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Comparison of Passivhaus Concept Buildings Used for Indoor Swimming Pools in Cold and Hot Climates

Soğuk ve Sıcak İklimlerde Kapalı Yüzme Havuzlarında Kullanılan Passivhaus Konseptinin Kullanımına Yönelik Karşılaştırılması

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ÖZET

Pasif Ev (Passivhaus), binanın enerji verimliliği sağlayabilmesi için iç mekân konfor koşullarını göz önünde bulundurarak değerlendirilmesi gerekmektedir. Bu doğrultuda binanın ısıl özelliklerini, yalıtımını, ısıtma/soğutma sistemlerini, aydınlatmasını, sıcak su sistemlerini, doğal havalandırmayı, binanın konumu ve yönelimi ile dış mekân iklim özelliklerini ve pasif güneş sistemleriyle güneşten korunma elemanlarını kapsaması gerekmektedir. Pasif Ev konsepti ilk çıktığında amaç soğuk iklime sahip ülkelerde ısıtma yükünü hafifleterek var olan ısıyı daha verimli kullanabilmeyi sağlamaktır. Enerji verimliliğini sağlamaya engel olan tüm elemanlar soğuk iklime uygun olacak şekilde tasarlanmıştır. Pasif Ev'lerin kullanımları günümüzde de en çok konut yapılarında kullanılmıştır ve küçük ölçekli ofis, konut vb. yapılarda kullanımı yaygındır. Büyük ölçekli yapılarda pasif evlerin havalandırma, aydınlatma, ısıtma ve soğutma gibi ihtiyaçları mekân genişledikçe performansta düşüşe neden olduğu görülmektedir. Sıcak iklimlerde ise ısıtma yükünün az olmasıyla soğutma yükünün fazla olması güneşe göre yapının tasarlanması gerektiği sonucuna varılmıştır. Bu çalışmada da Almanya'da soğuk iklime sahip Münih'te Pasif Ev konseptine sahip kapalı havuz yapısı ile Türkiye'de Antalya'da uygulanan kapalı havuz yapısı karşılaştırması yapılmıştır. Yapıların birbirleri ile enerji performansları Openstudio ve ClimatePlus simülatör programları ile ölçümlenmiştir. Elde edilen sonuçlara göre sıcak iklimlerde pasif evlerin kullanımının soğuk ülkelerde kullanımlar kadar verimli ve kâr sağlayan sistem olduğunu göstermektedir. Yapılarda ısı köprüsü oluşumlarının engellenmesi ve malzeme kalınlıklarının öneminin tahmini etkilediği maliyet ölçümü ile hesaplanmıştır.

Anahtar Kelimeler: *Pasif Ev, Enerji Etkin Bina, Termal Konfor, Bina Kabuğu, Isı Köprüsü*

ABSTRACT

Passive House (Passivhaus) should be evaluated considering the indoor comfort conditions in order for the building to provide energy efficiency. Accordingly, the building's thermal properties, insulation, heating/cooling systems, lighting, hot water systems, natural ventilation, location and orientation of the building and outdoor climate characteristics, and passive solar systems and sun protection elements are required. When the Passivhaus concept was first introduced, the goal was to reduce the heating load in cold climate countries and use the existing heat more efficiently, and all the factors that prevent it were designed to be cold temperature-appropriate. Today, Passivhaus concept buildings are primarily used in residential buildings and are widely used in small-scale offices, residences, and other facilities. In large-scale Passivhaus installations, ventilation, lighting, heating, and cooling requirements expand, increasing energy consumption. The buildings should be oriented with the sun in hot climates due to the low heating load and the high cooling load. This study is a comparison of the indoor pool structure with the Passive House concept in Munich, which has a cold climate in Germany, and the indoor pool structure implemented in Antalya, which has a hot climate in Turkey. In this regard, OpenStudio and ClimatePlus simulation programs are used to conduct research. The results obtained show that the use of Passivhaus in hot climates is as efficient and profitable as the use in cold temperatures. It is concluded that preventing the formation of thermal bridges in buildings, the thickness of the insulation materials, the importance of heat permeability, and conductivity coefficients also affect the annual cost.

Keyword: *Passivhaus, Energy Efficient Building, Thermal Comfort, Building Envelope Surface, Thermal Bridge*

1. INTRODUCTION

Today, with the increase in population and the development of technology, supply the increasing energy need causes a decrease in fossil fuels. The technological developments that started after the industrial revolution increased fossil fuel consumption and carbon dioxide emissions yearly. Worldwide energy needs increasing by 2.3% in 2018, indicating the highest growth rate in the last ten years (IEA, 2019). Buildings account for 40% of global energy use and 36% of global CO2 emissions (Kurt, 2012). In addition to the usage period in buildings, energy is also needed in the building and material construction process. The embodied energy of a material is the total amount of energy used to possess that material. This energy contains all the energy required for the raw material's extraction, transportation, and processing. Materials that have the most embodied energy per kg are usually related to metals or processes that require materials such as cement or ceramics formed by firing to reach high temperatures. These energy values are 2,598 MJ / m2 for ceramic materials and 124 MJ / m2 for wood materials. Every construction material releases CO2 over its entire life cycle, beginning with the manufacturing process. Global CO2 emissions from fossil fuel consumption and cement manufacturing grew by nearly 60% between 1990 and 2015 (PBL, 2020).

Heating, cooling, ventilation, and lighting consume a significant portion of the total energy consumed by the building. Building energy efficiency has a significant impact on lowering overall energy consumption in Europe; as a result, boosting building energy efficiency is one of the European Union's top priorities (Obrecht et al., 2019). Climate change has a significant impact on the building industry and many other industries, and the construction business consumes a considerable amount of energy. In Turkey, the transportation sector accounts for 20% of total final energy consumption, industry 43%, and buildings 37% (İnan and Başaran, 2014).

For the building to provide energy efficiency, taking into account the indoor comfort conditions, the thermal properties of the building, its insulation, heating/cooling, ventilation, lighting, hot water systems, natural ventilation, the location and orientation of the building and outdoor climate types, passive solar systems and sun shading elements need to be covered. Building demands such as heating, cooling, ventilation, and hot water preparation account for 75% of total energy use in homes (Kurt, 2012). According to the Turkish National Energy Efficiency Action Plan released by the Ministry of Energy and Natural Resources in 2016, the insulation applied to the exterior walls and the insulation in the buildings may lower the heating demands of the structures by 35 percent (ETKB, 2016). Thus, with the need to establish specific criteria in energy conservation, certain standards were needed to evaluate the environmental performance of buildings (Şahin Ergün, 2019). In some countries, building certification systems have been developed to improve performance. Today, there are more than thirty green building certificate rating systems developed by various governments (Öztürk, 2015). While all certification systems evaluate building performance, Germany also considers environmental and socio-cultural quality standards, unlike the certification system in other countries. These consist of economic quality, land quality, process quality, technical quality, and socio-cultural quality. The Passive House concept is a certificate system based on energy conservation of material, building components and building envelope performance. The Passivhaus Institute (PHI), established in Germany, is valid worldwide. From small-scale residential buildings to large-scale hotel buildings, including newly constructed buildings or renovating existing buildings, Germany, in particular, places a strong emphasis on sustainability, thanks to the development of passive structures and the focus on ecological footprints.

Germany was one of the first countries to start using passive energy and renewable energy. For this reason, it is leading other countries in this effort, especially in the building construction and operating system by Passive House standards. Germany is a cold and moderate region, and applying its buildings to this climate will not have the same effect in a hot and humid area. The building materials for each region, the construction methods and the targeted indoor temperature value (heating and cooling loads according to the external weather conditions) will differ. Instead of applying the construction methods following Passive House standards in cold climates with high heating loads, suitable comfort conditions should be determined for Antalya, where continuous cooling loads are high in summer. For this comparison, the construction methods, the users of the building, the building materials used, and the heat transfer coefficients will be examined on two sample buildings. This review will be an exemplary study in terms of deficiencies and completion in Turkey by comparing with the help of simulation. In this study, the building comfort values of a building that can keep the comfort of the building high in a large-scale facility in Germany and a building with the same function in Turkey will be compared.

Indoor pools are used for recreational, sports, and therapeutic purposes. These indoor pool buildings with high energy consumption must ensure that the occupants have enough indoor air quality and thermal comfort while also utilizing less energy (Sobhi, 2022). According to Li et al. (2021), a large amount of heat is needed to maintain the thermal comfort of both indoor and outdoor swimming pools in cold seasons. This motivates the development of various heating technologies aiming to reduce energy use, as well as operating and investment costs. In this context, the methods applied in cold climates can be implemented thanks to the Passivhaus construction concept, providing energy efficiency and reducing cost. There is no definite application example for this in hot climates. In this case, the study examines the performance of buildings with the same function by selecting indoor pool structures from two different countries and different climates. Both of these buildings have an indoor pool on the ground floor and spaces with different functions on the upper floor. Bambados Indoor Swimming Pool in Munich, Germany, was chosen as one of the buildings to be examined as a sample. In this structure, which consists of a sauna, gym, swimming areas, and changing rooms, the swimming area with high humidity was chosen. This building, which has a passive house certificate, was completed in 2011. The other sample is the indoor swimming area, sauna, dressing rooms, and gym, the entertainment section of the Jacaranda Hotel in Antalya (Side), Turkey. Only the swimming area will be included in the simulation in this study. The average regions of 600-800 m2 in these locations have high humidity. This building, which does not have a passive house certificate, was completed in 2013. The materials used, the construction method and the design methods for the building envelope were all examined.

There are only three buildings in Turkey as Passive House standards (SEPEV, 2020; Demirel, 2013). These buildings, completed in 2011, 2015, and 2016, have been certified by the Passive House Institute (PHI Database, 2020; PHI, 2020). The small-scale implementation of these three structures, which have been carried out in the last ten years, shows that it has just begun to develop, and the importance of studies on this subject is becoming more widespread day by day. This research aims to contribute to the development of Passive House structures in Turkey that offer comfortable and efficient energy consumption in large-scale swimming pool buildings. The thickness of the insulation materials, the formation of thermal bridges, and the humidity-temperature values affect the comfort in the space. For this reason, in this study, which will measure the effect on the cost, two different structures from Germany/Munich and Turkey/Antalya will be selected, and the materials used will be compared with the impact of the climate. The air thermal permeability coefficient of the materials, the thermal conductivity coefficient, and the heating and cooling loads according to the external weather conditions will be examined by comparing them with simulation tools. This comparison aims not only to use the Passive House concept in cold countries but also to ensure that their use in hot climates is met with less cost than their energy needs and more energy-efficient buildings.

2. PASSIVE HOUSE BUILDING DESIGN

A Passive House is a building standard that is energy efficient and comfortable. Passive House is not a brand name, but a construction concept that can be applied by anyone, anywhere. The Passive House includes buildings components such as wall and construction systems, windows, doors, connections, ventilation systems and compact systems (PHI,2020). These structures are specially designed by taking into account the sun, wind, and physical characteristics of the environment. When these structures are compared with other systems, it has been concluded that there is an average of 10 times less heat energy difference (Badescu and Sicre, 2003). The goal of Passive Houses is to standardize the process of enhancing energy efficiency. As a result, the Passive House's basic concept is centered on a method for limiting heat movement from the building envelope through improving insulation (Georges et al., 2014). The primary benefit of Passive House is that it lowers running costs by conserving energy and preventing internal thermal disturbance. The application examples whose construction was finished with the literature research considered all life-cycle activities, including material procurement and manufacture, on-site construction and use/maintenance, destruction of materials, and 70-year building life.

The passive house was first adopted in Germany in 1991 (Schnieders et al., 2015). Passive solutions such as insulation, low U-value windows, airtightness, and thermal bridge prevention were highlighted. Then, applications were developed in Austria and Switzerland (Schnieders et al., 2015). This concept, designed in a moderate climate zone, was later applied in cold climate zones. Passive House standards also created differences based on climatic conditions in Denmark, Sweden, Norway, Estonia, and Canada.

The passive house continued to be implemented and adjusted based on local climatic conditions (Wang et al., 2019). These studies are significant in evaluating passive techniques; however, they are confined to residential structures. These are focused on a climatic zone's unique or traditional architectural design language. According to Walikewitz et al. (2015), the average air temperature fluctuates depending on the size of the window, the exposure length, and the intensity and duration of direct solar radiation entering the room (Manu et al., 2019). Pisello and Cotana (2014) developed a roof solution in a traditional residential building in Italy that decreases peak indoor heating in the attic by up to 4.7°C in summer. These options may differ depending on the temperature and location of the passive buildings. Apart from Europe, there are some studies have been conducted in Korea (Kim, 2006), China (Borong et al., 2004), Japan (Ooka, 2002), and Turkey (Şerefhanoğlu Sözen and Gedik, 2007). All of this demonstrates the value of studying traditional architecture and development. Passive system applications such as the use of adobe constructions, the positioning of buildings according to the sun, the effect of spaces with courtyards or tiny windows according to the wind and temperature of the region have been noticed in particular studies in Turkey.

Completed certified buildings represent actual examples in the evaluation of passive strategies. The Frankfurt Höchst Clinic, which was the first Passive House hospital structure in 2020 with the Passive House concept that received the PHI certificate, the Explorer hotels (Germany and Austria), the first Passive House hotel structure in 2009 and 2014, the Ravensburg Art Museum, the first Passive House museum structure, in 2012 and the 2004 Passive House. These are the first Passive House structures implemented in Germany, such as the Montessori School, the first Passive House education building in 2007 (Passivhaus-Hallenbad Bambados Monitoring, 2011). However, most of the Passive Houses implemented other than these new examples are limited to residential buildings. This study focuses on the local and traditional architectural design language, especially in the climate zone when suitable comfort conditions can be applied in newly constructed buildings and reuse existing or historical buildings.

3. METHODOLOGY

In this study, buildings with the same function and completed in two different climates will be compared by simulation tools. One of the buildings, as an example, the Bambados Indoor Swimming Pool area, which is the first indoor swimming pool in Passive House standard as a large-scale structure in Munich, Germany, will be examined. In this structure, which consists of a spa, gym, sauna, swimming areas, and changing rooms, only swimming areas will be reviewed for the article. And also, passive house construction methods according to the moderate-cold climate, the differences in the U values of the materials used according to the environment, and the effect of the sun on the building will be examined mechanically and passively for the swimming pool. The other example will be analyzed as a large-scale case study in Side, Turkey, using ClimaPlus (2020), EnergyPlus (2020), and OpenStudio (2020) simulator tools to simulate an indoor swimming pool in a hotel building roughly equal to the other instance. The Munich and Antalya climate files in EPW format from the Climate One Building website were loaded into the program before the models were simulated using the EnergyPlus simulation to alter all environmental parameters. The ASHRAE Design Conditions Design Day Data (DDY) file was also used to import the design day. After applying the 3D design that defines the spaces for both models in OpenStudio, window/door areas and thermal insulation areas are specified. The roughness, conductivity, and density properties are processed by entering each material's U values and thicknesses used on the structure. All buildings are processed from floor to ceiling, and the results are examined by comparing two sample spaces. With the ClimaPlus simulation, the solar radiation graph falling on the building, indoor heat accumulation values , and heating and cooling months are reached. With these simulations, the humidity-temperature and heat loss rates will be compared, and the effect of thermal comfort areas on the cost in hot and cold climates will be examined.

3.1 Location and Climates

For example, compared to Turkey, especially Germany, the indoor swimming area is where Passive House standards first started. The fact that the first indoor swimming hall was built in Germany in 2011 at Passive House standards shows a leader in this significance. The selected sample buildings have different climate types. The Köppen-Geiger climate classification methodology divides climates into five main groups based on yearly and monthly temperature and rainfall: A (tropical), B (dry), C (temperate), D (continental), and E (polar). The second letter denotes the kind of seasonal precipitation, while the third indicates the degree of heat (Wikipedia, 2020). According to the Köppen-Geiger climate classification, Munich has a Dfb climate that is all-season rainy, winters heavy rainfall, and summers cool weather. It is crucial that the building materials used for Munich, which has a large-scale moderate-cold climate zone, keep the humidity constant in the place, the temperature values do not change according to the outdoor space, and the ventilation should be at the forefront. According to the Köppen-Geiger climate classification, Antalya has Csa (Mediterranean climate) climate in which winters are warm; summers are sweltering and arid.

Table 1. Climate Characteristics of Selected Regions (Climate Data, 2021; Wikipedia, 2020).

Province/ Country	Munich, Germany	Antalya, Turkey
Latitude	48° 08' N	30° 42' N
Longitude	11° 34' E	36° 53' E
Elevation (meters above sea level)	550 m	9 m
Climate	All season rainy continental climate Dfb	Summers hot and dry, Winters warm and rainy Csa
Annual average temperature (° C)	8,8 ° C	18,6 ° C
Maximum temperature value (° C)	22,8 ° C	34,1 ° C
Lowest temperature value (° C)	-5 ° C	5,8 ° C
Average humidity (%)	67%	70%
Daily Radiation Value (kWh / m2)	3,3 kWh/m2	4,5 kWh/m2
Annual solar radiation value (kWh / m2)	1204 kWh/m2	1646 kWh/m2
Annual average sunshine duration (h)	1780 h	2413 h

According to the climate values given in Table 1, it is seen that the temperature and solar radiation values in Turkey are higher than in Germany. The increase in temperature and the outdoor temperature add to the heat of the indoor spaces. Figure 1 and Figure 2 depict the graphics of the hourly heating and cooling degree days for each month in Munich and Antalya based on temperature values in outdoor situations. The number of heating degree days (HDD) and cooling degree days (CDD) in the graphics is a characteristic that is used to determine insulation, heating, and cooling expenses while constructing a building. The yearly number of warm days in Munich is 210, whereas the annual number of cooling days is 30. According to the Turkish State Meteorological Service (2020), the number of heating days is 124 days, and the number of cooling days is 148 days (MGM, 2020).

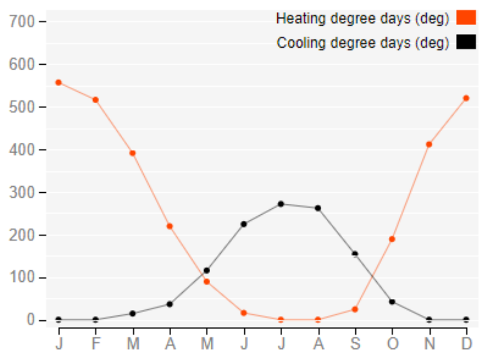

Figure 1. Munich heating and cooling needs

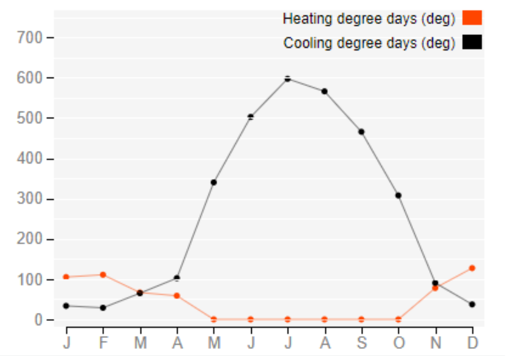

Figure 2. Antalya heating and cooling needs

Figure 3 and Figure 4 show the kWh values per square meter of the buildings located in the selected regions on the south, north, east, and west facades. Figure 3 and Figure 4 show the kWh values per square meter of the buildings located in the selected regions on the south, north, east, and west facades. The first graph (Figure 3) shows that directing towards the south in cold countries will give positive results since Munich, in a cold climate, gets too much sun on the south side. The second graph (Figure 4) shows that directing towards the southwest in hot countries will give positive results since Antalya, in a hot climate, gets too much sun on the southwest side.

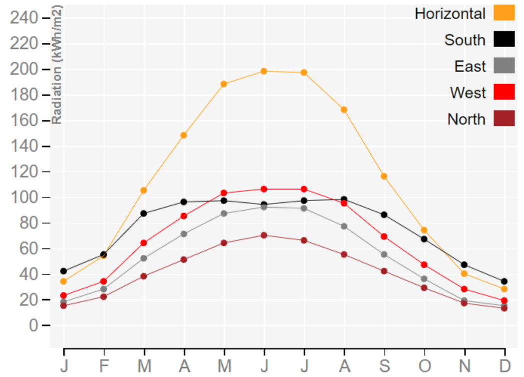

Figure 3. The solar irradiance per square meter in Munich (kWh/m2)

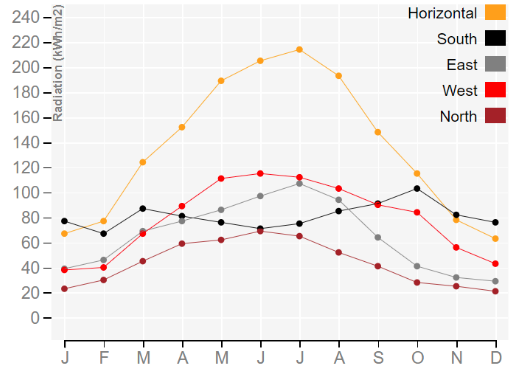

Figure 4. The solar irradiance per square meter in Antalya (kWh/m2)

3.2 Choice of Model Buildings

The square meters of the buildings to be analyzed were chosen close to each other. While researching, the addition of solar panels system and the use of HVAC systems are examined separately due to the differences in heating and cooling loads against climate. Figure 5 and Figure 6 show the currently selected buildings. Indoor pool areas in both buildings are on the ground floor. The upper floor of both buildings is a different function, the lower floor is the basement. Figure 5 and Figure 6 show the currently selected buildings.

Figure 5. Bambados Indoor Swimming Pool Munich, Germany

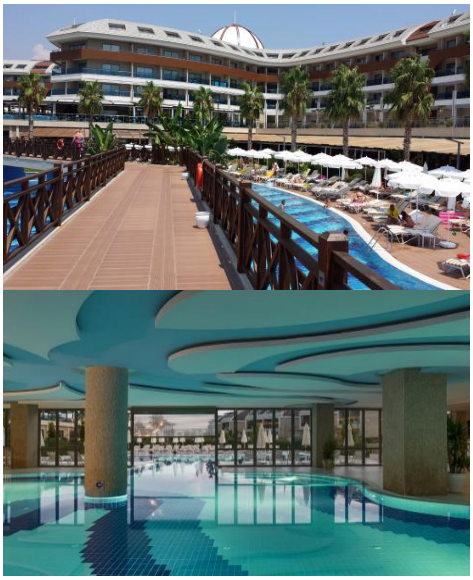

Figure 6. Jacaranda Hotel Indoor Swimming Pool Antalya, Turkey

The spa, sauna, Turkish bath, changing rooms, and gym within these structures are not within the scope of the article.

3.3 Choice of building performance simulation tools

In this study, Munich and Antalya climate data and information about the design will be guided by the Climaplus simulation. Solar radiation, radiation value graphs based on facades, temperature, and Psychometric graphics data are examples. These data values must be used in the procedures applied to the structures. Energyplus and OpenStudio simulator programs simulate sunlight, thermal comfort, ventilation, and energy modeling in the building. The swimming pool sections are then modeled on the plan, and the structures' inner space and outside walls are examined.

3.4 Passive House requirements and evaluation criteria

The primary premise of passive buildings is to keep all heat fluxes in and out of the building envelope as low as possible. Passive solar energy gains are beneficial to passive houses. Passive House structures that emerged in Germany continued to be built in cold climates. By 2015, there were 25,000 approved buildings in Europe, most located in Germany and then in the Scandinavian region. Therefore, the general principles planned for cold climates and moderate climates are as follows:

1. Without a separate heating and air conditioning system, a comfortable interior climate can be achieved: The annual heating need may be no more than 15 kWh / (m2a) according to the Passive House Planning Package (PHPP).

2. Passive House thermal comfort criteria must be met in every living space, both winter and summer. The following component properties are frequently the outcome of this:

- External component U-values must be less than 0.15 W / (m^2K).
- Windows and other transparent components must have less than 0.8 W / (m^2K) U-values.
- Transparent areas facing west or east (± 50 °) and translucent areas with inclinations below 75° to the horizontal must not take up more than 15% of the useable space behind them, or they must be protected from the sun with a reduction factor of at least 75%. Behind the south-facing windows, the maximum useable space is just 25%.
- The supply air temperature at the room's air outlet must not drop below 17 degrees. It is necessary to ensure that airflow is consistent throughout all rooms and areas (ventilation efficiency). The ventilation system must first and foremost be built for air cleanliness (DIN 1946). The ventilation system's noise level must be low (<25 dBa).
- The houses must have at least one openable outside air opening in each living space, and outside air must flow through the flat (free summer cooling).

3. The total demand for primary renewable energy (PER, as defined by the PHI method) for all household uses (heating, hot water, and household electricity) cannot exceed 60 kWh / (m^2a). PHPP is used to calculate the result.

The following five main principles guide the development of passive houses:

- Thermal insulation: All opaque components of the house's outside shell is so effectively insulated that they have a heat transfer coefficient (U-value) of no more than 0.15 W / (m^2K), which means that no more than 0.15 watts are lost per degree of temperature differential and square meter of the outside surface.
- Primary energy criteria: the energy consumption of all electrical equipment, including interior heating and used hot water, must not exceed the limit of 120 kWh /m.
- Passive house windows: The windows (glazing including the window frames) should not exceed a U-value of 0.80 W / (m^2K), with g-values around 50% (g-value = total energy transmittance, proportion of the solar energy available for the room).
- Ventilation: Heat recovery is achieved by ventilation. Comfort ventilation with highly effective heat recovery produces good indoor air quality and saves electricity. A heat exchanger returns at least 75% of the exhaust air from the fresh air in a passive home.
- Airtightness of the building: Leakage through uncontrolled joints must be less than 0.6 house volume per hour when tested with negative/positive pressure of 50 Pascal.
- Airtightness: According to the EN 13829 standard, a pressurization test should be performed on the building envelope, which should not exceed 0.6 h-1.
- No thermal bridges: Thermal bridges must be avoided by planning and executing all edges, corners, connections, and penetrations with extreme caution. Thermal bridges must be reduced as feasible if they cannot be avoided.
- Comfort criteria for indoor temperature in winter: The temperature inside the building should be kept above 20 °C.

- Comfort criteria for indoor temperature in summer: The temperature inside the building must remain within the comfort range defined in the EN 15251 standard. If there is an active cooling system, keeping the temperature below 26 ° C and not exceeding the temperature is necessary.

It has been observed that passive houses in terms of cooling load in hot climates may vary according to the environment. This situation will also be discussed in this study.

4. RESULTS AND DISCUSSION

The Bambados Indoor Swimming Pool is a modest glass building with a completely glazed open garden space on the north façade and a compact structure with a small glass area on the north façade. Locker rooms, administrative offices, and a spa area north of the building. The leisure and training pool is located to the southeast, while the sauna is southwest. Skylights light up the pool and patio areas. In particular building sections, there is a basement (technical floor). The foundation was built using drilled piles. The floor slabs in the basement and the non-basement size are insulated. Bored piles on the side of the building have additional insulation.

The building's thermal and thermal transmitting properties are summarized in Table 2. The efficiency of Passive Solar Design techniques is proportional to the size of the structure. When a building's size and scale surpass the Passive Solar Design components' criteria for the natural flow of conditioned air, mechanical help is necessary to disperse the gathered solar heat throughout the building. Fully active systems' efficiency may suffer, and the combination of Passive Solar Design and building design may be jeopardized. As a result, spaces with similar square meters were compared to highlight the consequences of different tactics on building design, which was the primary goal of this study.

Table 2. Thermal transmittance and used materials of the selected indoor swimming pools (Passivhause Institut Database, 2020)

Country	Bayern, Germany	Antalya, Turkey
Treated Floor Area	861 m^2	634 m^2
Construction type	Masonry construction	Masonry construction
Year of construction	2011	2013
Exterior wall: *U-value*	Reinforced concrete 2.300W / (m²K) 250mm, Mineral wool 0.035W / (m²K) 300mm	Reinforced concrete 1.1W / (m²K) 200mm, Stone wool 0.038W / (m²K) 50mm
Basement floor / floor slab: *U-value*	Reinforced concrete 2.300 W / (m²K) 400mm Insulation 0.045 W / (m²K) 300mm Screed 1.400 W / (m²K) 50mm	Reinforced concrete 1.1 W / (m²K) 200mm Insulation 0.03 W / (m²K) 60mm Screed 1.4W / (m²K) 30mm
Roof: *U-value*	Polystyrene rigid foam 0.035W / (m²K) 360mm Reinforced concrete 2.300W / (m²K) 260mm Wood 0.097 W / (m²K) 380 mm Concrete 0.095 W / (m²K) 610mm	-
Frame: *U-value*	PR element U 0.830 0.030m PR glass door U 2.00 width 0.170m RWA pencere U 1.24 width 0.108m aluminum-glass door U 2.30 width 0.135m	Window U: 2.4 width 0.012 m Door U: 4
Glazing: *U-dvalue*	U_g -value = 0,54 W / (m^2 K) g-value = % 49	U_g -value = 0,13 W / (m^2 K)
Airtightness	n_{50} = 0,07 / h	-
Heating Load *(annual)*	2423 h	542 h
Cooling Load *(annual)*	27 h	891 h

Airtightness is particularly important in indoor swimming pools due to the physics of the building. Essentially airtightness means a draught-free building envelope, protecting all of that heated air from inside your building from leaking to outside (Novo Design, 2020). In these chosen buildings a part of the main material concrete forms the airtight layer. In addition, thermal measuring instruments show that the connections (Figure 7) between the window and the wooden roof and the joints of the precast concrete elements are among the places to be considered.

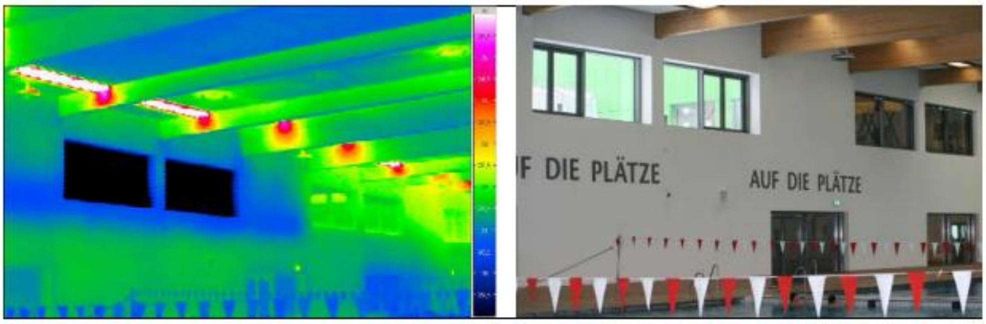

Figure 7. Thermal Bridges in Bambados Indoor Pool
https://passiv.de/downloads/05_hallenbad_bambados_monitoring_endbericht.pdf

Aluminum profiles are used for window frames. PVC frames were used only in technical rooms in the basement. The glass is applied with triple insulating glass (average: Ug = 0.54 W / (m²K), g-value = 0.49). Triple glazing has more heat retention than double glazing.

The essential condition for having an energy-saving structure is to have an airtight building envelope. Preventing thermal bridges or minimizing heat transfers is crucial in energy-saving building construction. In addition, directed ventilation is vital to avoid increasing humidity or keep it constant with evaporating water vapor in the indoor pool. Large areas of an indoor swimming pool have significantly higher indoor temperatures and humidity. Therefore, it is necessary to increase airtightness, mainly to preserve the indoor measured values. As a result, during the planning stage, the needed discount for Passive Houses with an air exchange rate of n50 = 0.6 h-1 for Bambados was applied as n50 = 0.2 h-1. It must function as an indoor swimming pool and the structure's scale.

The swimming pool was planned and built-in conjunction with Combined Heat Power (CHP). This local energy, produced with renewable raw materials, is another factor that contributes to the overall ecological concept of Bambados. The building is mainly heated by fresh air.

The results obtained in the simulation according to the energy efficiency show the appropriate temperature and humidity values of the dotted areas in Figure 8 and Figure 9 as two separate psychrometric charts. The values in the x-axis show the temperature, and the values on the right show the absolute humidity. The curved line indicates the relative humidity, and the values above the outermost parabola indicate the enthalpy (energy) value. At these points, it can be read from the graph that when the humidity increases in indoor pools, the temperature value should decrease, and the necessity of these values changes to prevent condensation in the interior. The difference between the two figures is that the density of points in comfort areas is higher in Antalya. According to the data, the marked blue area shows the comfort zone. It has been found that there are 900 hours of comfortable space for the Antalya indoor pool between 08:00 and 20:00 per year and 673 hours of a comfortable room for the Munich indoor pool between 08:00 and 20:00. The yellow area shows the high thermal mass area, and the pink site offers the passive solar energy recovery area.

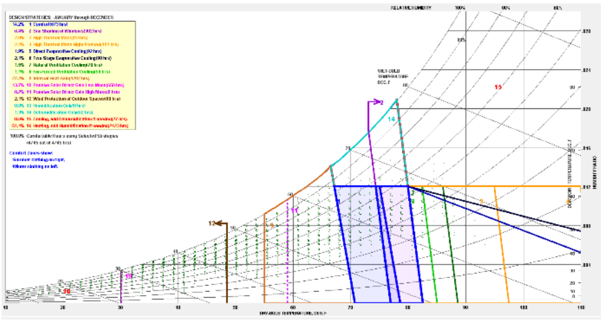

Figure 8. Psychometric analysis graphic of Munich indoor swimming pool

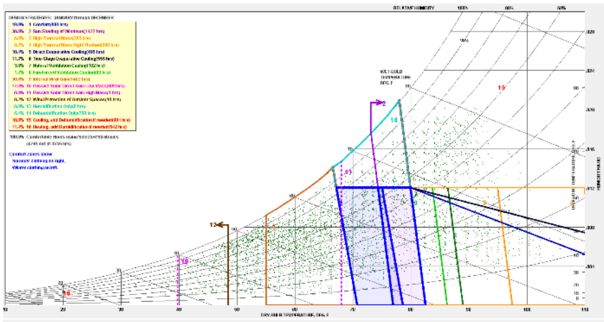

Figure 9. Psychometric analysis graphic of Antalya indoor swimming pool

The data obtained according to the psychometric analysis are shown in Figure 10 as a comparison.

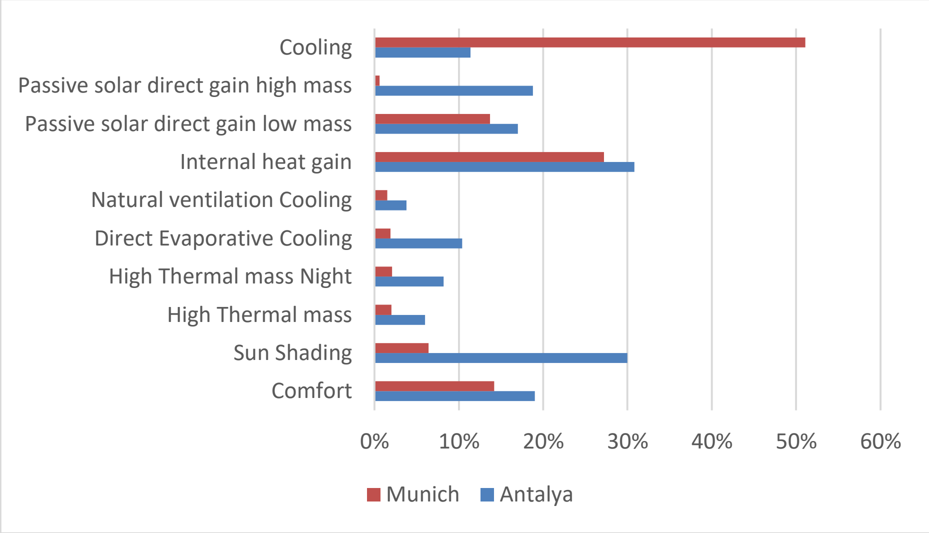

Figure 10. Comparative of indoor comfort values for two indoor swimming pools.

As a result of comparing the two indoor pool models, it was concluded that the heating load was higher 51.1% in Munich, and the cooling load was higher in Antalya by 18.8%. Passive solar gained by 17% in Antalya and 13.7% in Munich, which is close. The proximity of the values here means that the heat gain in Munich can be kept thanks to the insulations, and the heat loss is prevented in the interior against the cold air outside. The fact that the total heat gain is 27.2% in Munich and 30.8% in Antalya shows that passive solar gain has an effect. The high solar radiation value in Antalya also reveals the difference. The high thermal mass pointed out in Figure 10 shows that the amount of day and night heat is kept high in Antalya, and it is seen that the amount of natural ventilation and cooling are balanced. These values were evaluated as heating for five months and cooling for four months in Antalya. According to Figure 10, the internal heat gain is close to 30.8% in Antalya, a hot climate, and 27.2% in Munich, a cold climate. Sunshades on the windows on the south façade of the sample building in Antalya are more significant than in Munich in terms of solar radiation value. Results demonstrate how it can help with the cooling burden in the building's internal heat gain. When looking at Figure 10, it is clear that comfort is better than in Munich. The sample put in Antalya has a comfort rating of 19 percent, whereas the selection placed in Munich has a comfort value of 14.2%.

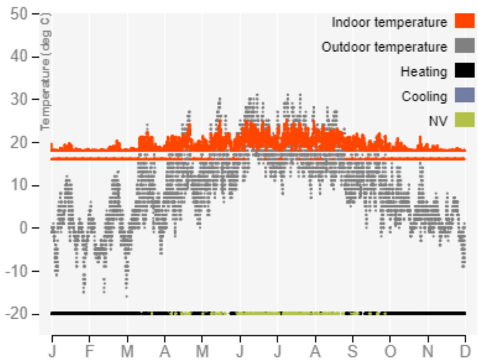

Figure 11. Uncomfortable hours due to high temperature in Munich

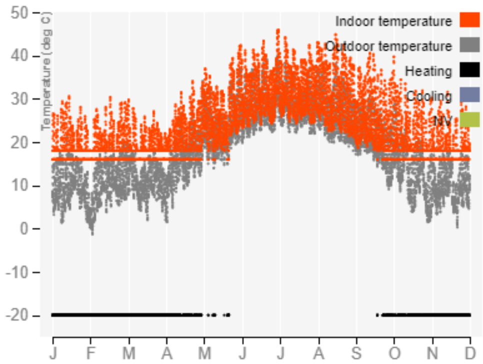

Figure 12. Uncomfortable hours due to high temperature in Antalya

The indoor pool in Munich has a total area of 861 m2. Figure 11 shows the graphics of indoor and outdoor weather conditions. It has been observed that the indoor temperature in the graph is 25 degrees on average, and no disturbing heat is observed. The diagram of the indoor pool with a total area of 634 m2 in Antalya is shown in Figure 12. Uncomfortable indoor air temperature between May and October indicates the need for natural ventilation and additional cooling load. In Table 3, the temperature difference between indoor and outdoor air conditions to reach the heat loss rate and annual heating losses. According to Munich weather conditions, it was concluded that it has -12 degrees outside weather and 11 degrees Antalya outside weather conditions.

Table 3. Annual heating/cooling losses and costs for two pools

		U-value *W / m²K*	Heat Loss Rate *W*	Annual Heating Losses *kWh / yıl*	Annual Heating Costs *€ / yıl*	Annual Cooling Losses kWh / yıl	Annual Cooling Costs € / yıl
Munich / Germany	Exterior wall (south)	0,113	52	110	723,58	15,66	103,37
	Interior wall (north)	0,144	646	1357	8957,33	193,88	1279,62
	Interior wall (east)	0,144	665	1397	9220,78	199,58	1317,25
	Interior wall (west)	0,144	665	1397	9220,78	199,58	1317,25
	Exterior window	1,24	5565	11687	77132,56	1669,54	11018,94
	Interior door	2,3	143	301	1988,23	43,04	284,03
	Roof	0,095	2699	5668	37411,40	809,77	5344,49
				Total €	**144654,66**	**Total €**	**20664,95**
Antalya / Turkey	Exterior wall (south)	0,628	75	93	616,75	138,30	912,78
	Interior wall (north)	0,439	500	621	4095,76	918,44	6061,73
	Interior wall (east)	0,439	595	738	4871,80	1092,47	7210,27
	Interior wall (west)	0,439	606	751	4958,03	1111,80	7337,89
	Exterior window	2,4	2448	3036	20034,43	4492,57	29650,96
	Interior door	4	91	112	742,45	166,49	1098,83
	Roof	0,628	4778	5925	39101,71	8768,26	57870,53
				Total €	**74420,94**	**Total €**	**110142,99**

When the building materials of the two countries are compared, the U-value (airflow coefficient) is low compared to cold climates, preventing the generation of thermal bridges with low conductivity. While the building material is applied in hot climates, the U-value is high, which means the heat loss is high. In this case, as seen in Table 3, the rate of heat loss varies according to the U-value, the temperature value of the indoor, and the lowest temperature of the outdoor area. While the lowest air temperature in Munich is -12 degrees, the indoor temperature is 21 degrees and has a total temperature difference of 33 degrees. The rate of heating loss varies depending on the U-value and the square meter of the wall. The annual heating loss is calculated by multiplying the U value by the temperature difference and multiplying the result with the annual heating time. Based on the current charge in Germany, the cost is calculated by multiplying the obtained findings by 6.6 € (Passipadia, 2020). In Antalya, the price is also calculated in Euro (€) currency to make the comparison easier. The overall expenses of heating and cooling are similar, according to the statistics in Table 3. While heating is seven months and cooling is one month in Munich, it is five months for heating and four months for cooling in Antalya. In Munich, the total cost of heating and cooling is 165,319 €, and in Antalya, the total cost of heating and cooling is 184,563 €. When the U values of the materials used in Antalya, which has a hot climate, are replaced with the U values of the building materials used in Germany, the annual average cost is 53.002 €. Results indicate that the average profit from building a whole indoor pool will be 131,561 Euros.

The low thermal conductivity values of building materials in Antalya are due to the thickness of the insulation materials used. For example, the thickness of the building material in the building in Antalya is 50 cm, while it is 300 cm or more in Munich. Although the conductivity factor of the building materials is close to each other, the thickness of the material used affects the prevention of thermal bridge formation more.

5. Conclusions

Despite the increase in technology and the adoption of energy-efficient technologies, gaps in the literature remain that limit our understanding of the impact of policies on the adoption of energy-related technologies. As the scale of the building grows, the importance of passive house use becomes evident. The Passive House requirements are a sustainable construction standard that, thanks to a vote by the European Parliament on January 31, 2008, will be applied by all member states until 2011. According to the Energy Efficiency Law

No. 5627 and the Energy Performance in Buildings regulation issued in response to this law, energy needs, insulation properties, heating and cooling system efficiency, and building energy consumption classification have been made in all facilities in Turkey since January 1, 2011. As a result, issuing an Energy Identity Certificate has become essential, and existing buildings must also receive this document by January 1, 2020. The European Parliament and the Council set this date in 2009 as the deadline for new buildings to be converted to buildings with low energy efficiency requirements.

Although Passive House standards are used for small-scale buildings and cold climates today, insulated buildings with good comfort conditions in hot and humid climates such as Antalya show that they significantly reduce cooling loads such as heating loads. This study it is aimed to provide thermal comfort of moist areas of large-scale indoor pool areas. For this reason, the method for reducing heating and cooling loads has been examined. Although the interior space dimensions of the two structures being compared are close to each other, it has been concerned that the comfort conditions in the interior are different depending on the climate, the thickness of the insulation materials, and the thermal permeability coefficients. As the thermal permeability coefficient decreases, the temperature value in the interior is preserved for a long time. Building materials with the most negligible heat permeability were used in Munich climate conditions, and building materials with high heat permeability were used in Antalya, where heat gain was constantly lost. If the materials used are the same, the thickness of the material has a significant contribution. Because as the thickness of the material increases, the heat permeability of the structure decreases. When the annual heat loss rates are compared, if the U value ratio of the materials used in Munich climate conditions is used in Antalya conditions, it will be more profitable than the current situation. In this case, the amount of heating and cooling costs corresponds to approximately 2.5 years.

Passive Houses in the Mediterranean region need less insulation than in Germany. Instead of triple glazing used in Germany, double glazing is sufficient in Turkey. Therefore, the south orientation of the building is as important as the location planning. The presence of a heat recovery ventilation system shows that it is an essential component for the location of the study. It is vital to have movable sunshades from outside to reduce the sunlight, especially in summer, in buildings oriented towards the south in Antalya, which receives much sunlight.

Besides the heating load, the cooling load is significantly higher in the Mediterranean region shows that thermal comfort is not only related to heating. It shows that insulation is also vital to prevent unwanted heat loss in case of cooling of the interior space with natural ventilation or operation of coolers in the area. It is crucial in this context to keep the energy consumption to a minimum and keep its own heat need in an ideal state for a long time. The corners of the space where the thermal bridge is located, the roof joining details, and the construction method of the window/door joint gap are not included in this subject. However, this subject can be studied in future studies and contribute to the literature. The study shows how the low heating energy consumption and the consequent low operating costs can be combined with a high level of thermal comfort. It is aimed that similar studies will increase in Turkey and be significant in terms of sustainability.

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