Comparison of conventional and passive public utility buildings in Poland

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Abstract. Poland sees the increasing popularisation of sustainable housing and the growing awareness of the importance of sport development. A good physical condition of residents translates into effective work, whereas caring for the environment improves living standards. Introducing healthy lifestyle from an early age has the best results. Due to this fact in Poland every school has its own sports hall. The pilot programme to build swimming pools near every primary school was introduced in Lower-Silesian district and it is called ‘Dolnośląski Delfinek’ (Lower Silesian Little Dolphin). Swimming pool buildings are characterised by high demand for heat. Their operation burdens district budgets and indirectly every taxpayer. Those facilities are occasionally rented commercially to earn some money for maintenance expenses. The costs usually exceed the income of those buildings. The article discusses results of thermo-vision (infrared) tests and presents the analysis of the technical documentation of twenty eight public utility buildings located in Poland. The investigations encompass conventional, energy-saving and passive buildings. The conventional buildings described in the work are school swimming pools from the programme ‘Dolnośląski Delfinek’ (Lower-Silesian Little Dolphin), whereas energy-saving and passive buildings include office, industrial, hotel, educational and sports buildings (including an indoor swimming pool). This article aims to find the most effective design manner and energy-saving sports buildings construction such as swimming pools. The results obtained in the tests indicate the necessity of compliance with the energy-saving technology in the design and construction of public utility buildings. A conclusion arises that swimming pool buildings are the most suitable candidates for passive buildings.

1. Introduction
The main challenge of our time is the climate crisis. The European Commission aims to reduce the greenhouse gas emissions by 2030 by at least 55% in comparison with the 1990 data [1]. One of the ways to meet the requirements of the proposed 2030 Target Plan is to reduce heat demand of public utility buildings. This lowers the CO₂ emission and also cuts the maintenance costs, which in turn helps the municipal budget. The most energy efficient option are passive buildings. Their energy demand is reduced by 80-90%, whereas the construction cost is only 5-10% higher than of a conventional building[2]. Passive facilities have already proved successful in many countries [3] as e.g. schools [4], office buildings [5] and health care centres[6, 7].

This study focuses on swimming pools, one of the most heat demanding type of public utility buildings. The assumption is that implementing passive solutions in the design and construction of these facilities substantially improves their thermal efficiency and contributes to reducing the CO₂ footprint.

The maintenance of conventional swimming pools is challenging for the municipal budget mainly because they need to be heated to min 30°C [8], which exceeds temperatures in other public facilities.
(20°C to 24°C). Other expenses involve e.g. water heating and consumption, and heat losses through windows and partitions. Using the Passive House Standard to construct a swimming pool is both pro-ecological and cost-effective. So far, Germany has two passive swimming pools, i.e. Lippe Bad Lünen [9] and Bambados in Bamberg [10] and Poland has one. They are a proof that passive solutions are a promising option for such facilities.

My research addresses this type of buildings because of a Polish pilot programme “Dolnośląski Delfinek” (Lower-Silesian Little Dolphin) [11, 12], in which municipalities are receiving state subsidies for the design and construction of school swimming pools. This is a long-term programme, so far operating in only one voivodship, but soon to be implemented in the whole country. I want to find the most effective solutions for the swimming pools to minimize their heat demand and reduce both the CO₂ emission and the maintenance costs.

2. Testing methods
For my research I investigated 28 facilities constructed between 2011 and 2020: twenty passive, three energy-saving buildings and five conventional indoor swimming pools. I used the following methods and techniques [13]:

- a) logical argumentation – description, clarification, logical interpretation, benchmarking, scaling of grades;
- b) experimental research - observation, measurement, statistics, parametric techniques;
- c) quantitative and statistical - measurement, counting of elements, analysis of non-parametric data;
- d) case studies - visual inspection of a research object, studies of archive records, analysis of documents, description, clarification, interpretation, benchmarking, measurement, counting, observation, surveys, interviews.

Table 1. Analyzed public utility buildings by function

| Analyzed public utility buildings by function | Conventional housing | Energy-saving housing | Passive housing |
|---------------------------------------------|----------------------|----------------------|-----------------|
| Sports halls                                 |                      |                      | 6               |
| Delfinek (Little Dolphin) swimming pools     | 5                    |                      |                 |
| Kindergartens                               | 2                    | 3                    |                 |
| Office buildings                            | 3                    |                      |                 |
| Health care centres                         | 3                    |                      |                 |
| Primary schools                             | 1                    |                      | 1               |
| Mini waterparks                             |                      |                      | 1               |
| Hotels                                      | 1                    |                      |                 |
| Cultural centres                            | 1                    |                      |                 |
| Industrial buildings                        |                      |                      | 1               |

I compared selected parameters of the buildings (table 1) using the data from my measurements and technical documentation, i.e. construction projects and detailed designs. I focused on calculating the compactness indicator of the building, i.e. the ratio of the external surface area (A) to the internal volume (V) (A/V). In passive buildings, this ratio should be ≤ 0.7 m²/m³ [14]. The appropriate shape [15, 16, 17, 18] and positioning of the building allows to reduce the heating costs by approximately 30% to 40% without incurring additional expenditures [19].

I investigated:
- the proportion of total glazing area to the wall area on individual façades with the assumption that the area of the entire façade is 100% on the basis of data from the documentation or my own measurements;
- the deviation of the building from the north, on the basis of data from the documentation or satellite maps [20];
- the building thermal insulation indicator, on the basis of data from the documentation or the energy performance;
- the primary energy ratios and demand ratios for usable energy on the basis of the documentation, energy performance or Passive House certificates.

I performed thermovision tests. Infrared thermography is the recording of images involving the detection of infrared radiation of an object and transforming this radiation into a visible image. The elements affecting the image and infrared interpretation include emissivity degree, reflection temperature, atmospheric temperature, distance and air humidity [21].

The objects presented in the study were tested with a FLIR i7 infrared camera in conditions where the minimum temperature difference was 10°C. During the tests, the emissivity factor was set at 0.95, which is characteristic of most building materials and corresponding to a mat surface. I used the iron palette and also took into consideration thermal reflections and humidity of the structural elements.

3. Definition of passive buildings

Most passive buildings, both in Poland and in other countries, are not public utility buildings but various types of low-intensity residential housing. The first passive building which was measured and tested after construction was low intensity terraced house in Kranichstein Darmstadt [22]. Poland has very few passive public utility buildings compliant with Darmstadt standards. It is difficult to determine their precise number because some of them are not certified. I have investigated most of them.

Passive buildings are heated by mechanically distributed air, without the need for conventional or surface heating systems [23]. However, in Poland it is often impossible to resign from the conventional heating because of the existing regulations and sanitary standards.

An essential parameter identifying a passive building is airtightness, and the related necessity to use mechanical ventilation with heat recovery. Users often do not understand airtightness and mechanical ventilation requirements and express their objections to them. Passive buildings are constructed with openable windows but opening the windows is not necessary because fresh, filtered air is supplied in appropriate amount to each space inside. Windows should be opened rationally and at appropriate times of the day [24, 25]. Opening a window in wintertime only increases heat losses but is recommended on summer nights as it facilitates the natural cooling of the building.

The criteria for a passive building are [26, 27, 28, 29, 30]:
- heating demand \( EU_{\text{conv}} \leq 15 \text{kWh/m}^2\text{a} \) or thermal load \( \leq 10 \text{W/m}^2 \);
- cooling demand \( \leq 15 \text{kWh/m}^2\text{a} \);
- primary energy demand for heating and cooling \( \leq 60 \text{kWh/m}^2\text{a} \) (compared to \( \leq 120 \text{kWh/m}^2\text{a} \) of previous years);
- airtightness \( \leq 0.6 \text{h}^{-1} \);
- excessive temperature frequency (above 25°C) \( \leq 10\% \) hours per year.

To conform to these criteria, the passive constructions have to meet some or all of the following six basic standards [31]:
- thermal insulation of partitions \( U \leq 0.15 \text{W/(m}^2\text{K)} \);
- appropriate positioning of the building;
- heat gains from solar energy;
- airtightness \( n_{\text{eq}} \leq 0.6 \text{ h}^{-1} \) and mechanical ventilation with minimum 75% heat recovery efficiency;
- window framework with heat transfer coefficient \( U \leq 0.7 \text{W/(m}^2\text{K)} \) and g coefficient approximately 50%;
- lack of thermal bridges.

At each design stage, the documentation should be verified with a dedicated programme, i.e. a passive building design package PHPP.
After the building is constructed, it should undergo a BlowerDoor Test to determine the building airtightness and, optionally, infrared tests to detect possible thermal bridges and air leakages. Energy consumption, pre-set ventilation and heating parameters can be monitored by installing BMS systems.

4. The analysis of technical documentation of the investigated buildings (Table 2-4)

| No. | Building Name (town where swimming pool is located) | Compactness A/V (1/m) | Deviation of the building from the north in degrees | Total glazing area to the wall area in % (S-South, N-North, E-East, W-West) | Walls thermal insulation coefficient U in W/(m² K) | Annual heat demand for primary energy EP and heating and ventilation usable energy ratio kWh/(m²a) | Heating and ventilation |
|-----|---------------------------------------------------|----------------------|------------------------------------------------------|--------------------------------------------------------------------------|-------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------|
| 1.  | Swimming pool in Głuszyca                        | 1.4                  | 38                                                   | 7 7 4 -                                                                  | 0.2                                             | 250                                                                              | heat recovery efficiency of ventilation units 60-75%; subfloor heating; in some rooms - panel radiators; source - system of gas absorptive heat pumps |
| 2.  | Swimming pool in Strzegom                        | 0.56                 | 46                                                   | 3 4 1 5                                                                  | 0.19                                            | 146.29 but EUco+w= 45.29                                                        | heat recovery efficiency of ventilation units 60-75%; Ventilation with three-stage heat recovery; subfloor heating; in some rooms - panel radiators; source - municipal heat generating plant and heat pumps |
| 3.  | Swimming pool in Chocianów                        | 0.37                 | 10                                                   | 3 5 0 9 1 8                                                              | 0.14                                            | 150                                                                              | heat recovery efficiency of ventilation units 95%; subfloor heating; in some rooms - panel radiators; source - school gas boiler room. |
| 4.  | Swimming pool in Góra                             | 0.77                 | 14                                                   | 6 7 7 9                                                                  | 0.19                                            | 150 but EUco+w= 32.33                                                           | heat recovery efficiency of ventilation units 54-76%; subfloor heating; in some rooms - panel radiators; source municipal heat generating plant and heat exchange system. |
Swimming pool in Twardogóra

**Table 3. Parameters of energy-saving buildings**

| No. | Building Name and town where building is located | Compactness A/V (1/m) | Deviation of the building from the north in degrees | Total glazing area to the wall area in % (S-South, N-North, E-East, W-West) | Walls thermal insulation coefficient U in W/(m²K) | Annual heat demand for primary energy EP and heating and ventilation-usable energy ratio kWh/(m²a) | Heating and ventilation |
|-----|-------------------------------------------------|----------------------|-----------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------------------|------------------------|
| 1.  | Primary school in Podgórzyn                      | 0.43                 | 3                                             | 2 1 1 1 2 4 1 0                                                            | 0.19                                          | 70.43 but EUco+w=13.67                                                                       | heat recovery efficiency of ventilation units 80% subfloor heating; source – heat pump           |
| 2.  | Kindergarten in Strzegom                        | 0.39                 | 9                                             | 3 4 8 9 8 0.16                                                            |                                               | 36.31                                                                                           | heat recovery efficiency of ventilation units 86-94%; subfloor heating; source – heat pump     |
| 3.  | Kindergarten in Złoty Potok                     | 0.38                 | 45                                            | 3 1 8 1 1 5 3                                                            | 0.11                                          | 165 but EUco+w=1.41                                                                           | heat recovery efficiency of ventilation units 87% subfloor heating and radiator heating; source – solid fuel (pellets) boiler |

**Table 4. Parameters of Passive buildings**

| No. | Building Name and town where building is located | Compactness A/V (1/m) | Deviation of the building from the north in degrees | Total glazing area to the wall area in % (S-South, N-North, E-East, W-West) | Walls thermal insulation coefficient U in W/(m²K) | Annual heat demand for primary energy EP and heating and ventilation-usable energy ratio kWh/(m²a) | Heating and ventilation |
|-----|-------------------------------------------------|----------------------|-----------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------------------|------------------------|
| 1.  | Primary school in Budzów with the branch in Grodziszcz | 0.74                 | 19                                            | 1 1 3 1 3 1 7                                                            | 0.19                                          | <=120 but EUco+w<=15                                                                           | heat recovery efficiency of ventilation units 80% |
| No. | Location                        | Efficiency | Source(s)                                                                 | Heat Recovery Efficiency |
|-----|---------------------------------|------------|----------------------------------------------------------------------------|--------------------------|
| 2.  | Hotel Bardo                     | 0.38       | Air heating; source – heat pump                                           | 60-75% subfloor heating; source – heat pump |
| 3.  | Zakole Club, Nowa Huta          | 0.81       | Heat recovery efficiency of ventilation units                             | 78-89%; ventilation air and subfloor heating; source – heat pumps and solar system. |
| 4.  | Centre for Sustainable Development and Energy, WGGiOS AGH, Miękinia | 0.57       | Heat recovery efficiency of ventilation units                             | 75%; radiator and subfloor heating; source – heat pump |
| 5.  | Sports hall Waganowice          | 1.13       | Heat recovery efficiency of ventilation units                             | 75% subfloor heating; source – heat pump |
| 6.  | Instytut Doradztwa Sp. z o.o., (Counselling Centre Ltd. co.) hall in Kokotów | 0.52       | Heat recovery efficiency of ventilation units                             | 92%; ventilation air heating; source heat pump |
| 7.  | Instytut Doradztwa Sp. z o.o., (Counselling Centre) Office building Kokotów | 0.58       | Heat recovery efficiency of ventilation units                             | 92%; ventilation air and subfloor heating; source – heat pump |
| 8.  | Health care centre in Słomniki   | 0.79       | Heat recovery efficiency of ventilation units                             | 80% ventilation air heating and radiator heating; source – gas boiler |
| 9.  | Sports hall in Słomniki          | 0.36       | Heat recovery efficiency of ventilation units                             | 75% subfloor heating, source – gas boiler |
| No. | Location                          | Area (m²) | HVAC Efficiency | Heat Source                          | Heat Source Details                                                                 |
|-----|-----------------------------------|-----------|----------------|--------------------------------------|--------------------------------------------------------------------------------------|
| 10  | Kindergarten in Słomniki           | 0.56      | 120 but EUco+V=15 | heat recovery efficiency of ventilation units 80%; subfloor heating; source – heat pumps and solar collectors |
| 11  | Mini waterpark in Siemiatycze      | 0.34      | 107 but EUco+V=10.47 | heat recovery efficiency of ventilation units 77.85%; subfloor heating; source – heat pump supported by cascaded gas condensing boilers; heat recovery from sewage, photovoltaic cells |
| 12  | District kindergarten in Rogowo    | 0.63      | 119 but EUco+V=14.2 | heat recovery efficiency of ventilation units 75%; subfloor heating; source – heat pump |
| 13  | Municipal sports hall OK in Brwinów| 0.37      | 120 but EUco+V=15  | heat recovery efficiency of ventilation units 70%; subfloor heating; source – heat pump supported by gas boiler |
| 14  | Rehabilitation centre in Szczerców | 0.95      | 119 but EUco+V=13.46 | heat recovery efficiency of ventilation units 87%; radiator heating; source – heat pump |
| 15  | Sports hall by the primary school in Beldów | 0.42 | 14.8 but EUco+V=8.4 | heat recovery efficiency of ventilation units 75-80%; ventilation air heating and the use of heating and cooling beams; source – heat pump |
| 16  | Kindergarten by the primary school in Beldów | 0.38 | 14.14 but EUco+V=14.53 | heat recovery efficiency of ventilation units 75%; ventilation air heating; source – heat pump |
| 17  | Crisis Management Centre in         | 0.33      | 68.9 but EUco+V=9.1 | heat recovery efficiency of ventilation units 84-85%; |
Table 5. Comparison of research results

| Building Description                                                                 | A (m²) | B | C | D | E | F | G | Heat Recovery Efficiency of Ventilation Units |
|------------------------------------------------------------------------------------|--------|---|---|---|---|---|---|---------------------------------------------|
| Health care and nursing centre in Kraków                                            | 0.40   | 20| 2 | 0 | 2 | 6 | 0.1| <=120 but EUco+W<=15 heat recovery efficiency of ventilation units 90%; radiator heating; source – heat pump and wind energy |
| Sports hall by II LO (secondary school) in Kraków                                    | 0.41   | 9 | 3 | 1 | 1 | 5 | 1  | 0.08/0.12 heat recovery efficiency of ventilation units 70 - 94%; convective panel radiator heating and subfloor heating; source – gas boiler |
| Passive hall of the University of Agriculture in Kraków                              | 0.33   | 28| 5 | 1 | 3 | 1 | 9  | 120 but EUco+W=15 heat recovery efficiency of ventilation units 75%; subfloor heating; source – gas boilers |

5. Results and discussion

In the 28 investigated buildings I observed the following (Table 5):

Table 5. Comparison of research results

| In conventional buildings: | In energy-saving and passive buildings: |
|----------------------------|----------------------------------------|
| the surface area to volume ratio is from 1.4 to 0.37 (1/m), I investigated only swimming pools characterised by a compact structure; | the surface area to volume ratio of the building is from 1.13 to 0.34 (1/m); |
| deviation from the north is less than 46°. The facilities were designed as extensions to existing schools, therefore it was necessary to adapt the design and construction to the existing infrastructure and site conditions; | deviation from the north is less than 39° except for one old renovated building, where the deviation is 48°. Most of the investigated buildings are extensions to the existing infrastructure which forced the designers to make concessions and adapt to the site conditions; |
| the south-facing walls have a high proportion of glazing; ‘Figure 1’ | 61% of the buildings have most of the glazing on the south-facing walls. As indicated by many researchers, this is the best orientation to locate most of glazing for the northern hemisphere [32, 33, 34, 35, 36]; ‘Figure 2’ |
| wall heat transfer coefficient is from 0.14 W/(m²K) to 0.2 W/(m²K); | wall heat transfer coefficient is from 0.08 W/(m²K) to 0.19 W/(m²K); |
| primary energy ratio is from 94.6 kWh/(m²a) to 250 kWh/(m²a); | primary energy ratio is from 14.08kWh/(m²a) to 120 kWh/(m²a); only in the health care centre the primary energy ratio is increased to 201 kWh/(m²a) to comply with the respective regulations; |
| usable energy ratio for heating and cooling is from 32.33 kWh/(m²a) to 45.29 kWh/(m²a); | usable energy ratio for heating and cooling is from 8.4 kWh/(m²a) to 15 kWh/(m²a); |
| heat recovery efficiency of ventilation units is from 70% to 95%; | heat recovery efficiency of ventilation units is from 60% to 95%; |
Heat sources are mainly gas boilers or municipal heating distribution networks, which allows quick adjustment to changing weather conditions; as heat pumps working parameters are low, it is necessary to predict and maintain constant temperature at all times, also when the building is not in use (kindergartens and schools during holiday or winter breaks).

The biggest number of flaws are in window and door framework elements, in fire-protection elements like smoke vents or fire protection windows. In one building there is a leak in the wall, which causes moisture, and in another building there is a crack in the thermal insulation of the exterior wall; Thermovision tests were performed during the COVID-19 pandemic. Some of the buildings operated on regular basis, some of them were not in use. The schools, sports halls and swimming pools were tested when out of service or before the opening hours. Kindergartens were used in accordance with the epidemiological regime. Indoor temperatures were maintained as under normal operating conditions. Because of a failure in the heating system in the sports hall in Bełdów, the inside temperature was 16.5°C.

**Figure 1.** Glazing to wall area ratio in conventional swimming pools.
Figure 2. Glazing to wall area ratio in energy-saving and passive buildings.

The infrared tests in energy-saving and passive buildings show the high quality of construction works. The buildings are properly constructed, with great attention to detail, only some minor defects were detected. The kindergarten in Strzegom, an old, rebuilt and thermo-modernized building, has a leak in the roof. The hotel in Bardo has linear thermal bridges on balcony connections. The extended and thermo-modernized historical building in Miękinia has a thermal bridge located on the framework. This thermal bridge occurred because the building was thermally insulated from the inside, which is not a common practice. There are also spot thermal bridges in the anchoring areas of the exterior stairs.

Most of the defects can be corrected by re-adjusting hinges and seals of windows and doors. The thermovision detected typical linear thermal bridges located at the area directly surrounding the window and door assembly. The wall thermal insulation layers are made properly and uniformly.

The infrared images interpretation must account for various elements which may distort the results. During the tests I detected the impact of the façade colour on the readouts. Similar observations were made by Alina Wróbel, PhD. The thermograms show temperature differences between façade colours on buildings insulated with the light wet method and covered with plaster of different colours. The absorption degree depends on the absorption coefficient of the plastered surface. Dark-coloured surfaces absorb more visible radiation than bright-coloured ones because radiation transforms into thermal energy. This phenomenon is observed on sunny days [37]. Infrared images also show the shading of façade areas.

After the construction was completed, all energy-saving buildings were checked for airtightness by BlowerDoorTest. The results are from 0.3h⁻¹ to 0.6h⁻¹.

In Poland, it is necessary to make a designed energy performance characteristics at the project stage. After the construction, the building should be audited for an energy performance certificate [38]. The analysis of the design documentation revealed inconsistency of available certificates and characteristics. Some buildings are documented as passive based only on the design data but the information was not verified after the construction works were completed. Most characteristics do not include actual thermal bridges or only include index values specified in related standards. One of the characteristics does not include thermal bridges of many balconies although the infrared tests revealed heat losses through these elements. A less experienced certifier may overlook some of the issues. It is necessary for a reliable certification to examine buildings and not only rely on their technical documentation.
Buildings should be certified based on calculations performed in one cohesive software programme and verified by certifiers performing precise re-calculations. The research by Xinxin Liang, Yaodong Wang, Mohammad Royapoor, Qibai Wu and Tony Roskilly [39], which demonstrates the actual difference in the energy consumption in existing buildings, proves that the certificates should be issued after reliable tests.

The primary energy ratio depends on the applied heat source, ground heat exchanger, additional photovoltaic cells and solar panels. This ratio and the usable energy ratio of heating and ventilating is calculated in energy performance. In some cases, the annual primary energy demand in the conventional buildings (250 kWh/m²a) is twice as much as in the passive buildings (120 kWh/m²a). However, one of the conventional buildings outperforms in this respect (94.6 kWh/m²a) some passive buildings (120 kWh/m²a). In the investigated passive buildings the primary energy ratio is lower by 50-85%, whereas the heating and ventilating-related usable energy ratio is lower by 67-74%.

Each reduction of primary energy consumption lowers carbon dioxide production. Research by Chiara Piccardo, Ambrose Dodoo and Lief Gustavsson [40] indicates the possibility to more than halve the CO₂ emission by adapting the building to an appropriate passive building standard. It confirms my observation and justifies my attempts to implement sustainable development in swimming pools, which, as already stated, are objects with high energy consumption and high CO₂ footprint.

During the infrared tests I noticed that in many buildings the windows were unnecessarily open despite a working mechanical ventilation. I talked to the users and identified the following reasons:

- the state sanitary and epidemiological airing recommendations for kindergarten buildings;
- unpleasant smell on the premises (e.g. body hygiene issues or “chemically” smelling decorations in the kindergarten);
- COVID 19-related sanitary regime recommendations – necessary room airing in public buildings;
- overheating;
- insufficient air quality caused by too many users in a room designed for less people;
- insubordination of office users – fluctuation of workers, some of whom are unfamiliar with the building operation technology. An example is opening the windows at the hottest time of the day despite a working mechanical ventilation with a recuperation system. The hottest air enters the rooms instead of being removed and the ventilation system works with doubled intensity to cool the space which is constantly supplied with hot air from the outside. This increases energy consumption.

The users indicated problems related to the improper adjustments of heating and ventilation parameters. In the kindergarten in Słomniki, the administrative staff complained about the insufficient heating in the rooms. In the design documentation I discovered that the rooms were provided with a subfloor heating. It was never switched on. Maintenance workers should be sufficiently trained and know how to operate the equipment.

Users have to change their habits, e.g. not switch the heating off when the objects are not used (holidays or winter breaks) as it takes time to restore the required temperature due to low heat parameter of thermal pumps, which undermines thermal comfort.

Passive buildings usually require the assumption of a certain base temperature, and its adjustment depends on the function of the room. Not all users feel equal thermal comfort at the same temperature settings. Some office workers or hotel guests find internal temperature of 20°C too low, particularly when seating for work, and use blow heaters [41].

The swimming pool is a type of building in which mechanical ventilation is indispensable. Higher humidity requires airtightness and appropriate building insulation thickness to prevent water from
condensing in the wall structure after reaching the dew point. The building airtightness required in passive housing protects the walls by preventing moisture penetration through cracks. In conventional buildings, warm and humid air enters the cracks and, after reaching the dew point, condenses in the cold part of the exterior barriers, causing moisture, moulding and, ultimately, structural damaging.

A further step in the passive housing development is the ‘be 2226’ concept, i.e. a building which does not require conventional heating, air-conditioning or mechanical ventilation. The idea assumes a well-insulated exterior envelope and a heat flow inside the building and an adjustable, multifunctional open plan of the interior and the structure. The thermal capacity of the walls allows to accumulate heat and reduce overheating of the building, which is impossible in EPS or mineral wool-insulated buildings [42]. In buildings based on the ‘be 2226’ concept, the exterior walls are composed of two layers of highly heat-insulating ceramic blocks. The ventilation is based on windows controlled by CO$_2$ sensors for the air inside the building [43,44].

Because of the COVID19 pandemic, I could not investigate any of the ‘be 2226’ buildings, However, on the basis of available documentation and publications I see the ‘be 2226’ standard possible and advantageous for public utility buildings.

I have not found examples of ‘be 2226’ swimming pools and I observe some limitations for the application of ‘be2226’ standards in these facilities (perhaps except office rooms) because the operation of swimming pool halls and sanitary facilities is based on mechanical ventilation, which provides users with necessary air and maintains appropriate air humidity. A solution could be a hybrid system with natural airing at night in the summer to lower the temperature.

6. Conclusions
Polish administrative districts usually choose sports halls and educational facilities, i.e. schools and kindergartens, to be built as passive buildings.

The highest number of thermal bridges is around fire window framework and staircase smoke venting elements. Such elements comply with fire protection standards but do not meet thermal insulation requirements.

Users should know how to manage the buildings. The buildings should be maintained by properly qualified and trained personnel capable of setting up and operating the ventilation system and the central heating equipment.

Buildings certification should be unified, and compliant with standards which should be verified at the design stage and after the building has been constructed (based on the actual consumption of utilities).

Swimming pools are easy to design in the Passive House standards because of the compact structure. The tests revealed that the conventional swimming pools are characterised by almost the same surface area to volume ratios as the passive ones.

The Passive House standard is the best option for swimming pools because airtightness, thermal capacity of the walls and mechanical ventilation (which also controls appropriate humidity level) are always essential in these facilities.

My research shows the advantages of implementing passive buildings as sustainable and cost effective solutions for swimming pools. In Poland it is possible to design and build an inexpensive passive school swimming pool within the ‘Dolnośląski Delfinek’ (Lower-Silesian Little Dolphin) programme.

The study not only contributes to the quality assessment of both conventionally constructed and Passive House public utility buildings but also highlights the importance of further comparative studies,
extending the scope by the ‘be 2226’ standard. Understanding the specific conditions in swimming pool halls, analyzing different functions of public utility buildings and comparing the conventional and Passive House facilities allows to choose the optimal construction standards. The tests and their results are unique and fill the gap in the field of public utility buildings with emphasis on swimming pools.

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