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ARCHITECTURAL COMPARISON OF CHOSEN PASSIVE BUILDING STANDARDS

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Abstract
The building sector consumes one-third of global final energy and emits nearly 40% of total CO_2 emission. To decrease those numbers, it is necessary to design sustainable buildings, which have low heat and cooling demand. The Passive House standard was designed to meet these requirements however, some imperfections were observed. Therefore, a new approach the "be 2226" standard was put forward. This paper presents major architectural differences of those concepts and discusses their advantages and disadvantages. The main purpose is to develop guidelines how to design energy-efficient passive architecture. The Author used own mixed research method that included literature studies, analyses of technical documentation, in situ examinations, own measurements, and infrared tests. The comparison of two passive standards established strong, proven solutions, as well as incompatibilities and flows of each standard. The research main findings are that all buildings should be built in the passive manner and it would be beneficial to implement mixed standard. The main conclusion is that architectural creation has a great impact on passive solutions in buildings.

Keywords: **Passive House buildings; Be 2226; Utility buildings; Design; Sustainable buildings; Architectural expression.**

1. INTRODUCTION

The world's CO_2 emission can have devastating impact on the future of Earth, therefore European Commission presented plans to reduce it [1]. One third of global final energy is consumed by the building sector that also emits 40% of total CO_2. The peak of the CO_2 emission (10GCO_2) was in 2019 because of the extreme weather conditions which increased the annual demand for commercial heating and cooling [2, 3, 4, 5, 6, 7, 8]. The need to adapt to climate variations with extreme hot summers has led to the modifications of passive buildings. The problem of overheating and its negative effects on human health [9] is observed and widely discussed in different regions of the world, even where the climate is [10] temperate, e.g., UK [11], Scotland [12], New Zealand [13].

To reduce the CO_2 emission architects should design sustainable buildings [14, 15] that not only have low heat and cooling demand but also limit overheating in the summer. To meet these requirements some standards were developed. The first concept was the Passive House standard: a solution to build cheaply, easily and energy-efficiently. The research done in objects constructed in this standard showed imperfections such as overheating in summers and inadequate air quality from mechanical ventilation [16, 17, 18, 19]. The sick building syndrome has been widely discussed [20, 21, 22, 23, 24, 25]. Therefore, a new solution – the "be 2226" standard – was developed. This concept invented by professor Dietmar Eberle also bases on an energy efficient, sustainable construction method and the elimination of complicated active methods and conventional heating. The "be 2226" building designed by Baumschlager Eberle

Architekten office has a very low demand for heating and cooling energy [26]. This article presents an architectural comparison of both concepts and discusses the advantages and disadvantages of selected buildings constructed in both standards. The purpose of this research is to define architectural most desirable passive characteristics that are favorable to create healthy, energy-efficient passive object. It is significant because it will lead to CO_2 reduction. The conclusion is that by correct architectural means, the building lifespan can be prolongated. The long-living building has to be energy-efficient to fulfill three pillars of sustainability (economic, social and environmental) [27]. The good architectural design can create passive building, that will need less technology over years to operate effectively even with new function inside.

2. DEFINITIONS OF STANDARDS

2.1. Passive house standard: the theory

Passive House is an energy-efficient building with extremely low heat and cooling demand of $E_{Uco+w} \leq 15$ kWh/m^{2}a or thermal load 10 W/m^2 [28, 29]. The air that ventilates the building is the only source of heating. Airtightness of the building should be below 0.6h^{-1} [30]. The building does not need active heating systems based on the combustion of non-renewable fuels and the primary energy demand for heating and cooling should be below or equal to 60 kWh/m^{2}a [31]. The excessive temperature (above 25^{o}C) occurrence should be lower or equal of 10% hours per year [32]. In Passive House buildings in the summer users' comfort is obtained without air conditioning. In the winter the heat is sourced from solar energy gains [33, 34], generated by users or inhabitants, electrical equipment and recovered from ventilation. To be certified, the Passive House has to meet above mentioned criteria. Possible components are: building envelope thermal insulation; location of the building in relation to the north; solar heat gains; building airtightness and mechanical ventilation; passive windows; thermal bridges elimination [35].

2.2. "be 2226" STANDARD: THE THEORY

The goal of the "be 2226" standard concept is to prove that a building will not need any conventional heating, cooling or air-conditioning. The wall surface temperature, depending on the season, is between 22 and 26^{o}C. In this building the temperature and air quality are controlled by CO_2 sensors that open and close window vertical vents [36, 37]. The "be 2226" buildings should respond more to the daily changes in occupants' behaviour than to the changing weather conditions. In "be 2226" standard the goal is to reduce the heat flow [38]. In the insulation of the building the U factor is essential, but it is limited to heat flow resistance and omits the storage capacity of the component that in "be 2226" standard is very important. The heat transfer rate decreases in relation to the increased heat capacity of the building element [39]. The building heating sources are: solar heat, body heat, electrical devices and artificial lightning heat. In the winter, it is preferable to store the heat inside the building rather than remove it by ventilation. To create a backup of the heat in the building on very cold winter days, artificial lights are turned on early in the morning.

2.3 Abbreviations and designations used in the paper

Table 1.
The examined buildings are designated by letters. Own study

letter	building	letter	building
A	"be 2226"	L	Centre for Sustainable Development and Energy in Miękinia
B	Sports hall in Waganowice	M	Crisis Management Centre in Aleksandrów Łódzki
C	Sports hall in Słomniki	N	Rehabilitation centre in Szczerców
D	Sports hall in Brwinów	O	Health care and nursing centre in Kraków
E	Sports hall by secondary school in Kraków	P	Health care centre in Słomniki
F	Sports hall of the University of Agriculture in Kraków	R	Primary school in Budzów
G	Sports hall in Bełdów	S	Mini waterpark in Siemiatycze
H	Kindergarten in Rogów	T	Hotel in Bardo
I	Kindergarten in Bełdów	U	Zakole Club Nowa Huta, Kraków
J	Kindergarten in Słomniki	W	Counselling Centre production hall in Kokotów
K	Counselling Centre office building Kokotów		

3. MATERIALS AND METHODS

The Author examined in situ 20 Passive House Standard public utility buildings constructed between 2011 and 2020. Fig. 1 shows diagram of amount of examined buildings and Fig. 2. shows its location.

The selected parameters of building comparison

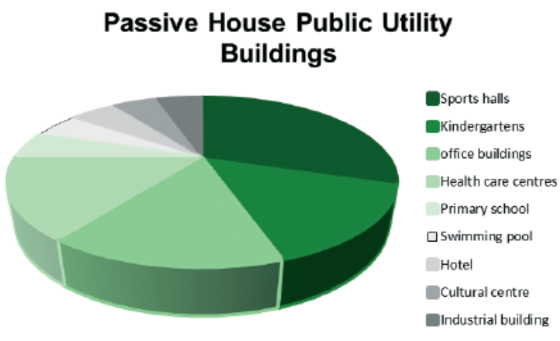


Figure 1.
Diagram of amount of examined Passive House public utility buildings in relation to their function. Own study

Figure 2.
Location of investigated Passive House buildings and "be 2226" building. Own study

were based on technical documentation and the Author's own measurements and observations. The declinations from the north and proportions of total glazing to wall area on façades were calculated from the documentations, satellite maps and the Author's own measurements. The assumption was that the entire façade area is 100% [40]. The investigated buildings were tested with a FLIR i7 infrared camera when the minimum temperature difference between the inside and outside of the building was 10°C.

For "be 2226" buildings the Author used literature review and documentation analysis. The in situ data were unavailable due to the COVID-19 restrictions.

For the researched buildings the Author used the following methods and techniques showed in Table 2. [41]:

Table 2.
Methods and techniques. Own study based on Niezabitowska E. D., (2014). Metody i techniki badawcze w architekturze (Research methods and techniques in architecture), Wydawnictwo Politechniki Śląskiej, Gliwice

method	technique
experimental research	measuring, observing, parametring
quantitative	measuring, elements counting, non-parametric data analysing
case studies	investigated object viewing, documents analysing, describing, explaining, interpreting, comparative analysing, measuring, observing, interviewing, polling

To identify the knowledge gap, the Author reviewed the literature on passive architecture of 62 items. Author is aware of wider range of examples of Passive House buildings, but the research is limited to Polish public utility architecture. The chosen "be 2226" example is the first existing building described and examined.

The combination of various, well-known methods, led to creating Author's own one. The chosen methods allowed the Author to systemize examinations and define aspects of passive architecture that can reduce environmental costs. In this research Author used six steps of research presented in Fig. 3.

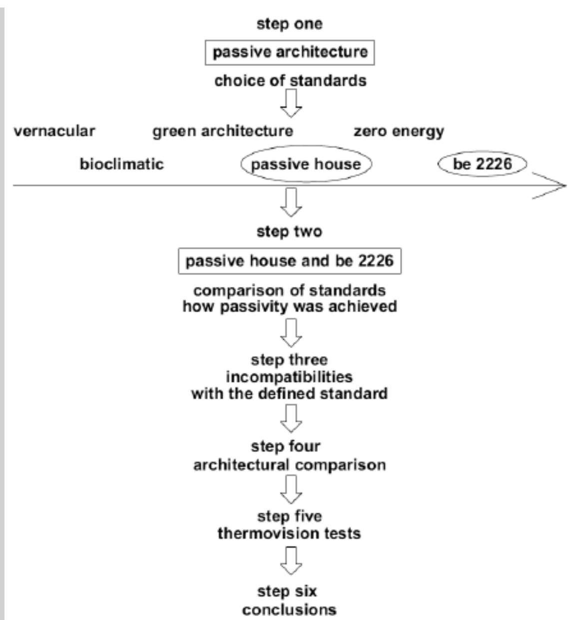


Figure 3.
Diagram of taken research steps. Own study

Table 3.
Author's own method. Own study.

Author's own method	
Subject	Standards of passive buildings
Objective	Optimization of passive standards
Scope of research problem	The analytical research, interpretation of architectural factors, diagnosis of the standards problems
Measures taken	Logical comparative analysis, deduction, literature research, synthesis, drawing conclusions
Techniques applied	Observation, measurement, parametric techniques, counting of elements, analysis of non-parametric data, visual inspection of the investigated object, analysis of documents, description, clarification, interpretation, benchmarking, observation

4. RESULTS AND DISCUSSION

4.1. Comparison of standards

Both the Passive House and the "be 2226" standards use very simple construction methods and eliminate complicated active ones, which makes them energy efficient. Table 4. shows main assumptions of both standards and shows their principal differences.

To compare standards the Author chose six architectural features showed in Fig. 4 enabling to achieve passivity of the buildings such as: main plan and function arrangement, daylight delivery through the windows, proportion of the buildings shape, primary function declination from the north, shape of façades and compactness of the buildings.

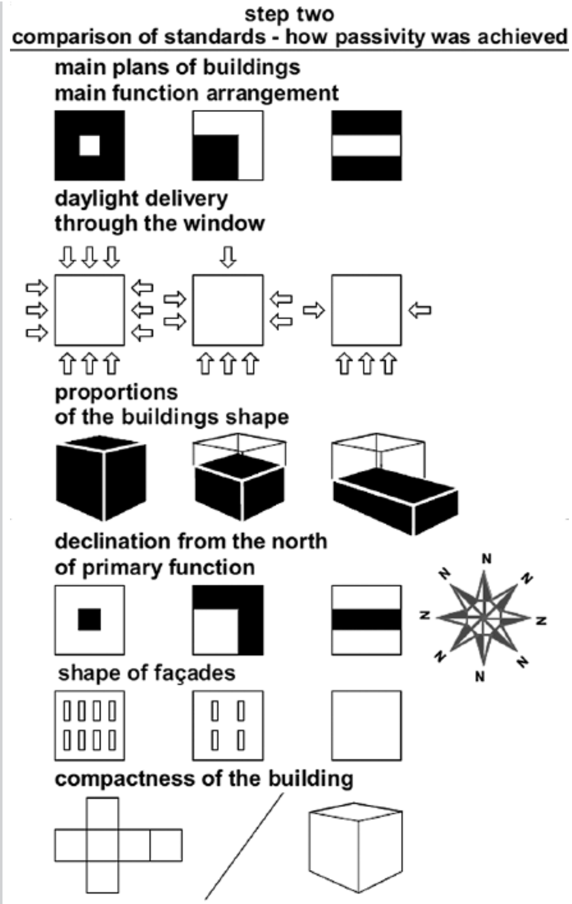


Figure 4.
Architectural features enabling to achieve passivity of the buildings. Own study

Table 4.
Comparison of passive standards – principal differences and similarities. Own study

	Passive House	"be 2226"
Conventional heating and cooling	elimination	elimination
High quality of temperature and air quality	delivered by mechanical ventilation	delivered directly via opened vents controlled by CO_2 sensors
Well-insulated outer envelope material	polystyrene or mineral wool	constructed with two layers of a high insulating brick used as a storage mass
Wall thermal insulation coefficient U	between 0.08 and 0.19 W/(m^{2}K) A significant problem with overheating in summer because the used thermal insulation materials do not accumulate the heat inside	0.161 W/(m^{2}K) (calculated by the Author with the assumption that the insulating bricks coefficient for the plastered wall is λ =0.126 according to the producer's specifications)
Heat	provided exclusively by mechanical ventilation with recuperation	stable indoor temperature (despite the weather change from extreme cold to extreme warm) secured by thermal storage capacity of "be 2226" building envelope walls

4.1.1. Functional arrangement of the buildings

THE "BE 2226"

The "be 2226" is a prototype building designed by baumschlager eberle architekten. It was built between 2010 and 2013. It is located in Lustenau in the state of Vorarlberg in Austria and 2226 is the house number.

The "be 2226" floor plan is open. The primary function of the building is located around the core of the building that is created by the communication and auxiliary spaces. The building consists of six floors.

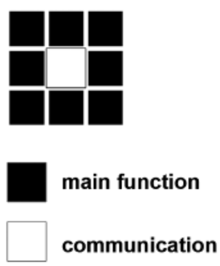


Figure 5.
The "be 2226" building plan diagram (Commercial building, Lustenau, Austria). Own study

PASSIVE HOUSE BUILDINGS

The functional arrangement of passive buildings differs in terms of their main function. Author identified 10 different arrangements of main function and communication and assigned them to 20 examined buildings.

4.1.2. Daylight delivred through the windows

In "be 2226" building daylight is delivered equally inside the building from all four sides via evenly distributed windows. In Passive House buildings there are different schemes of daylight distribution varying according to the function and lighting needs of the rooms.

In sports halls daylight is mainly delivered through the south (south-west) glazing on the elongated façade. The cloakrooms in 67% buildings have daylight through the openable windows.

Daylight to the newly constructed office buildings is delivered from the south and the east. Daylight from other directions is limited to necessary room illumination in accordance with the regulations. The office

Table 5.
The diagrams show the main plans of the buildings divided according to their function arrangement. Own study

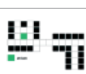
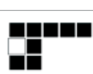
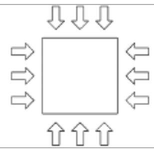
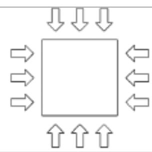
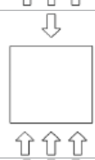
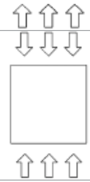
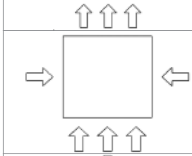
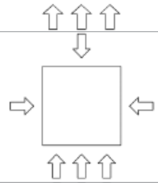
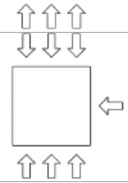
Building plan diagram 	Description
	Crossed communication dividing auxiliary functions and main function sticked to them. This arrangement appears in five buildings: B, C, D, E, F.
	L-shaped function plan with straight line of communication leading to main function. This arrangement appears in one building: G.
	Simple plan with communication dividing building to two parts of main and auxiliary functions. This arrangement appears in five buildings: H, I, J, R, T.
	The communication in shape of letter T, divides functions of building to main bigger function and two auxiliary functions. This arrangement appears in three buildings: K, M, U.
	Communication dividing object to compact main function on one side and auxiliary functions divided by additional corridors. This arrangement appears in one building: L.
	The U-shaped communication with main function on one side. This arrangement appears in one building: N.
	Building consists of two - one with atrium in the middle and one L-shaped building. This arrangement appears in one building: O.
	T-shaped communication dividing main function in three parts. This arrangement appears in one building: P.
	The communication is located in one corner of the building leaving an open space for swimming hall. This arrangement appears in one building: S.
	The communication is minimalized to the one part of office building. This arrangement appears in one building: W.

Table 6.
The diagrams show daylight access to the buildings divided according to the evenness of the access. Own study

Diagram of light access	Description
"be 2226"	
	Daylight is delivered equally inside the building from all four sides via evenly distributed windows.
Passive House	
	Daylight is delivered equally inside the building from all four sides via evenly distributed windows. This arrangement appears in two buildings: O, T.
	Daylight is mainly delivered through the south (with slight deviations) glazing on the elongated façade. This arrangement appears in one building: B.
	Daylight is mainly delivered through the south (with slight deviations) glazing on the elongated façades. This arrangement appears in four buildings: C, D, E, F.
	Daylight is mainly delivered through the south from one main elongated façade. Daylight from other directions is limited to the necessary room illumination in accordance with the regulations. This arrangement appears in three buildings: G, J, K.
	Daylight is mainly delivered through the south glazing on the elongated façade, from other directions it is limited to the necessary room illumination in accordance with the regulations. This arrangement appears in seven buildings: H, I, L, M, N, P, S.
	Daylight is mainly delivered through the east and the west façades. There are no windows on the north façade. The short south façade is also perforated with windows. This arrangement appears in three buildings: R, U, W.

building L is a renovated historical object. Daylight is mainly delivered from the south-east. On the first floor there are guests' rooms and windows are all around the building.

In mini waterpark daylight is delivered to the main function (the swimming hall) mainly from the south, only few windows are on the east and the west façades. The northern rooms (which are used for educational purposes) have only necessary fire proof windows.

In building U daylight is mainly delivered through the south glazing protected from the sun with an outdoor shelter with an openwork roof. The west façade has no glazing. On the north there are only few windows in accordance with the regulations.

4.1.3. Proportions of the buildings

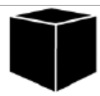
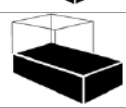
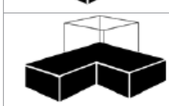
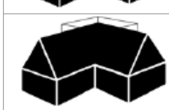
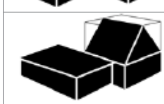
The proportion of the "be 2226" building is the perfect cube 24m in length, width and height.

The Passive House buildings differ in shapes and proportions.

The mini waterpark S, including the basement, is nearly the same height, length and width. The building was squeezed in between existing objects and has some undercuts to accommodate and meet fire regulations.

The proportions of all sports halls are elongated cuboids irrespective of the roof type. The shape of the sport hall B corresponds to the shape of the adjacent buildings. It is designed to form the impression

Table 7.
The diagrams show main shape allocation of the investigated buildings. Own study

Diagram of light access	Description
"be 2226"	
	Cube
Passive House	
	Cube. This arrangement appears in one building: S.
	Elongated cuboid. This arrangement appears in eight buildings: C, D, E, F, H, J, P, R.
	Buildings with pitched roof. This arrangement appears in six buildings: B, I, K, L, M, N.
	Elongated cuboids placed in L-shape. This arrangement appears in three buildings: G, O, W.
	Elongated cuboids placed in L-shape with pitched roof. This arrangement appears in one building: T.
	Combination of elongated cuboid and pitched roof cuboid. This arrangement appears in one building: U.

of a big barn pierced through by a smaller one. The sports hall G has a shorter L-shape building for auxiliary spaces attached to a cuboid hall.

The kindergartens H and J have poor proportions. The buildings are too low with very long south and north façades. The kindergarten I has a complex shape. The proportion of the building is retained by stepwise arrangement of three elements that are attached to one long cubature. The construction resembles a combination of small detached houses, blending in with the village architecture.

The office building K has the proportions of a detached house. It was designed as a residential building and transformed into an office building. The building L is a renovated and enlarged historical building. The proportions are retained due to the pitched roof. The building M is a squat mass with a slightly inclined sloping roof. The proportions would be better if the building was cubic or had a higher pitched roof.

The proportions of the rehabilitation centre N relate to the shape of the surrounding farm buildings. The proportions of the roof to its elongated rectangular plan are correct and eye – friendly. The proportions of the health centre O are correct due to the division of the building into a two-storey block connected by a breezeway to the three-storey L-shaped block of the other wards. The bend of the building gives the impression of a shorter object and a friendlier scale for the user. The health centre P has an elongated cuboid shape. Its height is limited, but the shorter first floor improves the perception of building.

The building of primary school R is an elongated cuboid with offsets from the south and the north. The height of the building is smaller than its length.

The L-shape of the hotel T consists of two elongated cuboids with pitched roofs.

The U club consist of are two intermingling elongated cuboids; one roof flat and the other roof pitched. The proportions of the flat-roofed building are retained by contrasting it with the pitched roof on the other building.

The production hall W is L-shape building with the elongated rectangular proportions of production and storage halls. To minimise the length of the building, a square, half cubic office building was added (the height of the cube is not equal to the length of its side).

4.1.4. Primary function and declination from the north

The “be 2226” building has the primary function positioned evenly in all geographical directions.

In the sports hall B the main function is located as if added at the end of the building. The deviation from north is 1°. The sports halls C and E have northern location with deviation of 14° and 9°. The main function have windows located above three meters from south and north. The auxiliary spaces are in the south. They are halved by communication to cloakrooms and storage rooms under the grandstands. The sports hall D mirrors the same layout east-west and the declination from north is 4°. The sports hall F is declined from the north by 28°. In sports hall G the main function is located south-west with deviation of 39°. L-shape background facilities are added to the main function. The communication is located from the north and the cloakrooms are only on one side.

In the kindergartens H and J (deviation from north 23° and 14°) the main function is located in the south-west. The buildings are divided by communication into two parts – the primary function and the auxiliary space. In the kindergarten J there is one open space used as an exercise room or a stage for plays, placed on the north side of the building. Despite its complicated shape, the kindergarten I has the distribution of functions analogous to the other kindergartens and deviation from north of 39°.

In the office buildings K and L (deviation from north 3° and 48°) communication divides the building south-west. In the office building M the division is into the east and the west and the deviation from north is 20°. In the southern part there are offices and common spaces and the north side of the buildings is for auxiliary spaces.

In the single-storey rehabilitation centre N (deviation from north 12°) the functions are divided into the auxiliary facilities that are placed in the north and the east and the main function in the west and south. The health care centres O and P (deviation from north 20° and 14°) have the function divided by communication. The main function is placed on both sides.

The Primary school R consists of three pieces: two elongated cuboids placed at an angle to each other and connected by an internal trapezoidal communication. The main function is located in the west and east and the deviation from north is 19°.

The main function in mini waterpark S is situated in the south and west and the deviation from north is 15°. The communication and auxiliary spaces are located in the north and the east.

The main hotel T floors with guests’ rooms have communication inside the building and rooms exposed to the south and the north and the deviation from north is 25°.

The primary function in U club is located in the south and the auxiliary functions are in the north and the deviation from north is 6°. The communication halves the building.

The primary function production hall W is located in the east and the deviation from north is 8°. The office section is located in the south- west part of the building.

4.1.5. Shape of façades

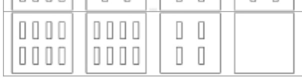
In “be 2226” building all façades are equal, have the same dimensions and the same number of windows. They look similar, with only minor differences.

One sports hall has a pitched roof, the other five sports halls have flat roofs with parapets. There are two types of façades: a short and small one with barely any windows, and a long one with a lot of glazing. The façades are colourful. Their architectural expression is made by artificial divisions, which do not result from the structure, function or form. Half of the sports halls have external blinds on windows to prevent overheating and provide visual comfort.

The investigated kindergartens have flat roofs with parapets, only one has a pitched roof. All buildings have colourful façades. Their architectural expression is made by artificial divisions, which do not result from the structure or form. In two kindergartens the colours of the façades reflect the function breakdown of individual classrooms. Two kindergartens have the shape elongated in one direction. One building is made in a stepwise manner and looks like three gradually advancing semi-detached buildings. One kindergarten has a protruding part of the second floor hanging over the ground floor entrance. The classroom windows have external blinds, which are used to prevent overheating and to darken the rooms for the use of projectors during the lessons. One kindergarten has an overhanging roof to provide shade in the summer and daylight in the winter.

All three office buildings have elongated shapes with pitched roofs. The office building L is a historic building after renovation and extension. This building has the genuine façade stone material (the insulation was applied inside). The office building K has wooden elements integrated into the plaster wall of the

Table 8.
The diagrams show the shapes of the façades divided according to their functions. Own study

Diagram of façades	Description
"be 2226"	
	All façades have the same dimensions and the same number of windows.
Passive House	
	Regardless the proportions of façades all of them have equally spaced windows.
	There are three types of façades: a short, small one with no windows, a long one with a lot of glazing and a long one with fewer windows.
	There are two types of façades: a short one with no windows, and a long one with a lot of glazing.
	There are three types of façades. One with a large number of windows, one with fewer windows, and one without glazing
	There are two types of façades. One with a large number of windows, and one with fewer windows.
	There are two types of façades. One with barely any windows, one with no windows and one long façade with a lot of glazing.

façade. The building M has colourful façades. Their architectural expression is made by artificial divisions, which do not result from the structure, function or form. All buildings have windows with external blinds.

All health care centres have elongated shapes. One building has a pitched roof, the other two have flat roofs with parapets. All buildings have colourful façades. Their architectural expression is made by artificial divisions, which do not result from the structure, function or form. The buildings O and P have rhythmically arranged windows. All buildings have windows with external blinds.

The southern and northern façades of primary school R are smaller with few windows. The western and eastern facades have rhythmic glazing. The outside openwork sun shaders are mounted over the classroom windows. The climbing plants give the façades an additional seasonal warmth regulation effect.

The mini waterpark S is located between the existing school buildings and sport hall building. The most glazing is on the south façade. Other façades have only necessary glazing.

The hotel T building has a sculptured shape due to its L-shape, the balconies and the pitched roof.

The U club is made of two interlocking solids, one with a flat and one with a pitched roof. The materials used on façades are brick and steel. Most windows are on the southern façade.

4.1.6. Compactness of the building

The smaller value of the A/V compactness ratio (the external surface area A to the internal volume V) is observed in low-energy buildings. In Passive House buildings, this ratio should be $0.7 m^2/m^3$ [42]. The complicated and fractured shape of the building leads to more thermal bridges. In buildings with a complicated shape the surface area is bigger, which increases the radiation area. This leads to a higher heat demand. Therefore, the compactness of the building is very important. The appropriate orientation and shape of the building [43, 44, 45, 46, 47, 48, 49] can reduce heating costs up to 40% [50].

The investigated Passive House buildings have the A/V ratio between 0.34 and 1.13 m^2/m^3 and 75% of them have the compactness ratio below 0.7 m^2/m^3.

The compactness ratio of "be 2226" building is 0.24 m^2/m^3.

4.2. Incompatibilities of the investigated buildings with the defined passive house standard

Both Passive House and "be 2226" standards are based on eliminating conventional heating and cooling. 75% of the investigated Passive House standard public utility buildings (15 out of 20) have conventional heating with subfloor heating or panel radiators.

Low heat and cooling demand in buildings is often obtained by using renewable energy [51]. This is a change of heat source but not a real reduction of heat

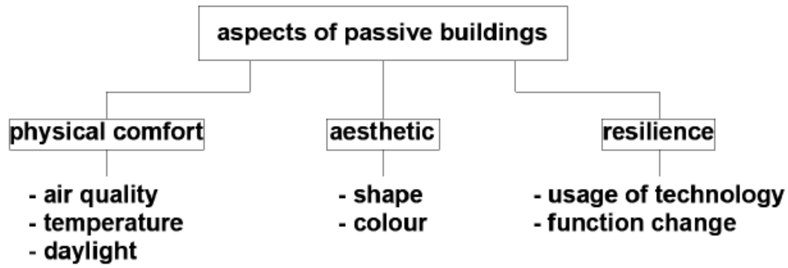


Figure 6.
Aspects of passive buildings defined by Author. Own study

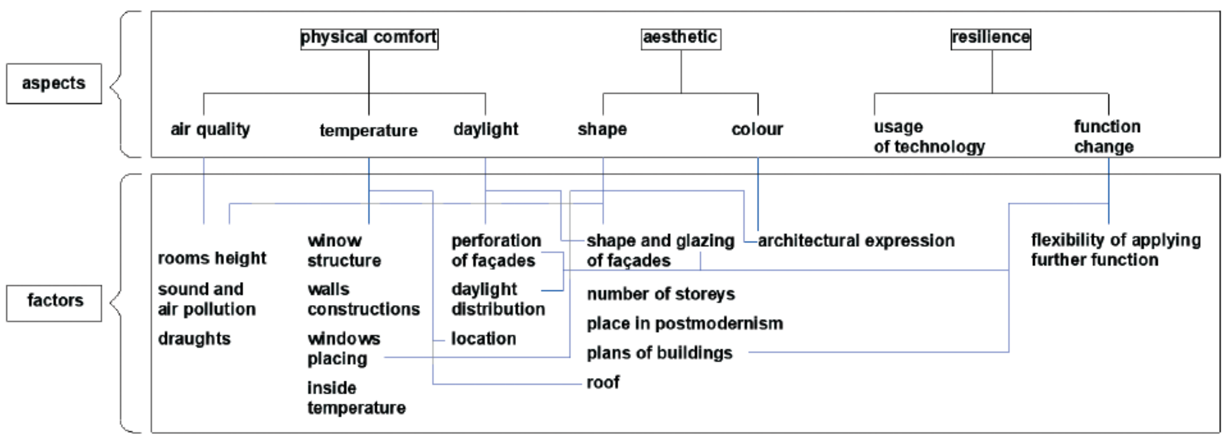


Figure 7.
Assignments of investigated factors. Own study

demand. The primary energy is calculated by multiplying the end energy by a coefficient which indicates the energy source (electricity, gas, renewables).

The Passive House buildings have high interior heat gains and show very low demand value for heating but demand a cooling system. A well-insulated building envelope is one of the reasons of overheating. The excessive gained heat has no place to be stored. Other researchers point out the problem of summer overheating of Passive House buildings [52, 53].

4.3. Incompatibilities of the investigated buildings with the defined "be 2226" standard

The "be 2226" building described in this paper is a model building that complies with all the requirements of the "be 2226" standard. It was impossible to investigate the building in situ due to the COVID -19 pandemic restrictions so the Author relays on the literature and building documentation. There are very few respective documents because the standard is relatively new.

4.4. Architectural comparison

Author defines three aspects of passive buildings – physical that is responsible for comfort, aesthetic that is responsible for beauty and resilience responsible for building lifespan. The users' comfort in passive buildings is achieved by good air quality, stable temperature and sufficient daylight delivery. The aesthetic of beauty is defined by building shape and colour. The resilience is responsible for longer lifespan, that can be achieved by building's ability to change its function and avoiding implementation of complicated technology that have to be replaced during its use.

To examined aspects of passive buildings Author defined and compared the factors that need to be investigated and has grouped them into aspects of passive buildings. Because it is impossible to only assign some factors to one aspect Author presents in Fig. 7. all assignments of given factors for the purpose of this research.

Table 9.
Architectural comparison – physical aspect – users' comfort. Own study

Passive House	"be 2226"
Rooms height	
The celling heights depends on the function of the building and varies from 2.5 m to over 7.5 m in sports halls. The mechanical ventilation is set for the number of users resulting from the project assumptions.	The ground floor is slightly higher, and other floors have equal celling height of 3.3 m. In high rooms, carbon dioxide can accumulate near the celling like warm air [54] in a larger volume so frequent ventilation is not necessary. The amount of fresh air depends on the number of people in a room and is regulated by CO_2 sensors.
Sound and air pollution	
In Passive Houses sound pollution from the outside is not a problem because the airtight windows do not need to be open. The ventilation system has acoustic silencers, but the sound of air flow can be noticed.	When the vents are open the outside sound and air pollution in some environments can negatively affect the users.
Draughts	
The thermal comfort in the Passive House is achieved by the same temperature along walls and windows. There are no draughts or temperature differences that could be felt by the users (above 4^{o}).	During ventilation draughts can appear. The cold winter air penetrating the room can be unpleasant for the user sitting next to the opened vent.

Table 10.
Architectural comparison – physical aspect – users comfort – temperature. Own study

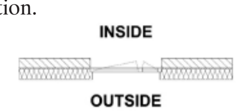
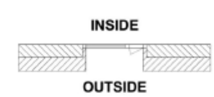
Passive House	"be 2226"
Window structure	
Double and triple pane windows have the U factor from 0.6 to 1.3. The higher U value factor is caused by using fireproof doors and windows. All the investigated buildings have openable windows.	Triple pane windows with a U factor 0.5 are fixed glazing. Every window has openable independent ventilation flap.
Walls constructions	
The external walls are made of reinforced concrete, masonry structures, wooden or mixed constructions. All investigated buildings have thermal insulation of polystyrene or mineral wool. The thickness of all walls varies from 48 to 65 cm.	The walls with two layers of a high insulating brick are 76 cm thick.
Windows placing	
Windows are placed in the insulating layer near the structural part of the wall. The insulation is superimposed on the window frame from the outside. Some of the windows are installed in the construction part of the wall due to their fire proof function.  Figure 8. Window installation in the wall in a Passive House building. Own study.	Windows and vents are placed in the inner part of the wall, giving the plasticity of a concave-convex façades. The window seems frameless on the façade as if emerging from the openings in the wall.  Figure 9. Window installation in the wall in a "be 2226" building. Own study.
Inside temperature	
The designed temperature is not less than 20^{o}C. This can cause some problems. Hotel guests and office workers complain about low temperatures and sometimes use additional blow heaters for thermal comfort. The humidity and air quality depends on mechanical ventilation. The frequency of filter changes is relevant. The ventilation system is designed for a certain number of people in a room, so if there are more of them inside, the comfort cannot be reached.	The comfort and health aspects are obtained by temperature between 22 and 26^{o}C and humidity not below 40%. These parameters may be achieved due to the heat storing capacity of the brick walls and their ability to absorb and storage water vapor [55].

Table 11.
Architectural comparison – physical aspect – users' comfort – daylight. Own study

Passive House	"be 2226"
Perforation of façades.	
The arrangement of the building envelopes differs according to the function. In 55% of the buildings the most perforations are on the southern façade. The deviation from the north is between 1 to 48°. In school and health care facilities the northern facades have equal numbers of rows and columns of windows.	All façades are perforated equally regardless of their orientation. Vertical arrangements of the vents are the best solution for the differences in pressure.
Daylight distribution and façades perforation [56]	
The distribution of light in rooms depends on the façade orientation. Spaces used more than 4 hours a day have window glass area of minimum 1/8 of the floor area. The total glazing area to the wall area: – 0–28% on the northern façades – 0–31% on the eastern façades – 0–36% on the western façades – 11–44% on the southern façades.	The distribution of daylight is equal in all rooms. The 16% of each façade surface are windows. Large windows gain daylight and solar radiation. This reduces the use of artificial light and energy consumption. The balance between the windows and the solid façade wall was calculated as optimal for office buildings.
Location	
The investigated Passive House buildings relate to their surroundings. They have different locations – in the city, as extensions of existing buildings or on new sites surrounded by fields. They are simple in architectural expression. They try to be consistent and compact. They are correct but not timeless. The proportions are not sophisticated and repeat common patterns assigned to their functions.	The location of "be 2226" building is a commercial zone, surrounded by modern buildings made of glass and metal. This building is different in shape and perforation. It is a white cube with columns and rows of identical windows. It stands out from the surroundings.

Table 12.
Architectural comparison – aesthetic aspect – shape. Own study

Passive House	"be 2226"
Shape and glazing of façades	
The shape and amount of glazing of façades differ depending on the orientation to the north. The buildings have rectangular shapes, which are extended and exposed to the south (with deviations).	All four façades have exactly the same dimensions and the windows-to-walls ratio.
Plans of buildings	
The plans of the buildings differ depending on the function of the object. The rooms of basic function are larger and situated in the south – west or east. Auxiliary rooms are situated in the north. Most of the buildings are constructed with corridors in the middle and spaces on both sides.	The open plan on all storeys is created by two staircases and two sanitary facilities. It divides the space into four parts on each floor.
Roof	
The shapes of roofs differ from flat through gable to multi-pitch. None of the investigated buildings has a gravel or green roof. Some roofs have solar or photovoltaic panels.	Over the typically thermoinsulated roof there is a layer of round grain gravel.
Number of storeys	
The investigated buildings have from one to four floors and some of the buildings have basements. The number of floors in a Passive House building is not limited because the building can be of any construction. The height of the building depends only on the function and local legal regulations.	The building has six floors and according to the static requirements it is the limit for this kind of construction [57].
Place in postmodernism	
The investigated Passive House buildings tend to be postmodern average designs, with a potential but also with flows (wrong proportions, colour-based, artificial division of façades, designing inside-out with closed plan)	The proportions of the "be 2226" building are beautiful It is a perfect 24x24x24 meter cube. This elegant building goes beyond the postmodern state of architecture full of glass covered offices and commercial buildings façades [58].

Table 13.
Architectural comparison – aesthetic aspect – colour. Own study

Passive House	"be 2226"
Architectural expression	
Passive House buildings have a user-friendly scale because the usable area is not too big. The façades of some Passive House objects are articulated with the southern façade roof overhang for shadowing windows in the summer, or with plenty of balconies around the building. All buildings play with colour. The façade expression is blank and plain sometimes created only by the colour, not by the architectural procedure. This colour application tends to be insincere. A façade should be created by the shape of the building.	The scale of "be 2226" building is adequate and user-friendly. The relation between the material and the geometry of the building is balanced. The façades have small deviations in the form of irregular projections and setbacks. Minimal deviations from the perfect geometry of the cube also appears in ancient Greek architecture, this technique is to highlight the effect of the building on the viewer [59].

Table 14.
Architectural comparison – resilience aspect – change of function. Own study

Passive House	"be 2226"
Lifespan of the building [60, 61]	
All investigated Passive House buildings are designed from inside out. The shapes of the buildings are determined by their function and the requirements of the standard. The function may be slightly modified but the plan is mostly closed and intended for the specified function. Dietmar Eberle points out that in the twenty first century buildings tend to be designed from the inside out and it is incorrect. Those buildings have a short lifetime in terms of their interior organization.	Due to the open plan, the building can change its function in the future. It is crucial for the environment, because the lifespan of those buildings is extended. When the building is public or municipal and is created from outside in, its lifetime is much longer. Public acceptance of the exterior appearance guarantees long lifespan of the building – architecture creates sustainability [62]. Investigations of Dietmar Eberle conclude that the key to the acceptance of a building is the emotional appreciation.

4.5. Thermovision tests results

In Passive House buildings the thermovision tests showed the natural thermal bridges on window installation areas. Thermal bridges are minimized but not completely eliminated. The fire proof doors and windows due to their installation requirements show bigger thermal bridges on thermograms.

In 'be 2226' building the thermovision tests were not conducted because of the Covid – 19 pandemic regulations, but the documentation states that the brick joint insulation of high-insulating stone overlaps the window frame and eliminates the thermal bridge of the window installation.

4.6. Summary comparison

Table. 15 shows summary comparison of standards. All investigated buildings were allocated to chosen factors described in this research. The chart has sign '+' meaning, that factor appears and sign '-' meaning, that factor does not appear. The buildings are ordered by letters as in point 2.3. of this paper.

Table 15.
Summary comparison of passive standards. Own study

	A	Total	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R	S	T	U	W	Total
Number of floors	6		1	2	2	2	2	1	1	1	2	2	2	2	1	4	2	2	3	3	1	2	
Resilience	+	1	-	-	-	-	-	-	-	-	-	+	+	-	-	+	+	+	-	+	-	-	6
Aesthetic	+	1	-	-	+	-	+	-	-	+	+	+	+	-	+	+	+	-	+	+	+	+	13
Equal daylight delivery	+	1	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	+	-	+	-	-	4
Differentiation of facades	-	0	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	+	+	18
Compactness < 0.7 m^2/m^3	+	1	-	+	+	+	+	+	+	+	+	+	+	+	-	+	-	-	+	+	-	+	15
Good proportions	+	1	+	+	+	+	+	+	-	+	-	+	+	-	+	+	-	+	+	+	+	+	16
Conventional heating in building	-	0	+	+	+	+	+	-	+	-	+	+	+	-	+	+	+	-	+	+	+	-	15
Sound pollution from outside	+	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Sound pollution from inside	-	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	20
Draughts	+	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Pitched roofs	-	0	+	-	-	-	-	-	-	+	-	+	+	+	+	-	-	-	-	+	+	-	8
Colorful facades	-	0	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	-	+	-	-	15

5. CONCLUSIONS

The investigated buildings are public utility buildings. The Polish district authorities decide to build sports halls, health and educational buildings in Passive House standard.

The conclusion is that all buildings, regardless of their function, should be built in the passive manner. It would be beneficial to consider at least the most efficient "be 2226" standard assumptions to be implemented to future passive designs.

The investigated Passive House buildings have from one to four floors and the "be 2226" building has six floors. The height of the "be 2226" is limited and is a disadvantage. On the other hand there are no limitations to build more storeys in Passive House buildings.

Thermal bridges are present in all investigated buildings, particularly around the smoke venting elements and fire windows and doors, which fail the Passive House thermal insulation requirements.

Both standards have a compact structure. They tend to be consistent in shape and the "be 2226" building is an ideal cube.

My research shows that the architectural creation has a great impact on passive solutions in buildings. The shape, orientation and glazing of a building influence its thermal efficiency. Some architectural elements such as roof eaves overhangs and external blinds improve indoor quality.

The architectural quality of the Polish Passive House public utility buildings should be higher. Their visual appeal should be created not only by artificial wall divisions made by colours, but should result from the architectural composition.

The main conclusion is that the buildings should have open plans so that they could be used in the future for a new, entirely different function. The daylight should be delivered equally to all parts of the building from the four cardinal directions. This allows to change the function over the years.

The study contributes to the evaluation of both passive standards and emphasizes the significance of further comparative research, which should be extended to include in situ investigation of "be 2226" buildings. The described investigations and outcomes are unique. This research fills the gap in the field of architectural approach to designing energy-efficient passive public utility buildings.

REFERENCES

[1] Communication from the Commission to the European Parliament, the Council, "The European Economic and Social Committee and the Committee of Regions, Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people, Brussels, on 17.9.2020, COM(2020) 562 final

[2] https://www.iea.org/topics/buildings access date 28.05.2021

[3] Ford B., (2001). Passive downdraught evaporative cooling: Principles and practice. *Architectural Research Quarterly, 5*(3), 271–280. doi:10.1017/S1359135501001312

[4] Flynn E., (2016). (Experimenting with) Living Architecture: A practice perspective. *Architectural Research Quarterly, 20*(1), 20–28. doi:10.1017/S1359135516000166

[5] Schiano-Phan R., (2010). Environmental retrofit: Building integrated passive cooling in housing. *Architectural Research Quarterly, 14*(2), 139–151. doi:10.1017/S1359135510000758

[6] Pylsy P., Lylykangas K., Kurnitski J., (2020). Buildings' energy efficiency measures effect on CO_2 emissions in combined heating, cooling and electricity production. *Renewable and Sustainable Energy Reviews,* 134, 110299, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2020.110299.

[7] Lin Y.-H., Lin M.-D., Tsai K.-T., Deng M.-J., Ishii H., (2021). Multi-objective optimization design of green building envelopes and air conditioning systems for energy conservation and CO_2 emission reduction. *Sustainable Cities and Society*, 64, 102555, ISSN 2210-6707, https://doi.org/10.1016/j.scs.2020.102555.

[8] Piccardo C., Dodoo A., Gustavsson L., (2020). Retrofitting a building to passive house level: A life cycle carbon balance. *Energy and Buildings*, 223, 110135, ISSN 0378-7788. https://doi.org/10.1016/j.enbuild.2020.110135.

[9] Hajat S., Vardoulakis S., Heaviside C., Eggen B. (2014). Climate change effects on human health: projections of temperature-related mortality for the UK during the 2020s, 2050s and 2080s. *J. Epidemiol. Community Health, 68*(7), 641–648. CrossRefView Record in ScopusGoogle Scholar.

[10] Beizaee A., Lomas K.J., Firth S.K. (2013). National survey of summertime temperatures and overheating risk in English homes. *Build. Environ*., 65, 1–17 Google Scholar.

[11] Morgan C., Foster J.A., Poston A., Sharpe T.R. (2017). Overheating in Scotland: contributing factors in occupied homes. *Build. Res. Inf.* (1–2), 143–156 Google Scholar.

[12] Lomas K.J., Porritt S.M. (2017). Overheating in buildings: lessons from research. *Build. Res. Inf*., *45*(1–2), 1–18, CrossRefView Record in ScopusGoogle Scholar.

[13] Hajat S., Vardoulakis S., Heaviside C., Eggen B. (2014). Climate change effects on human health: projections of temperature-related mortality for the UK during the 2020s, 2050s and 2080s. *J. Epidemiol. Community Health, 68*(7), 641–648. CrossRefView Record in ScopusGoogle Scholar

[14] Hrivnak J., (2007). Is relative sustainability relevant? *Architectural Research Quarterly, 11*(2), 167–176. doi:10.1017/S1359135507000644

[15] Voelcker A., (1999). Handbook of Sustainable Building by David Anink, Chiel Boonstra and John Mak James and James, London, 1996176 ISBN 1873936 389 (pb). *Architectural Research Quarterly, 3*(3), 286–286. doi:10.1017/S1359135500002128

[16] Goncalves V., Ogunjimi Y., Heo Y., (2021). Scrutinizing modeling and analysis methods for evaluating overheating risks in passive houses. *Energy and Buildings*, 234, 110701. ISSN 0378-7788. https://doi.org/10.1016/j.enbuild.2020.110701.

[17] Gourlis G., Kovacic I., (2017). Passive measures for preventing summer overheating in industrial buildings under consideration of varying manufacturing process loads. *Energy*, 137, 1175–1185, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2017.05.134.

[18] Kisilewicz T., Dudzińska A., (2015). Summer overheating of a passive sports hall building. *Archives of Civil and Mechanical Engineering, 15*(4), 1193–1201. ISSN 1644-9665. https://doi.org/10.1016/j.acme.2015.03.002.

[19] Sepúlveda A., De Luca F., Thalfeldt M., Kurnitski J., (2020). Analyzing the fulfillment of daylight and overheating requirements in residential and office buildings in Estonia. *Building and Environment*, 180, 107036, ISSN 0360-1323. https://doi.org/10.1016/j.buildenv.2020.107036.

[20] Ah-Young L., Miryoung Y., Eun-Hye K., Hyun-Ah K., Myoung Ju L., Hae-Kwan C., (2021). Effects of mechanical ventilation on indoor air quality and occupant health status in energy-efficient homes: A longitudinal field study. *Science of The Total Environment*, 785. https://doi.org/10.1016/j.scitotenv.2021.147324.

[21] Ben-David T., Waring M. S., (2016). Impact of natural versus mechanical ventilation on simulated indoor air quality and energy consumption in offices in fourteen U.S. cities. *Building and Environment*, 104, 320–336. https://doi.org/10.1016/j.buildenv.2016.05.007.

[22] Baker N., (1996). The irritable occupant: Recent developments in thermal comfort theory. *Architectural Research Quarterly, 2*(2), 84–90. doi:10.1017/S1359135500001287

[23] Heyman J., (1999). Developments in Structural Form by Rowland Mainstone 2nd edition Architectural Press, Oxford, 1998384. *Architectural Research Quarterly, 3*(3), 285–286. doi:10.1017/S1359135500002116

[24] Ramirez-Figueroa C., Beckett R., (2020). Living with buildings, living with microbes: Probiosis and architecture. *Architectural Research Quarterly, 24*(2), 155–168. doi:10.1017/S1359135520000202

[25] Cook J., (1997). The Skyscraper Bioclimatically Considered By Ken Yeang. Academy Editions, 269 pp., numerous illus. ISBN 1 85490 431 0 PB. *Architectural Research Quarterly, 2*(3), 92–94. doi:10.1017/S1359135500001470

[26] Junghans L., (2016). The Energy Concept in be 2226 The Temperature of Architecture Portrait of an Energy-Optimized House Edited by Dietmar Eberle and Florian Archer Basel, 45–54.

[27] Purvis B., Mao Y., Robinson D., (2019). Three pillars of sustainability: in search of conceptual origins. *Sustainability Science. 14*(3), 681–695.

[28] Feist W., (2002). Passivhaus Projektierungs Paket 2002, Anforderungen an qualitaetsgepruefte, Passivhaeuser Passivhaus Institut, Darmstadt, Germany, (Passive house planning package 2002, requirements for quality-tested passive houses Passive House Institute, Darmstadt, Germany) Google Scholar.

[29] Feist W., Schnieders J., Dorer V., Haas A., (2005). Reinventing air heating: convenient and comfortable within the frame of the passive house concept. *Energy Build*, 37, 1186-1203.

[30] Schnieders J., Hermelink A., (2006). CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive House being an option for sustainable building Energy Policy, 151–171.

[31] Feist W., Pfluger R., Kaufmann B., Schniders J., Kah O., (2007). Passivehaus-Projektierungspaket Anforderungen an qualitaetsgepruefte Passivhaeuser, Passivhaus Institut, Darmstadt.

[32] Pitts A., (2017). Passive House and Low Energy Buildings: Barriers and Opportunities for Future Development within UK Practice. *Sustainability, 9*(2), 272. https://doi.org/10.3390/su9020272

[33] Monsen W.A., Klein S.A., Beckman W.A., (1981). Prediction of direct gain solar heating system performance. *Sol Energy*, 27, 143–147.

[34] Oliveira A.C., de Oliveira, Fernandes E., (1992). A new simplified method for evaluating the thermal behaviour of direct gain passive solar buildings. *Sol Energy*, 48, 227–233.

[35] Schnieders J., Feist W., Pfluger R., Kah O., (2007). CEPHEUS 2001 CEPHEUS Naukowa analiza i ocena Raport końcowy. Instytut Budownictwa Pasywnego, Darmstadt 2001/2.

[36] Hui P.S., Wong L.T., Mui P.S., (2008). Using carbon dioxide concentration to assess indoor air quality in offices. *Indoor Built Environment*, 17, 213–219.

[37] Almeida R.M.S.F., Pinto M., Pinho P.G., de Lemos L.T., (2017). Natural ventilation and indoor air quality in educational buildings: experimental assessment and improvement strategies. *Energy Effic*, 10.

[38] Junghans L., (2016). The Energy Concept in be 2226 The Temperature of Architecture Portrait of an Energy-Optimized House Edited by Dietmar Eberle and Florian Archer Basel, 45-54.

[39] Keller B., Magyari E., (1998). A universally valid strategy for low energy houses. *Renewable Energy*, 15, 401–406.

[40] Potrč Obrecht T., Premrov M., Žegarac Leskovar V., (2019). Influence of the orientation on the optimal glazing size for passive houses in different European climates (for non-cardinal directions). *Solar Energy*, 189, 15–25. ISSN 0038-092X.

[41] Niezabitowska E. D., (2014). Metody i techniki badawcze w architekturze (Research methods and techniques in architecture), Wydawnictwo Politechniki Śląskiej, Gliwice.

[42] Feist W., (1998). Wirtschaftlichkeit ausgewählter Energiesparma nahmen im Gebäudebestand, Passivhaus Institut, Darmstadt (Efficiency of selected energy saving measures in existing buildings, Passive House Institute, Darmstadt).

[43] Ciardiello A., Rosso F., Dell'Olmo J., Ciancio V., Ferrero M., Salata F. (2020). Multi-objective approach to the optimization of shape and envelope in building energy design. *Applied Energy*, 280, 115984. ISSN 0306-2619.

[44] Kheiri F., (2018). A review on optimization methods applied in energy-efficient building geometry and envelope design. *Renewable and Sustainable Energy Reviews*, 92, 897–920. ISSN 1364-0321.

[45] Gleń P., Suchorab Z., Widomski M.K., (2019). The impact of the cubature of the building on the effectiveness of passive housing. *AIP Conference Proceedings* 2133, 020015. https://doi.org/10.1063/1.5120145

[46] Parasonis J., Keizikas A., Kalibatiene D., (2012). The relationship between the shape of a building and its energy performance. *Architectural Engineering and Design Management, 8*(4), 246–256. DOI: 10.1080/ 17452007.2012. 675139

[47] Huang Y., Niu J., (2016). Optimal building envelope design based on simulated performance: history, current status and new potentials. *Energy Build*, 117, 387–398.

[48] Ouarghi R., Krarti M., (2006). Building shape optimization using neural network and genetic algorithm approach. *ASHRAE Trans,* 112(PART 1), 484–491.

[49] Zemella G., De March D., Borrotti M., Poli I., (2011). Optimised design of energy efficient building façades via evolutionary neural networks. *Energy Build*, 43, 3297–3302.

[50] Wang W., Zmeureanu R., Rivard H., (2005). Applying multi-objective genetic algorithms in green building design optimization. *Build Environ*, 40, 1512–1525, 10.1016/j.buildenv.2004.11.017

[51] Hayter SJ., Kandt A., (2011). Renewable energy applications for existing buildings – preprint. Proceedings of the 48th AiCARR international conference; 1–15.

[52] Kisilewicz T., Dudzińska A., (2015). Summer overheating of a passive sports hall building. *Archives of Civil and Mechanical Engineering, 15*(4), 1193–1201. ISSN 1644-9665.

[53] Mlakar J., Štrancar J., (2011). Overheating in residential passive house: Solution strategies revealed and confirmed through data analysis and simulations. *Energy and Buildings, 43*(6), Pages 1443–1451. ISSN 0378-7788. https://doi.org/10.1016/j.enbuild.2011.02.008.

[54] Massman W.J., (1998). A review of the molecular diffusivities of H_2O, CO_2, CH_4, CO, O_3, SO_2, NH_3, N_2O, NO and NO_2, in air, O_2 and N_2 near STP. *Atmospheric Environment, 32*(6), 1111–1127.

[55] Hugentobler W., (2016). Health Aspects in be 2226 The Temperature of Architecture Portrait of an Energy-Optimized House Edited by Dietmar Eberle and Florian Archer Basel, 143–153.

[56] Leskovar V.Ž. , Premrov M., (2011). An approach in architectural design of energy-efficient timber buildings with a focus on the optimal glazing size in the south-oriented façade. *Energy Build*, 43, 3410–3418.

[57] Aicher F., (2016). Material, Type, Site in be 2226 The Temperature of Architecture Portrait of an Energy-Optimized House Edited by Dietmar Eberle and Florian Archer Basel, 131–142.

[58] Steiner D., (2016). Back to Architecture in be 2226 The Temperature of Architecture Portrait of an Energy-Optimized House Edited by Dietmar Eberle and Florian Archer Basel, 35–43.

[59] Feireiss K., (2016). A Personal Approach in be 2226 The Temperature of Architecture Portrait of an Energy-Optimized House Edited by Dietmar Eberle and Florian Archer Basel, 25–33.

[60] Till J., Schneider T., (2005). Flexible housing: The means to the end. *Architectural Research Quarterly, 9*(3–4), 287–296. doi:10.1017/S1359135505000345

[61] Schneider T., Till J., (2005). Flexible housing: Opportunities and limits. *Architectural Research Quarterly, 9*(2), 157–166. doi:10.1017/S1359135505000199

[62] Aicher F., Eberle D., (2016). In Defence of the User in be 2226 The Temperature of Architecture Portrait of an Energy-Optimized House Edited by Dietmar Eberle and Florian Archer Basel, 163–178.