panel with the division into months. It is also possible to simulate the operation of a single photovoltaic panel, with full freedom of input data. Using the PVGIS site, the average energy potential in terms of solar energy for Poland was calculated (based on 20 samples). Assuming the technical characteristics of the photovoltaic modules installed in exemplary passive house, as well as the shape of the roof of the building, system estimated losses due to temperature and low irradiance at 12.6%. Amount of produced energy from a photovoltaic system installed (nominal power of 2 500 W) was average 178.66 kWh per month, 59.67 kWh for the winter months and 266.67 kWh for the summer months, and for the whole year it reached 2 322.60 kWh. For maximum power (3 400 W) the average was 242.98 kWh per month, 81.03 kWh for the winter months and 362.67 kWh for the summer months, and for the whole year it reached 3 158.70 kWh. Due to the achieved level of energy requirements for heating the building at 14 kWh/ m^2 per year, for the usable floor area of 178,36 m^2, the annual energy requirement for interior heating would be 2497.04 kWh. Additionally installed photovoltaic module system for the nominal power level will meet the energy needs for interior heating at 93%, while at maximum power – at 126%. (Photovoltaic GIS – Interactive Maps, *re.jrc.ec.europa. eu/pvgis*, 2017.05.07; Suri, Huld, Cebecauer, Dunlop 2008).

7. Summary

Passive housing, an idea born in the minds of German engineers, brought energy efficiency to a higher level, by providing thermal comfort with minimum energy consumption, precisely sealing the building and protecting it with a thick layer of insulation while not suffocating the inhabitants. The use of renewable energy sources combined with the idea of passive houses with assumption to reach the highest level of independence from traditional technical infrastructure networks, seems to be the only effective and (most importantly) long-term solution to the existing energy crisis.

The purpose of the article was verification of the possibilities of creating such a near-autonomous passive house. After a thorough analysis of installations available on the Polish market and by calculating additional costs, comforting vision of such project was presented, along with the estimation of meeting the primary needs of the residents.

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Abstract

The global energy crisis has created the need for implementing energy-efficient solutions in the case of spatial planning and architecture. Raised energy prices encourage energy saving and implementation of new technologies (eco-friendly technologies). These aspirations are met by introducing appropriate technological solutions, to ensure the highest self-sufficiency of buildings, and by using renewable energy sources to cover the remaining energy needs. The concept of passive housing has become the answer to all these needs – it features thermal comfort with minimum energy requirements. Additional implementation with the use of renewable energy sources was proposed in this article, in order to achieve partial independence from traditional technical infrastructure.

Keywords:
passive house, energy-efficient building, eco-friendly technologies, spatial planning

Koncepcja niemal autonomicznego domu pasywnego

Streszczenie

Światowy kryzys energetyczny zrodził potrzebę wprowadzania energooszczędnych rozwiązań również w przypadku planowania przestrzennego i architektury. Rosnące ceny energii zmuszają nas do oszczędzania oraz wdrażania nowych technologii (technologii przyjaznych środowisku). Dążenia te spełniane są poprzez wprowadzanie odpowiednich rozwiązań technologicznych, służących zapewnieniu jak największej samowystarczalności energetycznej budynków oraz poprzez wykorzystanie odnawialnych źródeł energii do pokrywania pozostałego zapotrzebowania energetycznego. Odpowiedzią na te potrzeby stała się koncepcja budownictwa pasywnego – charakteryzującego się komfortem cieplnym przy minimalnym zapotrzebowaniu na energię. W artykule zaproponowano dodatkowe uzupełnienie o użycie odnawialnych źródeł energii, w celu osiągnięcia częściowej niezależności od tradycyjnych sieci infrastruktury technicznej.

Słowa kluczowe:
dom pasywny, budownictwo energooszczędne, technologie przyjazne środowisku, planowanie przestrzenne