Passivhaus

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Passivhaus or Passive House buildings are low-energy buildings in which the design is driven by quality and comfort, hence achieving acceptable levels of comfort through post-heating or post-cooling of fresh air. Additionally, Passivhaus building design follows the Passivhaus design criteria, as described in the Passive House Planning Package (PHPP). This article aims to introduce the Passivhaus background, development, and basic design principles. Finally, it also presents a brief description of the performance of Passivhaus buildings.

Keywords: Passivhaus ; Low-energy buidlings ; Energy-efficient buildings

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A Passive House, or “Passivhaus”, which is the original German term, is: “[…] a building, for which thermal comfort (ISO 7730) can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions—without the need for additional recirculation of air [1].”

The Passivhaus method evolved from Swedish super-insulated homes and passive solar architecture, which seek to minimise space heating and to improve the thermal transmittance (U-values) of the building envelope (building fabrics, windows, and doors). These developments led advances in insulation, thermal bridging, airtightness and controlled ventilation, and the commercialisation of triple glazing windows [2].

The term “Passivhaus” was created from a research project in 1988 by Professor Wolfgang Feist from the Institute for Housing and Environment (Germany), Professor Bo Adamson from Lund University (Sweden), and [3]. The first Passivhaus dwellings were built in Darmstadt (Germany) in 1990 as an outcome of their experiments and were followed by the establishment of the Passive House Institute (PHI) in 1996.

The Passivhaus construction design method is founded on five essential principles: (i) super-insulation, (ii) thermal bridge-free construction, (iii) airtight building envelopes, (iv) mechanical ventilation systems with heat recovery (MVHR), and (v) high-performance doors and windows [4]. The correct application of these principles should guarantee high levels of indoor environment comfort, especially indoor air quality. Finally, to reduce further the energy consumption, the use of energy-efficient electric appliances and lighting is critical to achieving the low-primary energy demand required. **Table 1** presents the main criteria for Passivhaus certification. The complete design criteria are available in the Passive House Planning Package (PHPP) [5]—current version: version 9. During the certification process, a Passivhaus certification body verifies the PHPP analysis, construction record, and post-completion tests (blower door and ventilation rates). The different certification levels for Passivhaus buildings are EnerPHit for refurbishment projects, Passivhaus Plus for near-zero-energy buildings, Passivhaus Premium for positive energy buildings, and Passivhaus Classic for low-energy buildings.

Table 1. Overview of the main Passivhaus certification criteria for Central European climates. Adapted from [6].

Passivhaus Certification Criteria (Residential)	Cool-Moderate Climate (Central European)	
Specific heating demand	**≤15**	**kWh/(m^{2}a)**
OR specific heating load	**≤10**	**W/m^2**
Specific cooling demand	**≤15**	**kWh/(m^{2}a) + 0.3 W/(m^{2}aK). DDH**
OR specific cooling load	**≤10**	**W/m^2**
AND specific cooling demand	**≤4**	**kWh/(m^{2}a). σe + 2 · 0.3 W/(m^{2}aK). DDH-75 kWh/(m^{2}a)**
Specific total primary energy demand	**≤120**	**kWh/m^2/a**
Airtightness n50	**≤0.6**	**h^{-1} (@50 Pa)**
Overheating frequency	**10%**	**Percentage of time with operative temperature above 25 °C**

σe Annual mean external air temperature (°C); DDH refers to Dry Degree Hours.

In cold climates, heating load and heating demand are the most critical aspects to avoid the use of conventional heating systems, ensuring comfortable indoor environment levels [7]. The Passivhaus design and calculations are set to provide the highest level of thermal comfort only by air heating. Comfortable indoor temperatures (indoor operative temperature ≤25 °C) are achieved and maintained without conventional heating through the supply-air heating load that should not exceed 10 W/m^2. To achieve such levels of thermal comfort, the volumetric capacity of the system, supplied flow rates (30 m^3/h per person), indoor temperatures, and treated floor area in the project are considered to calculate the peak supply-air heating load [5]. Thus, high levels of indoor environment comfort are linked directly to energy-efficient design as an incentive. Hence, the Passivhaus standard began as an ultra-low-energy concept rather than to reduce CO2 emissions. The Passivhaus standard addresses energy demand reduction and thermal comfort, unlike other low-carbon standards prioritising energy-efficient design.

In Passivhaus buildings, moisture is removed through ventilation as the infiltration air volume flow is minimal due to high levels of airtightness and is hence insufficient to remove it [8]. In order to do this, outdoor airflow of 5–10 L/s per person (~0.3–0.6 air changes per hour or equivalent to 18–36 m^3/h per person) is recommended [9]. Such levels of ventilation should guarantee that CO2 peak levels are not higher than 1500 ppm, as stated in the German standard (DIN1946). The Passivhaus ventilation design is based on the German standard (DIN1946).

Passivhaus was developed for buildings in Central European countries. Nonetheless, it has expanded beyond Europe as it has gained popularity across the globe. As of March 2018, the Passivhaus database [10] had recorded 212 buildings outside of Europe, built predominantly in the USA (92), Canada (42), New Zealand (22), Japan (21), and China (16). The Passivhaus standard is starting to gain popularity in warmer climates such as those found in Latin America. This article aims to define the Passivhaus background, design concept, and principles, as well as present an overview of the studies that have shaped the Passivhaus. Finally, it briefly presents the performance of Passivhaus buildings, although it is not intended as an exhaustive literature review.

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