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THE SUSTAINABLE BUILDINGS E-LEARNING PROGRAM

Module 9

ENERGY-EFFICIENT AND PASSIVE BUILDING DESIGN

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TÜRKİYE SUSTAINABLE BUILDINGS NETWORK

The Türkiye Sustainable Buildings Network was established as part of the “Türkiye Sustainable Buildings Network Project,” which is co-funded by the European Union under the Civil Society Action towards European Green Deal Grant Scheme. The project is coordinated by WRI Türkiye, in partnership with the Zero Energy and Passive House Association (SEPEV) and with the support of the Danish Green Growth Network (DGGN).

The network operates with the aim of supporting climate action in the building and construction sector, promoting green transformation, enhancing the technical knowledge and skills of sector stakeholders, and mainstreaming the concept of sustainable buildings.



As part of this effort, the Sustainable Buildings E-Learning Program has been developed to serve as a comprehensive knowledge resource for all stakeholders in the building sector. The program consists of 10 training modules designed to contribute to the sector's sustainability, energy efficiency, and low-carbon transition goals.

Module 1: Overview of Sustainable Buildings

Module 2: Decarbonization in the Building Sector and the Whole Life-Cycle Approach

Module 3: Sustainable Building Materials

Module 4: Sustainable Construction and Demolition Practices

Module 5: District Heating and Cooling Systems

Module 6: Innovative Building Technologies

Module 7: Financing Instruments for Sustainable Buildings

Module 8: Emissions Trading Systems and the Building Sector

Module 9: Energy-Efficient and Passive Building Design

Module 10: The European Green Deal and the Building Sector

For more information about the Türkiye Sustainable Buildings Network and to access other modules, please visit [the link](#).



MODULE OBJECTIVES



Combatting climate change, ensuring energy supply security, and the sustainable transformation of the building sector are increasing interest in energy-efficient and passive building design. Globally rising energy costs and environmental impacts make low-energy consumption solutions in the construction sector necessary.

This module aims to understand the basic principles of energy-efficient building design, the concept of passive buildings, and the contribution of these systems to sustainable urban planning. The objectives of the module are as follows:

- To comprehend the basic principles of energy-efficient building design and evaluate building solutions that minimize energy consumption.
- To understand the principles of passive building design and analyze the effects of the building envelope on energy performance.
- To identify passive design strategies such as insulation, airtightness, thermal mass, and window systems, and evaluate their applicability.
- To optimize indoor comfort through strategies such as building orientation, solar gain, and natural ventilation.
- To examine the effects of airtightness, thermal bridges, and condensation control on building health and energy consumption.
- To compare passive and active systems and determine in which situations passive solutions provide advantages.
- To become familiar with certification processes and learn design methods in line with the Passive House standard.
- To analyze successful passive building implementations through real project examples and case studies.

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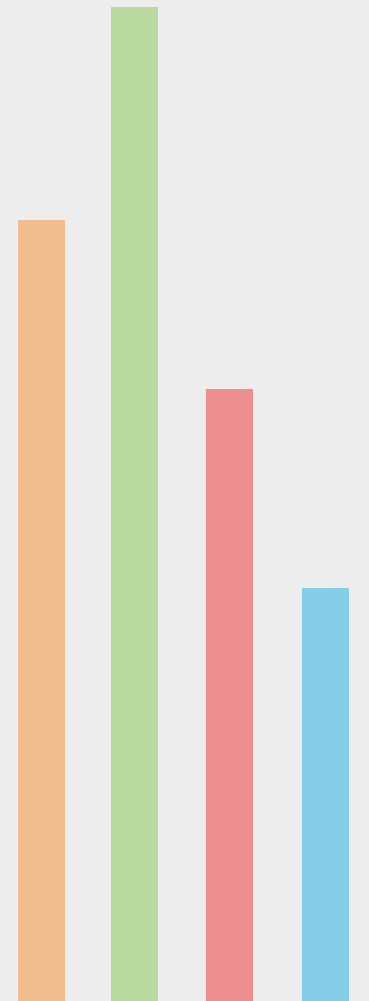
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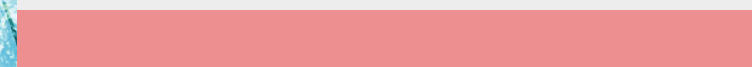
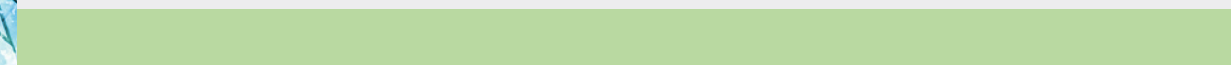
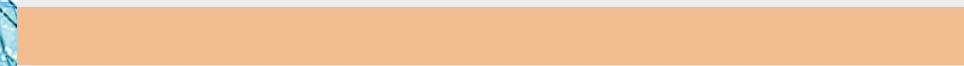
References





Section 1

INTRODUCTION AND BASIC CONCEPTS





1.1. The Importance of Energy Efficiency

Energy, which is an integral part of daily life, is increasingly needed due to rising living standards, growing population, and industrialization. The increase in energy demand brings with it many problems, including ecological imbalance, price increases, market distortions, depletion of resources, deterioration of budget and current account balance, and external dependency. The increasing energy demand and the resulting problems negatively affect the economy, the environment, and social life — in other words, every aspect of sustainable development. The aim of this study is to highlight the critical role of energy efficiency in buildings in sustainable development and to develop measures that will protect not only present but also future generations.

ENVIRONMENTAL IMPACTS OF ENERGY EFFICIENCY:

The environment is the entirety of physical, biological, social, economic, and cultural elements with which humans and other living beings interact throughout their lives.

It is estimated that by the middle of the century, the world population will double and economic development will continue uninterrupted. This situation is expected to significantly increase global demand for energy services by 2050. In parallel with this increase, environmental problems such as acid rain, ozone depletion, and global warming are also expected to intensify in correlation with energy consumption.

The main causes of global and environmental problems arising during energy production and consumption are the types of fuels used and the technological systems employed in converting these fuels into energy.

By ensuring energy savings, it is possible to contribute to the following:

- Achieving cleaner air quality,
- Protecting water resources,
- Increasing access to clean and healthy food,
- Reducing the effects of global warming.



1.1. The Importance of Energy Efficiency

ECONOMIC IMPACTS OF ENERGY EFFICIENCY:

Energy is one of the most important inputs in the economy. Energy resources, which are used in almost every field from industry to transportation and from commerce to production, are essentially considered indispensable elements of today's world. In this context, the demand for energy resources is following an increasingly upward trend. Among these energy resources, fossil fuels account for the largest share in terms of use, with approximately 80%. However, the decreasing lifespan of fossil resources puts the growing trend of consumption at risk. It is currently estimated that existing reserves of fossil fuels will be depleted in 55 years for oil, 48 years for natural gas, and 280 years for coal. Based on this, there is a growing global focus on the search for new and alternative energy sources. With energy efficiency:

- Dependency on external resources will be reduced,
- Economic growth of the country will be supported,
- Individuals' living standards will rise.

SOCIAL IMPACTS OF ENERGY EFFICIENCY:

Energy efficiency is an important social issue that benefits society in many ways. First and foremost, energy efficiency practices reduce energy consumption and thereby decrease energy expenses. This provides significant financial relief, particularly for low-income families, and can reduce energy poverty. At the same time, energy-efficient homes and buildings offer more comfortable and healthier living spaces, which enhances the overall well-being of society. Energy efficiency also has positive effects on health by reducing environmental impacts. Cleaner air quality contributes to a decrease in respiratory diseases and an improvement in general health conditions. This reduces healthcare costs and increases the overall health and well-being of society. Energy efficiency not only provides economic and environmental benefits but also plays an important role in terms of social equity and justice.

- Energy efficiency contributes to strengthening social equality.
- Reduced energy costs can help reduce income inequality and facilitate access to energy, especially for low-income groups.
- This supports the strengthening of social justice and the formation of a more equitable social structure.

1.2. Energy Consumption and Emissions in Buildings

As a country heavily dependent on foreign energy sources, Türkiye imports the majority of the energy it consumes. In recent years, significant efforts have been made to improve this unfavorable situation through the effective use of renewable energy sources and energy efficiency. The Energy Efficiency Law, which came into force in 2007, has led to the implementation of various projects aimed at the efficient use of energy, the prevention of waste, the reduction of energy costs that burden the economy, and the protection of the environment by increasing the efficiency of energy sources.

Within the scope of harmonization with the European Union, legal regulations in the field of energy have been introduced to develop legislation and policies, and a holistic design approach focused on energy performance is being promoted in the public domain. Raising awareness and increasing knowledge on this issue is also among the main objectives.

In Türkiye, energy-saving targets have been set primarily for the building, industrial, and transport sectors, and project initiatives have been launched accordingly. These efforts aim to raise public awareness by scaling up existing practices and disseminating successful examples.

The Energy Performance of Buildings Directive (EPBD), updated in 2024, has made the goal of achieving a carbon-neutral building stock by 2050—set under the European Green Deal—more concrete and binding. The main changes introduced by the revised directive are as follows:

KEY UPDATES AND TARGETS

1. Zero Emissions Requirement for New Buildings:

1. As of 2030, all new buildings must be zero-emission.
2. For new public buildings, this requirement is brought forward to 2028.

2. Mandatory Renovation Plans for Existing Buildings:

1. The least energy-efficient 16% of the building stock must reach energy class E by 2030 and class D by 2033.
2. These targets are supported through mandatory energy classification and improvement programs.

3. Energy Performance Certificates (EPCs):

1. The new rating systems ensure greater transparency and comparability of energy performance.
2. Digitalization of EPCs is encouraged, with data being collected on centralized platforms.

4. Renewable Energy and Smart Systems:

1. Strong incentives have been introduced to make the installation of solar energy systems mandatory in new and renovated buildings.
2. Integration of IoT (Internet of Things) and AI (Artificial Intelligence)-supported smart energy management systems into HVAC (Heating, Ventilation, and Air Conditioning) systems is also being promoted

1.3. Overview of Passive Building Design

The Beginning of Passive House Design:

In May 1988, Wolfgang Feist and Bo Adamson asked themselves how buildings could be designed to be more sustainable and energy-efficient. Building on this research and with the support of architects Bott and Ridder, Feist constructed and completed the first Passive House building in 1991 in Darmstadt, Germany. Through this work, Feist introduced a vision for the future of the construction sector, one that combines energy efficiency—and thus sustainability—with optimal comfort, cost-effectiveness, and good indoor air quality. The Darmstadt-Kranichstein row houses, inhabited by four families, continue to perform as planned more than twenty years later: the measured annual energy consumption has remained below 15 kWh per square meter of living space per year.

Passive Houses are at least 75% more energy-efficient than standard buildings in Europe, and up to 90% more energy-efficient compared to current standards in Türkiye. In Passive House projects that have been piloted in Türkiye, evaluations are still being carried out today, and their success in terms of energy efficiency has been proven.

The world's first Passive House emerged as a research topic in 1988 and was brought to life in 1991 when four families moved in. The project was realized with the following features:

- Super-insulation,
- An airtight building envelope,
- High-quality windows,
- Heat recovery ventilation.

The building also served as a research project and was monitored in detail over many years. It continues to be studied today and demonstrates 75% energy efficiency compared to European standards. [2]



Image 1: The first Passive House project built in Darmstadt-Kranichstein

1.3. Overview of Passive Building Design

THE FIRST PROJECTS IMPLEMENTED UNDER THE EUROPEAN UNION'S FIFTH FRAMEWORK PROGRAMME:

CEPHEUS was the first international Passive House project implemented as part of the European Union's Fifth Framework Programme.

A total of 250 Passive House units were designed and constructed within 14 building projects. Five European countries from Northern, Western, and Central Europe—Germany, Austria, France, Switzerland, and Sweden—participated in the project.

Most of the projects were monitored in detail. Heating energy savings were 90% or more compared to conventional buildings. The average additional investment costs were approximately 8% higher than those of buildings meeting the minimum required standards. [2]

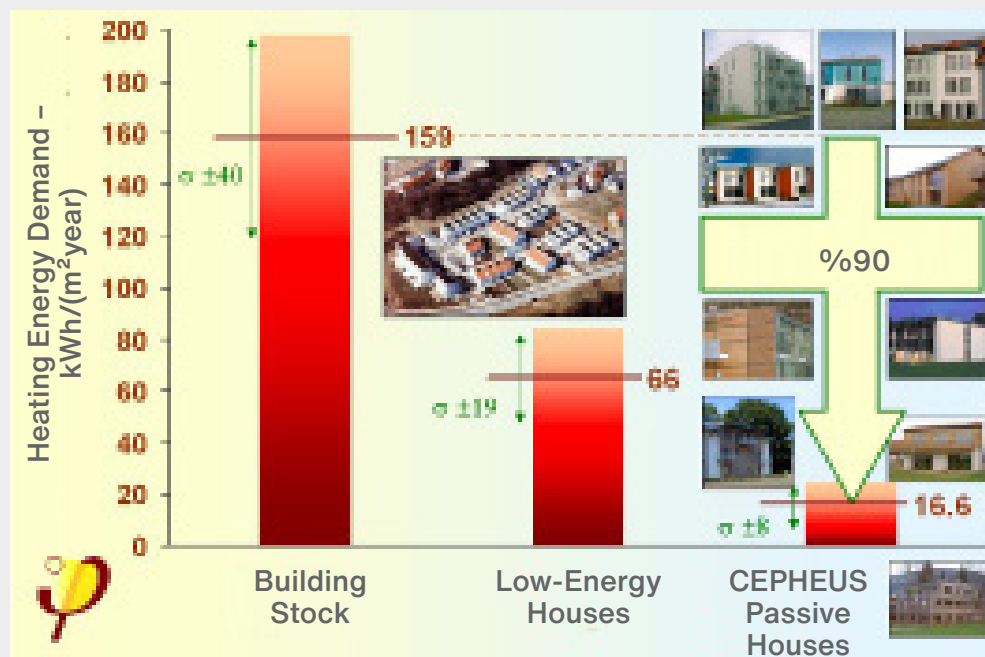


Figure 2. Comparison of annual heating energy demand in the buildings within the scope of the CEPHEUS project.



Figure 3. Passive House projects implemented in various locations across Europe (CEPHEUS)

1.3. Overview of Passive Building Design

Passive House buildings combine high thermal comfort with very low energy consumption. High-performance windows, superior insulation, and heat recovery ventilation, combined with quality design and craftsmanship, are the key elements that distinguish Passive House construction from others. Despite their exceptional efficiency, these buildings harmonize perfectly with their conventional neighbors in appearance. This is because the Passive House defines a performance standard, not a specific construction method: Passive House buildings must meet defined energy demand targets, but designers are free to choose how to achieve them.

Core principles of Passive House buildings:

- Extremely high levels of insulation
- Well-insulated window frames and glazing
- Thermal bridge-free design and construction
- Airtight building envelope
- Highly efficient heat or energy recovery ventilation system [2]

The **U-value** indicates the amount of heat that passes through each square meter of a building element when there is a temperature difference of 1°C.”

Principles for Cold and Temperate Climate Zones

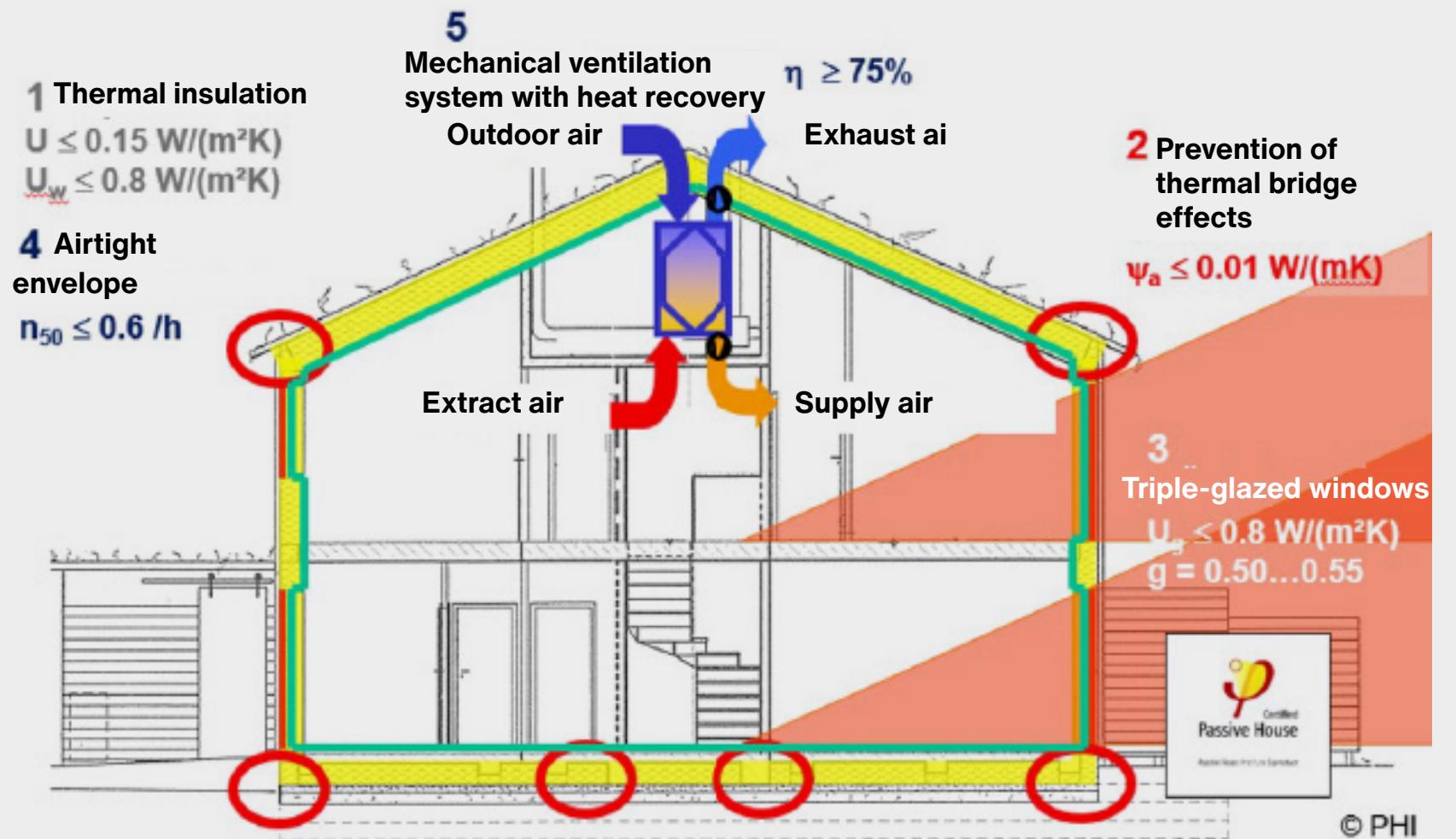
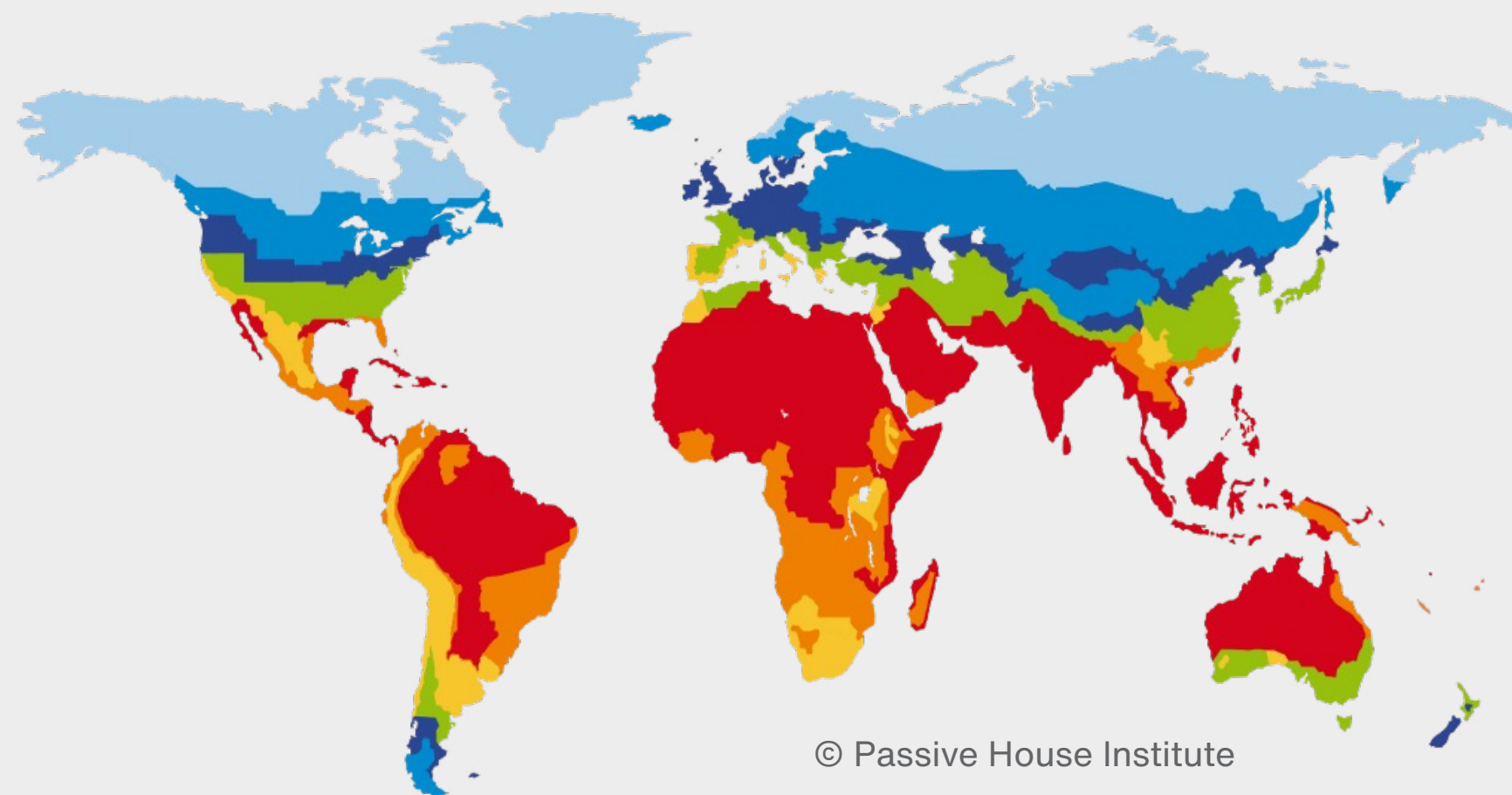


Figure 4: Core principles of Passive House buildings

1.3. Overview of Passive Building Design

The Passive House standard offers flexible and optimized performance criteria for different climate conditions around the world. This flexibility particularly allows the target U-values for building components to vary depending on their geographical location and climate type. In this slide, global climate zones are visualized on a map, and the maximum recommended U-values by the Passive House Institute for each climate zone are presented.

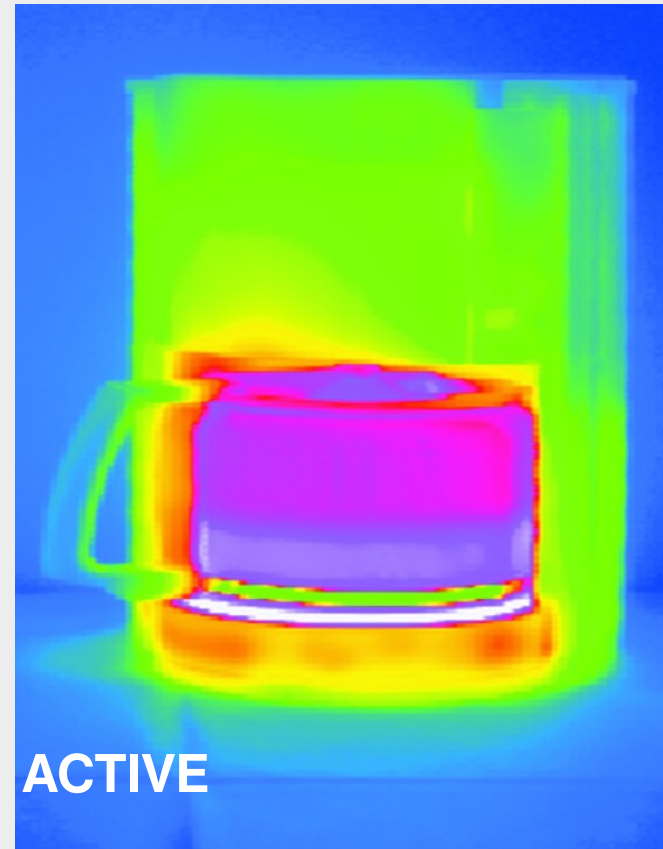


	Arctic	Cold	Cold – Temperate	Warm – Temperate	Warm	Hot	Very Hot
Walls (opaque)	0.09	0.12	0.15	0.3	0.5	0.5	0.3
Recommended glass type	Vacuum / quadruple low-e glass	Triple or quadruple low-e glass	Triple low-e glass	Triple low-e glass	Double low-e glass	Double solar control glass	Double solar control glass
Window U-value, installation MAX (vertical) (W/m ² K)	0.45	0.65	0.85	1.05	1.25	1.25	1.05

1.4. Comparison of Passive and Active Design

In standard buildings, heat losses are considerably high. However, in Passive House buildings, a highly insulated and airtight building envelope is used to minimize these losses. This allows indoor temperatures to remain stable without the need for an additional heating system.

Conventional “active” approach:
Continuous reheating



Conservation of thermal energy with the effective
“passive” approach → thermal insulation

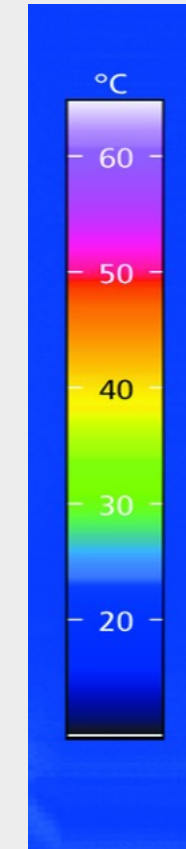
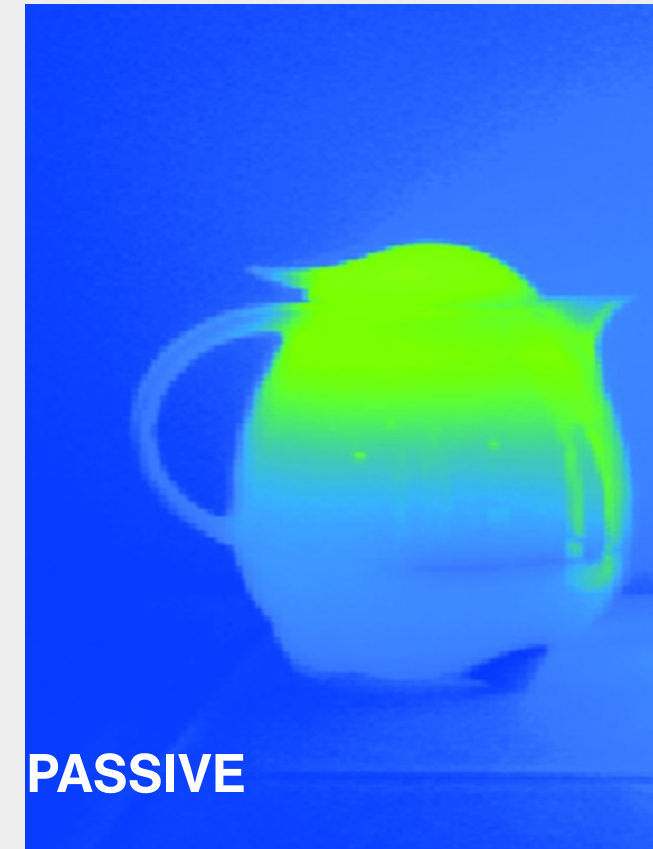


Figure 5: Comparison of Passive and Active

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1.4. Comparison of Passive and Active Design

In a Passive House building, heat losses are so minimal that there is almost no need for heating. Solar gains, building occupants, household appliances, and even the heat recovered from exhaust air cover a significant portion of the heating demand. The remaining demand can typically be met through the ventilation system.

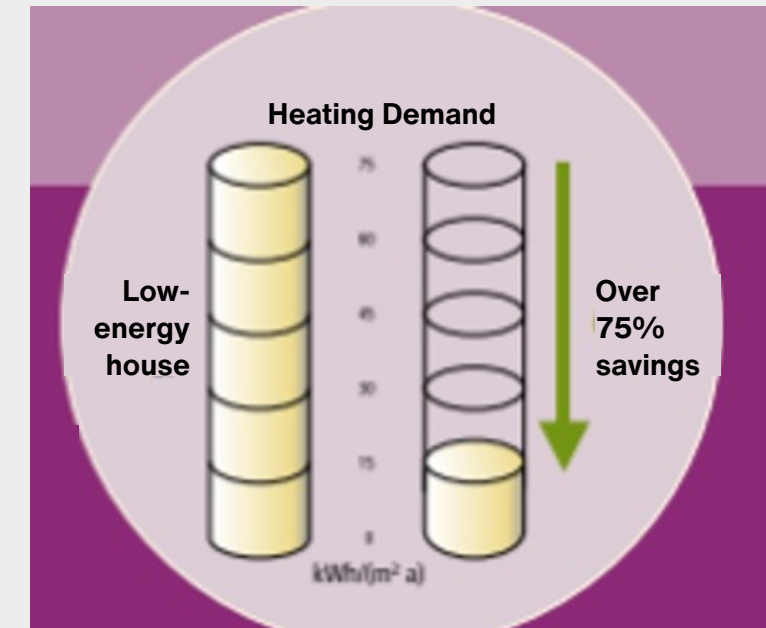
While Passive House buildings use energy passively, they are active in terms of comfort.

Buildings equipped with active systems (heating, ventilation, and air conditioning) largely depend on mechanical systems and energy-consuming technologies to maintain a comfortable indoor environment (temperature, humidity, air quality). In such buildings, climate control systems must operate continuously to maintain indoor temperatures, whereas this is not necessary in Passive House buildings.

Thanks to five core principles, Passive House designs achieve up to 75% energy savings compared to Active Designs according to European Union building standards.

Compared to Active Building designs, Passive House designs are:

- Cost-effective over the building life-cycle,
- Comfortable,
- Sustainable,
- Innovative,
- Adaptable to different climate zones,
- Durable,
- Non-complex structures.



Advantages of Passive House Buildings [1]

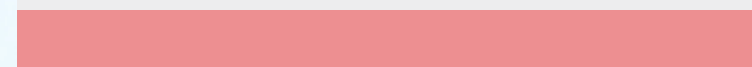
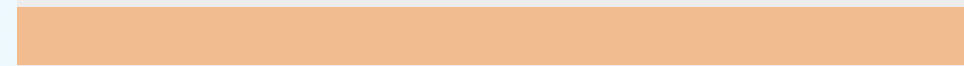
Key Advantages

- High level of comfort
- Consistent supply of fresh air throughout the entire building
- Long-lasting structure: mold-free buildings with significantly reduced risk of moisture damage
- Extremely low heating and cooling costs despite rising energy prices
- Significantly improved indoor environment



Section 2

FUNDAMENTAL PRINCIPLES OF PASSIVE BUILDING DESIGN



2.1. Building Envelope and Thermal Performance

The building envelope holds a significant place within the Passive House criteria. Buildings that are designed with decisions made during the design phase can be realized at a lower cost and with reduced energy consumption throughout their life cycle. Passive House buildings differ from “normal” buildings in many ways. The defining characteristic of Passive House buildings is their high level of insulation and airtightness to minimize heat losses. Highly insulated external building components are optimized and work perfectly with all other components to provide a comfortable indoor climate and the desired energy savings. Implementing a Passive House requires high standards for individual building components. For example, the U-values of the building elements should be below $0.15 \text{ W}/(\text{m}^2\text{K})$ (for Central European settlements).



© Passive House Institute

When designing the building envelope in Passive Houses, the following high standards must be ensured:

- Thermal insulation
- Airtightness
- Thermal bridge-free design

2.1. Building Envelope and Thermal Performance

When designing the building envelope of Passive House buildings, energy efficiency, comfort, and durability are fundamental. In this process, the function of basement floors must be clearly defined during the design phase. Whether basement volumes are located inside or outside the conditioned space directly affects the thermal insulation strategy.

The building facade and all exterior surfaces of the structure must have high thermal protection properties. The U-values of opaque building elements such as roofs, exterior walls, and floor slabs must be below $0.15 \text{ W}/(\text{m}^2\text{K})$. This minimizes heat loss.

Insulation materials and windows must be carefully installed without creating thermal bridges. The U-value of windows should be below $0.8 \text{ W}/(\text{m}^2\text{K})$. To achieve this:

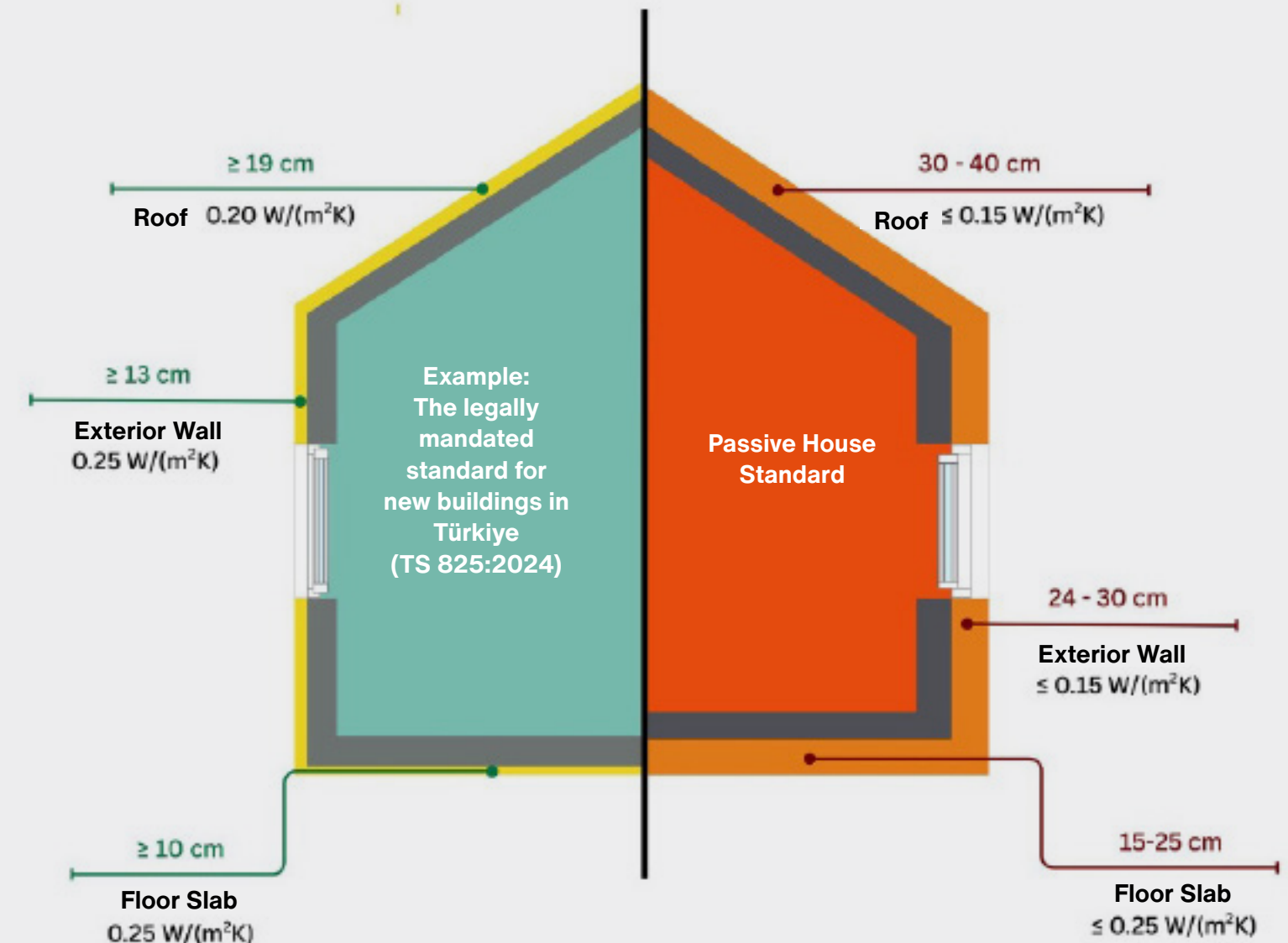
- Insulated window frames,
- Triple-glazed window systems must be used.

The glass used should also have a total solar energy transmittance (g-value) of 50–55%. This allows sunlight to provide passive heat gains, reducing heating loads during winter months.

The thermal building envelope must be enclosed by an airtight layer created with interior plaster, wood-based panels, or specialized membranes. This airtightness is measured by the Blower Door Test, and the n50 value must not exceed 0.6 air changes per hour.

- To prevent overheating during summer months:
- Large glazed surfaces are used on the south facade,
- External shading systems (external shading elements) should be installed on windows on the east and west facades.

Graphic: Comparison of Insulation U-values and Thicknesses According to TS 825:2024 and Passive House Standard for the Cold-Temperate Climate Zone in Türkiye



© SEPEV

2.1. Building Envelope and Thermal Performance

When designing the building envelope of Passive House buildings, it is important to define energy boundaries. In the figure, the red dashed line indicates the energy boundary, while the green dashed line represents the airtightness boundary.

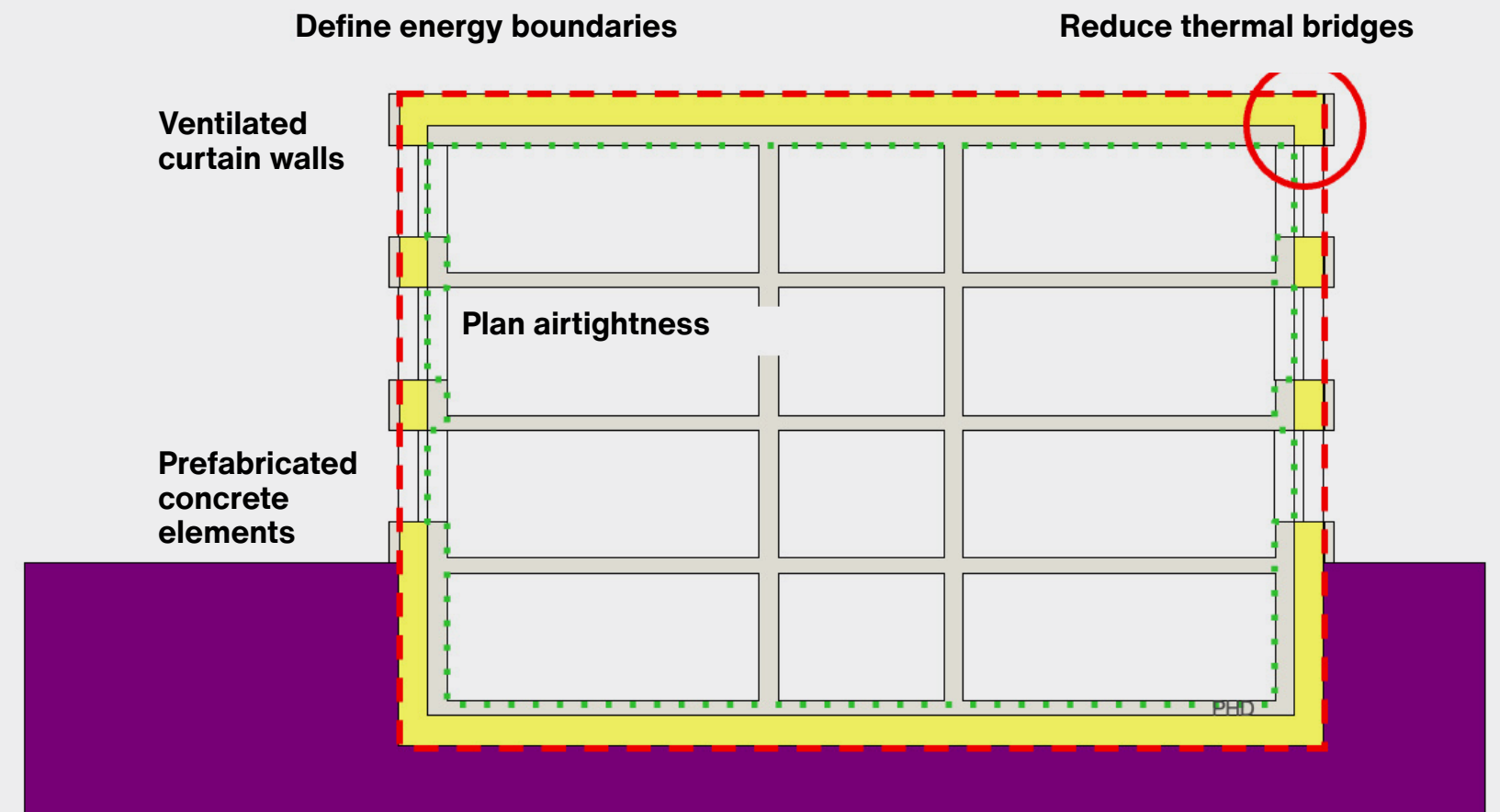
When Defining Energy Boundaries:

It is crucial to design all details of the building envelope to minimize heat loss. If an exterior cladding is to be installed, attention must be paid to using anchoring (mounting) materials with low thermal conductivity. This helps prevent thermal bridges that may occur on the facade. Additionally, continuous insulation must be ensured between building elements such as windows, roof, floor slab, and foundation, and detail solutions must be meticulously developed during the design phase to avoid thermal bridges. This holistic approach enables the high energy efficiency, which is one of the fundamental requirements of the Passive House standard [2].

A **thermal bridge** refers to areas where **heat** transfer between the interior and exterior of a building occurs faster than normal. In these areas, heat effectively “bridges” through structural components and easily escapes outside (or enters inside during summer).

Thermal bridges typically occur at:

- Locations where insulation is interrupted
- Window edges
- Protruding structures such as balconies and cantilevers
- Roof-to-wall junctions
- Conductive materials like metal anchors and connectors



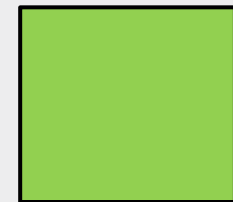
2.1 Building Envelope and Thermal Performance

Passive House principles can be applied to any type of design. However, the more compact a building design is, the easier and more efficient it becomes to achieve the desired outcome. In Passive House buildings, thermal bridge-free design is of vital importance. This approach prevents unwanted heat losses, ensures energy savings, and enhances the building's overall efficiency.

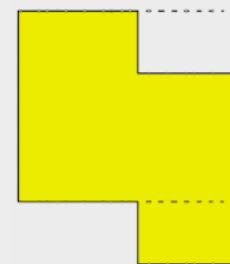
An increase in the building envelope area directly affects the heating demand and this effect varies depending on the surface-to-volume ratio.

For instance, a 10% increase in the building envelope may require approximately 20 mm of additional insulation, whereas a 20% increase may necessitate 40 mm of additional insulation thickness.

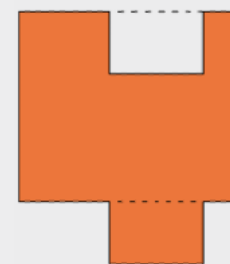
Therefore, a compact design offers economic advantages both during construction and throughout the building's life cycle.



Compact condition



**10% increase
Insulation = 20 mm**



**20% increase
Insulation = 40 mm**

The Continuity Principle:

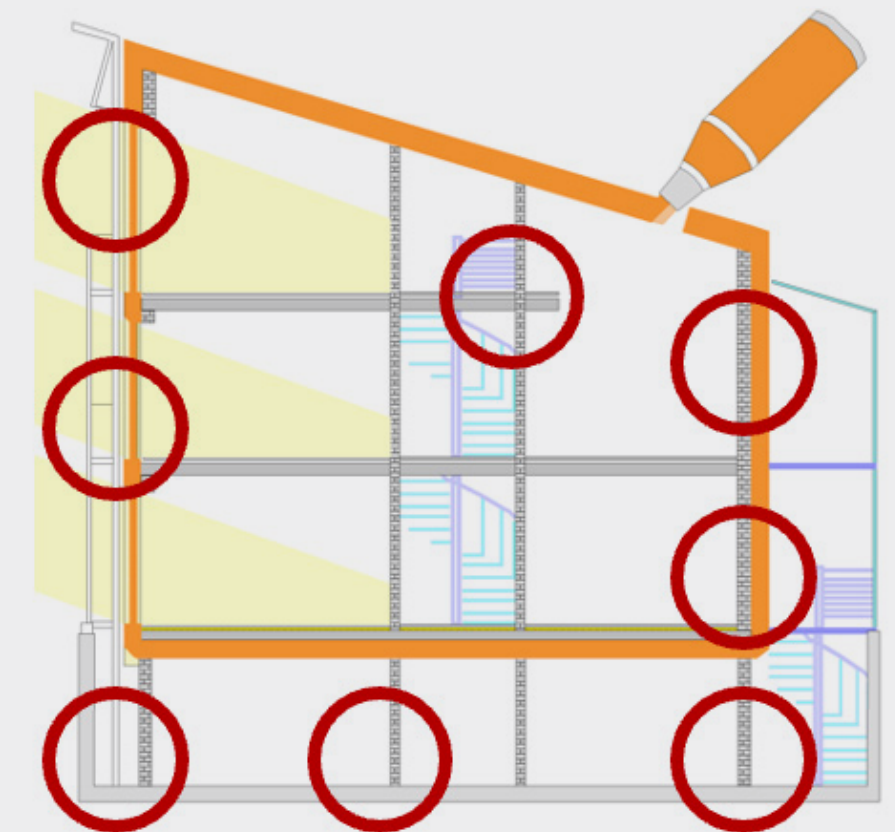
There must be no interruptions in the insulation envelope; thermal insulation should be applied continuously across all surfaces. This is a critical factor in minimizing heat loss.

The Penetration Principle:

If the insulation layer must be penetrated or if materials must pass through it, the materials used should have the lowest possible thermal conductivity. Suitable materials include aerated concrete, wood, polyurethane (PUR), or foam glass.

The Connection Principle:

At the joints between different building components, insulation layers must be seamlessly connected across surfaces. This prevents thermal bridging and avoids unnecessary energy loss.



© Passive House Institute

The insulation envelope surrounds the entire conditioned volume.

**Thermal bridge-free design:
 $\Psi_e \leq 0.01 \text{ W/(mK)}$**

2.2 Insulation Techniques and Materials

Insulation Material	Thermal Conductivity λ [W/(mK)]
Aerated concrete	0.080 – 0.250
Wall with insulated brick	0.070 – 0.120
Wood fiberboard	0.045 – 0.090
Mineral wool	0.036 – 0.045
Mineral fiber lamella	0.041
Polystyrene	0.031 – 0.045
Polyurethane	0.024 – 0.035
Foam glass panel	0.040 – 0.060
Foam glass gravel, dry	0.070 – 0.090
Foam glass gravel, wet	0.130 – 0.140
Aerogel insulation mat	0.014 – 0.017
Vacuum insulation panel (VIP)	0.007 – 0.008

Table: Thermal conductivity values of materials [2]

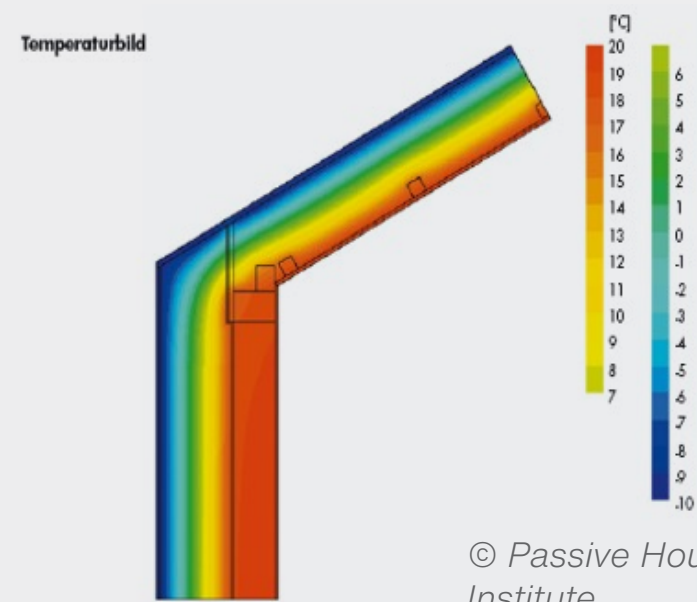
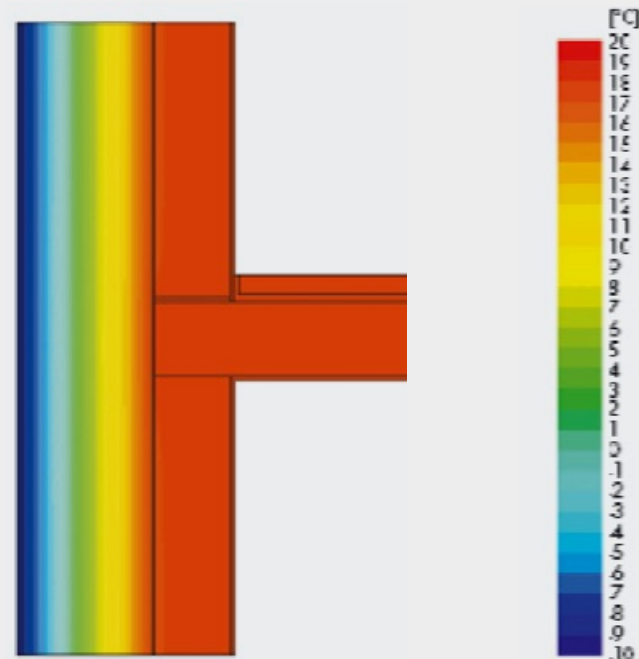
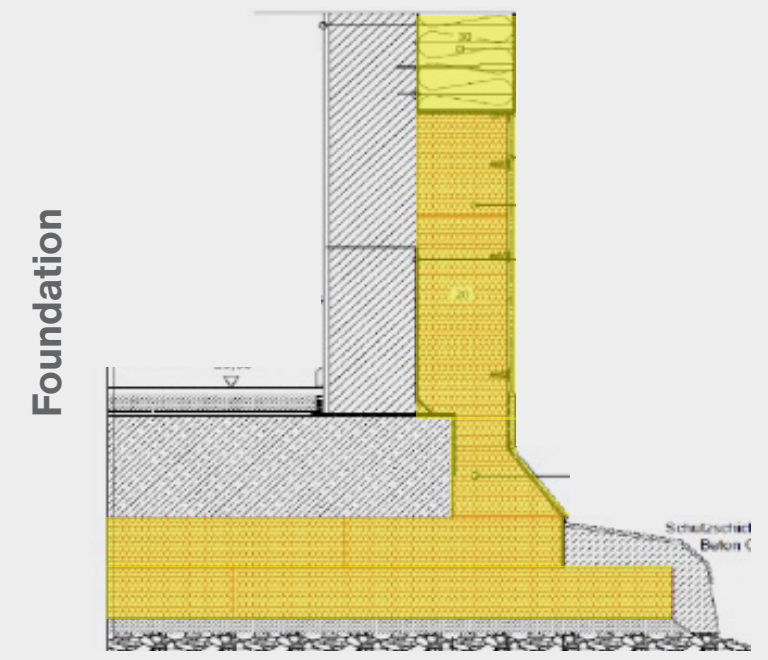
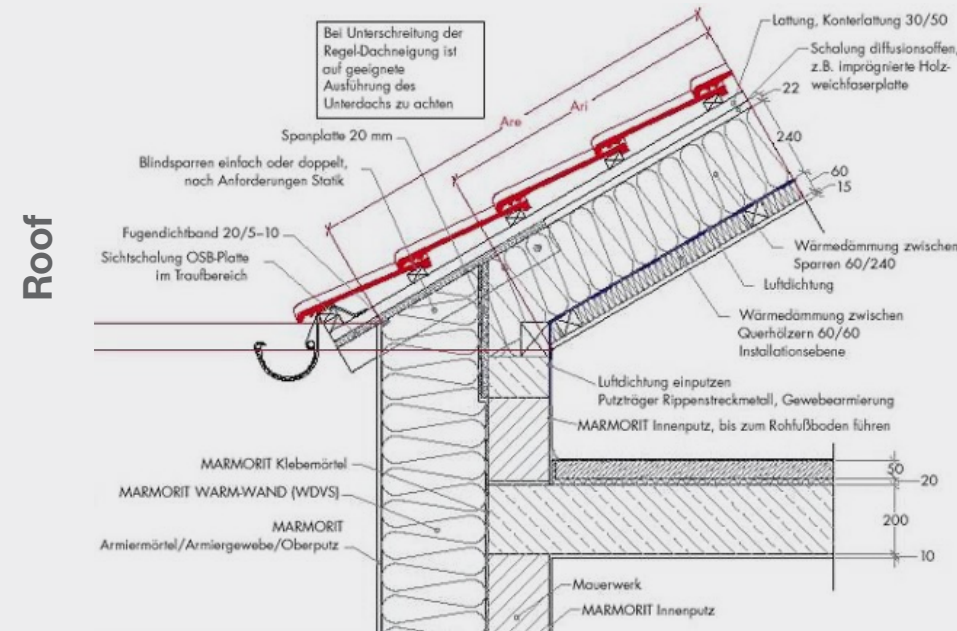
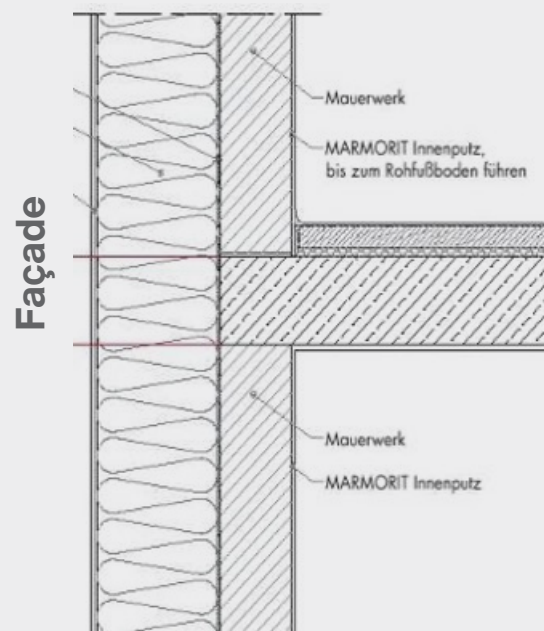
In order to meet Passive House criteria in the building envelope, the thermal conductivity of the materials to be used is of critical importance. The required insulation thickness largely depends on the location of the building and its architectural design.

Material	λ [W/(mK)]	Thickness [cm]
Cellulose	0.080 – 0.250	25 - 30
Mineral wool	0.070 – 0.120	23 - 26
Polystyrene	0.045 – 0.090	20 - 26
Polyurethane	0.036 – 0.045	13 - 23
Vacuum insulation panel	0.041	2 - 5

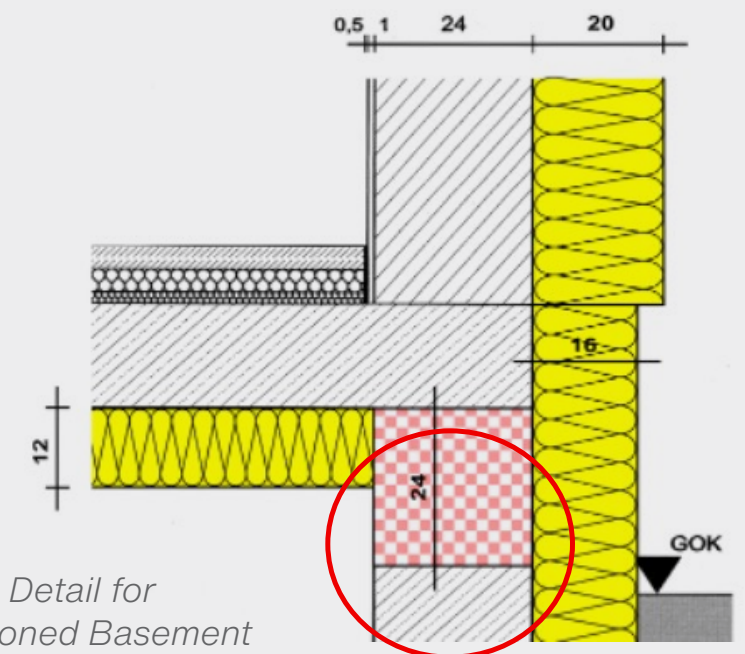
Required λ -values and layer thicknesses of typical materials to achieve a U-value below 0.15 W/(m²K) for Passive House buildings [2]

2.2 Insulation Techniques and Materials

The insulation in the building envelope must be continuous. To prevent heat losses through the façade, foundation, and roof, the continuity of the insulation must be maintained. Below, you can find typical insulation techniques used in Passive House building envelopes.



© Passive House Institute



Insulation Detail for Unconditioned Basement

2.3. Building Orientation and Solar Gains

In passive house design, building orientation and solar gains are critically important for energy efficiency. Proper orientation and effective use of sunlight minimize the building's energy consumption by reducing heating demand.

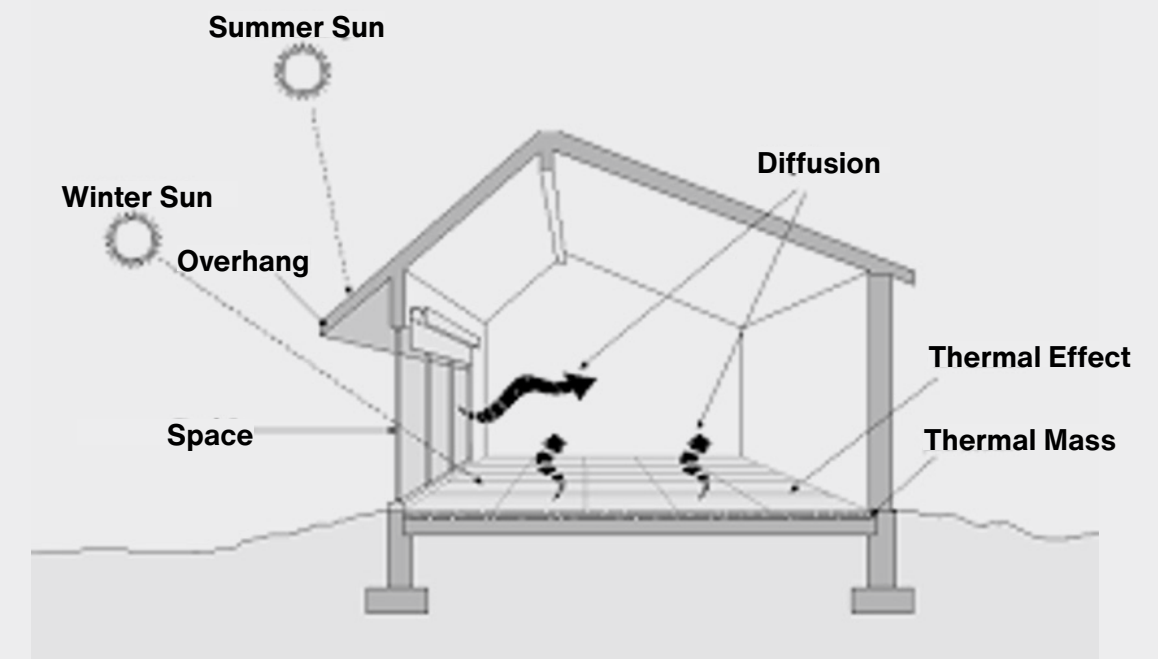
1- Building Orientation

- **South Orientation (for the Northern Hemisphere):** Main living areas and large windows should be positioned on the south façade. This ensures maximum solar gain in winter, while appropriate shading prevents overheating in summer.
- **North Façade:** Windows should be kept to a minimum on this side, as it causes the most heat loss. Less frequently used spaces such as storage rooms and bathrooms can be located on the north side.
- **East and West Façades:** These façades receive direct sunlight during summer. Since the west façade in particular can cause overheating, shading elements (e.g., pergolas, exterior shutters, vegetation, etc.) should be employed.

2- Solar Gains and Shading

- **Passive Solar Gain:** Extensive glazed surfaces on the south façade provide maximum solar energy benefit during winter.
- **Thermal Storage:** Materials with high thermal mass such as concrete, stone, or brick should be used indoors to store heat during the day and release it at night.
- **Shading Elements:** To prevent overheating in summer, overhanging roofs, sun breakers, shutters, or exterior blinds should be preferred.
- **Roof Slope and Solar Panels:** If possible, the roof should be sloped towards the south and the optimum angle for solar panels should be determined.

In passive house design, building orientation and solar gains not only enhance energy efficiency but also provide thermal comfort and reduce heating and cooling costs. With proper planning, energy savings of up to 90% can be achieved.



Schematic Diagram of Direct Gain System

2.4. Natural Ventilation Strategies

Unlike controlled ventilation systems specifically designed and integrated into buildings, natural ventilation refers to uncontrolled air exchange achieved through the manual or automatic opening of windows

In Passive House buildings, natural ventilation is a system designed to minimize energy consumption while enhancing indoor environmental quality. These buildings are optimized in design to reduce the need for heating and cooling. When properly designed, natural ventilation can improve indoor air quality and reduce energy consumption.

Methods used for natural ventilation in Passive House buildings include:

1- Cross Ventilation

- Openings such as windows or vents are placed on opposite façades of the building.
- Wind enters from one side and exits from the other, ensuring continuous renewal of indoor air.

2- Stack Ventilation

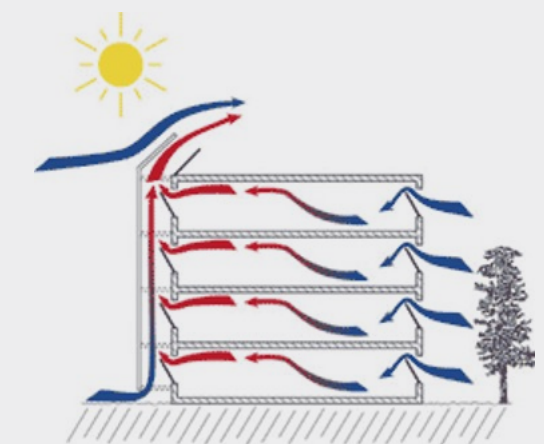
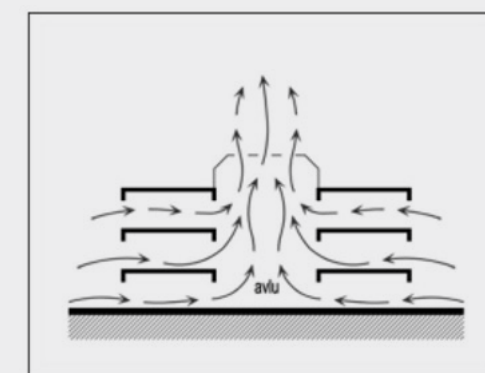
- Warm air rises while cooler air remains near the ground.
- Ventilation openings at the top of the building allow warm air to escape, while lower openings enable the entry of fresh air.

3. Atrium (Shaft) Utilization

- A glazed atrium (interior courtyard) is located at the center of the building.
- Air inside the atrium heats up with solar radiation, rises, and creates a natural air circulation.

4. Cooling with Wind Towers

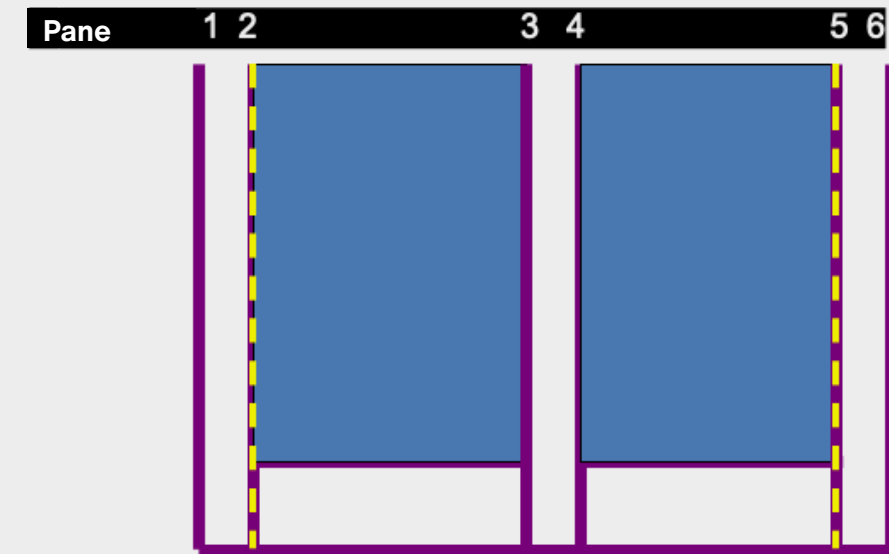
- A technique commonly used in desert climates.
- Tall wind towers capture the wind and direct it into the building, allowing hot air to rise and exit.



Natural Ventilation Strategies

2.5. Daylighting and Glazing

Solar control is one of the most critical elements in buildings for ensuring energy savings, thermal comfort, and visual comfort. With the use of solar control elements, direct solar radiation entering the building from the outside can be managed. This enables shading control as well as thermal and visual comfort in the desired space and time. The optimal architectural integration of solar control elements significantly affects the efficient use of solar energy, a natural energy source. Considering optimal design factors in façade design—one of the most important aspects of building design—plays a crucial role in achieving the desired level of energy conservation and gain.



Glazing

U_g [W/(m²K)]

- | | |
|---|-----------|
| a) Single glazing | ≈ 5.0 |
| b) Double glazing | 3.0 |
| c) Triple glazing | 2.3 |
| d) Double glazing (with Argon*) | 2.2 |
| e) Double glazing (with Argon*) and coating | 0.9...1.3 |
| f) Triple glazing (with Argon*) and coating | 0.5...0.8 |

*Cavities between panes filled with argon gas.

2.5. Daylighting and Glazing

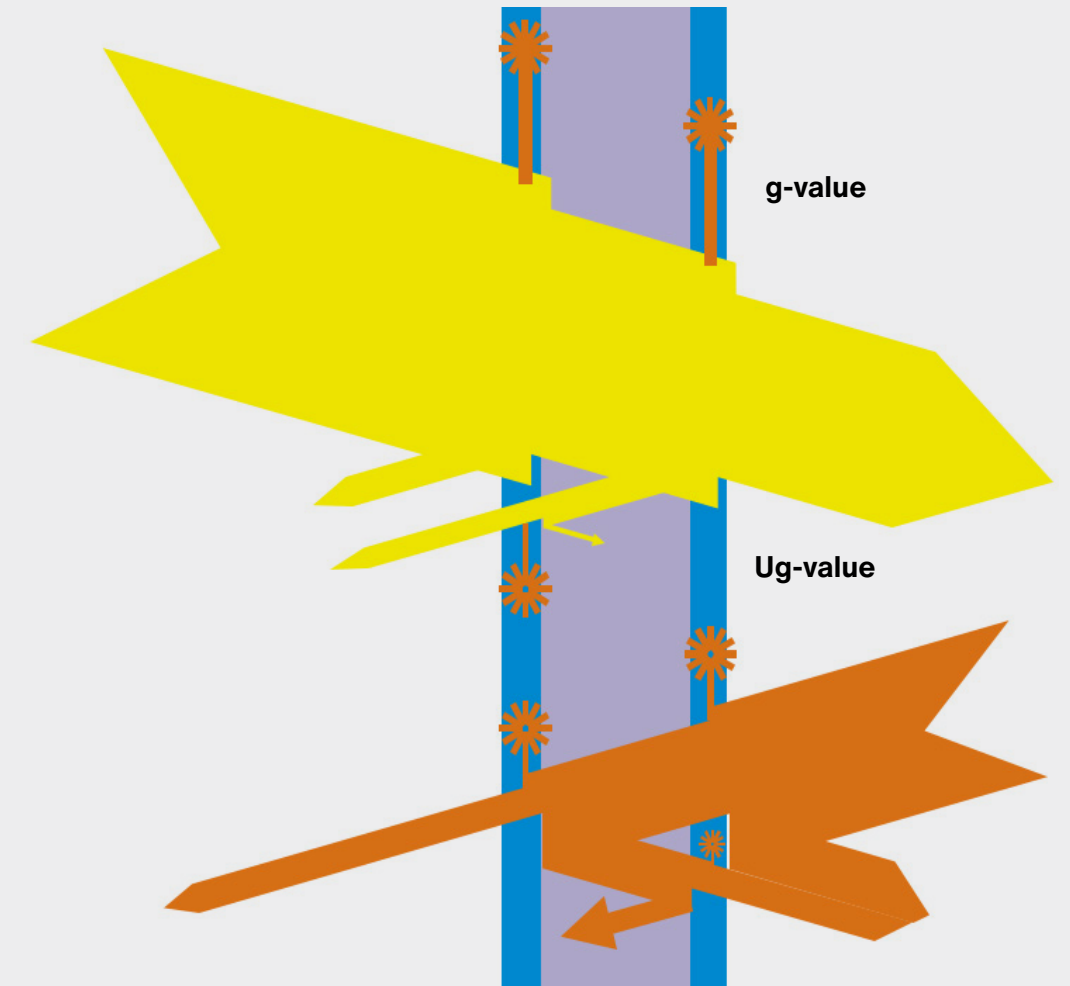
A single-glazed window (a) typically has a Ug-value of approximately $5.0 \text{ W}/(\text{m}^2\text{K})$, where the Ug-value represents the thermal transmittance of the glazing. This value is influenced by surface film coefficients, which can vary depending on external conditions such as wind. When a second (b) and third (c) glass pane is added to the glazing system, the Ug-value can be reduced by about half. The cavities between the panes can be filled with inert gases such as argon to minimize heat loss through conduction and convection. This can lower the Ug-value to approximately $2.2 \text{ W}/(\text{m}^2\text{K})$.

One of the key components of energy-efficient glazing is low-emissivity (low-e) coatings, which are applied to one of the glass surfaces to reduce its thermal emissivity. With such a coating, a double-glazed unit filled with argon gas (e) can achieve a Ug-value as low as $1.1 \text{ W}/(\text{m}^2\text{K})$.

To achieve even higher insulation performance, triple-glazing systems with two gas-filled cavities and two low-emissivity coatings (f) can be used, reducing the Ug-value to around $0.50 \text{ W}/(\text{m}^2\text{K})$.

The **Ug-value** is an indicator of conductive heat losses through the glazing.

The **g-value** (also referred to as SHGC – Solar Heat Gain Coefficient) refers to the total amount of solar energy transmitted through the glazing, including both direct solar radiation and secondary heat emission from the outer to the inner surface.



© Passive House Institute

2.6. Airtightness and Air Infiltration Management

Uncontrolled air leaks can lead to energy loss, uncomfortable living conditions, and structural problems in a building. Therefore, airtightness is critically important both for the building's health and occupant comfort.

An airtight building envelope is essential for the following reasons:

- **Prevents condensation within the structure (structural damage):**

Especially during cold seasons, if warm, humid indoor air penetrates the colder parts of the construction, water vapor in the air may condense there. In such cases, the insulation performance decreases, and the building materials can be damaged.

- **Prevents air drafts (living comfort):**

Many people are sensitive to drafts. Uncontrolled airflow caused by leaks can significantly disrupt thermal comfort.

- **Prevents cold floors on the ground level (living comfort):**

During winter, cold air often enters the lower parts of the building (stack effect). This can create pockets of cold air on the ground floor, reducing occupant comfort.

- **Prevents harmful substances from entering indoor air:**

If air enters the building through leaks, harmful substances (e.g., radon gas from the ground or basement) may infiltrate the indoor air. Additionally, moisture escaping from the building can lead to mold growth inside the construction, and reverse airflows (e.g., between summer and winter) can cause airborne mold spores that negatively affect indoor air quality.

- **Ensures proper operation of the ventilation system (air quality):**

If uncontrolled air exchange occurs, the ventilation system will not operate efficiently. Consequently, the effectiveness of a high-efficiency heat recovery system will decrease.

- **Maintains the insulation effect of external building components:**

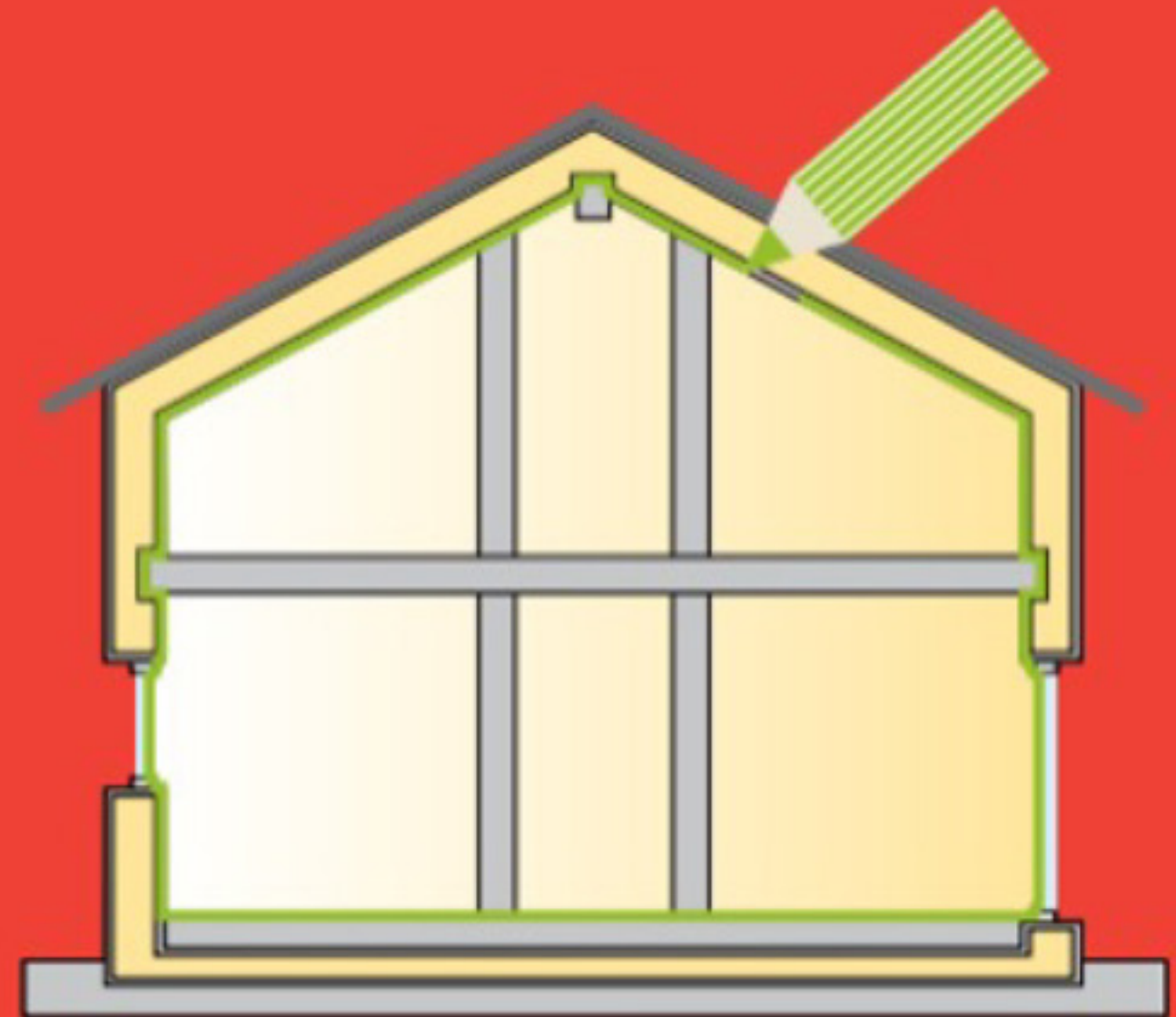
For thermal insulation, the air trapped in the cavities of insulation materials must remain almost stagnant. If air passes through the insulation material, deformation over time is inevitable.

- **Ensures sound reduction performance of building components:**

Even small gaps in a wall can significantly reduce sound insulation. Similarly, improperly sealed windows allow external noise to penetrate easily. This adversely affects the overall acoustic performance of the building. Therefore, improving airtightness is important not only for energy efficiency but also for effective sound insulation.

2.6. Airtightness and Air Infiltration Management

A Passive House's airtight layer (green line) continuously surrounds the thermal envelope of a building without gaps. It should be possible to draw a continuous airtightness line without lifting the pen. The materials to be used and the connections to be made for each detail must be defined during the planning phase. A similar "pen rule" applies to the thermal bridge-free insulation layer (yellow). Inevitable penetrations must include components and materials with the lowest possible thermal conductivity.



The Principle of Airtight Building Envelope in Passive Houses [1]

2.6. Airtightness and Air Infiltration Management

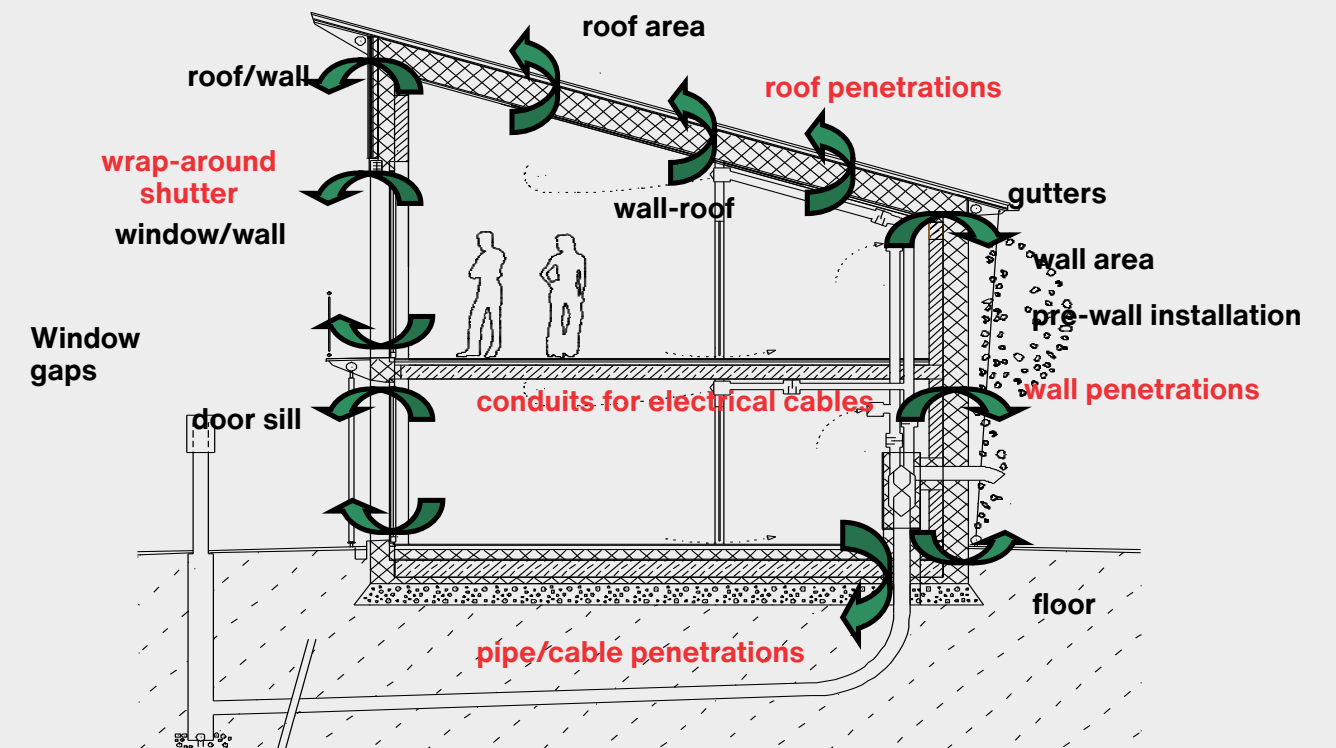
In Passive House buildings, an airtightness test is conducted after the building envelope is completed. This test allows for the measurement of unwanted air leakage within the structure. Various materials have been developed to prevent undesired heat losses in the building.



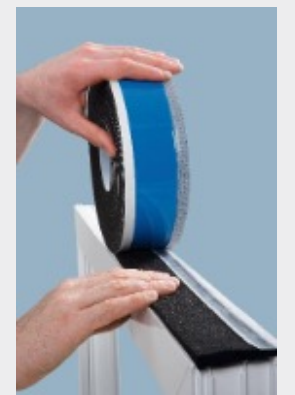
The main reasons for ensuring airtightness in a building are as follows:

- To reduce energy losses caused by air leaks, thereby lowering heating and cooling costs,
- To prevent moisture and mold formation, avoiding structural damage and unhealthy living conditions,
- To block unwanted airflows from the outdoor environment, enhancing indoor comfort,
- To enable proper design of mechanical ventilation systems in order to control indoor air quality and provide the necessary amount of fresh air.

These factors demonstrate how critical airtightness is for creating energy-efficient and healthy indoor environments [2].



Pasif Ev Kesiti [13]



Detail materials produced to prevent air leakage in Passive House buildings

2.6. Airtightness and Air Infiltration Management

TESTING THE AIRTIGHTNESS OF PASSIVE HOUSE BUILDINGS;

Operating Principle of the Pressure Test

Air is extracted from the building using a fan, which results in a (partially) low pressure of 50 Pa throughout the entire building. To maintain this constant negative pressure, the exact same amount of air must enter the building through all leaks as is being extracted by the fan.

The volumetric airflow is thus drawn centrally at one point and enters the building through all leakages that may be present in various parts of the building envelope. Under these pressure conditions, all leaks throughout the building can be easily detected and subsequently sealed.

The actual measurement takes place after leak detection. For this, airflow rates are measured at a minimum of five different pressure levels (negative pressure). The same measurement is then repeated at a minimum of five pressure levels under positive pressure. Using these data, the average volumetric airflow rate at 50 Pa is calculated. The leakage volumetric flow rate at the reference pressure difference of 50 Pa, denoted as V_{50} , is based on the building's net internal volume. The standard metric for building airtightness is the air change rate at a pressure difference of 50 Pa, referred to as n_{50} . [2]



Airtightness Test Visuals in Passive House Buildings



1. Example:
Connection point between a concrete wall and a concrete slab



2. Example:
Siphon on a masonry wall

2.7. The Role of Thermal Mass

In Passive Houses, thermal mass is a key element that stabilizes indoor temperatures by storing heat. When used correctly, it increases energy efficiency by reducing heating and cooling demand.

THE ROLE OF THERMAL MASS IN PASSIVE HOUSES INCLUDES:

1. Heat Storage and Delayed Release

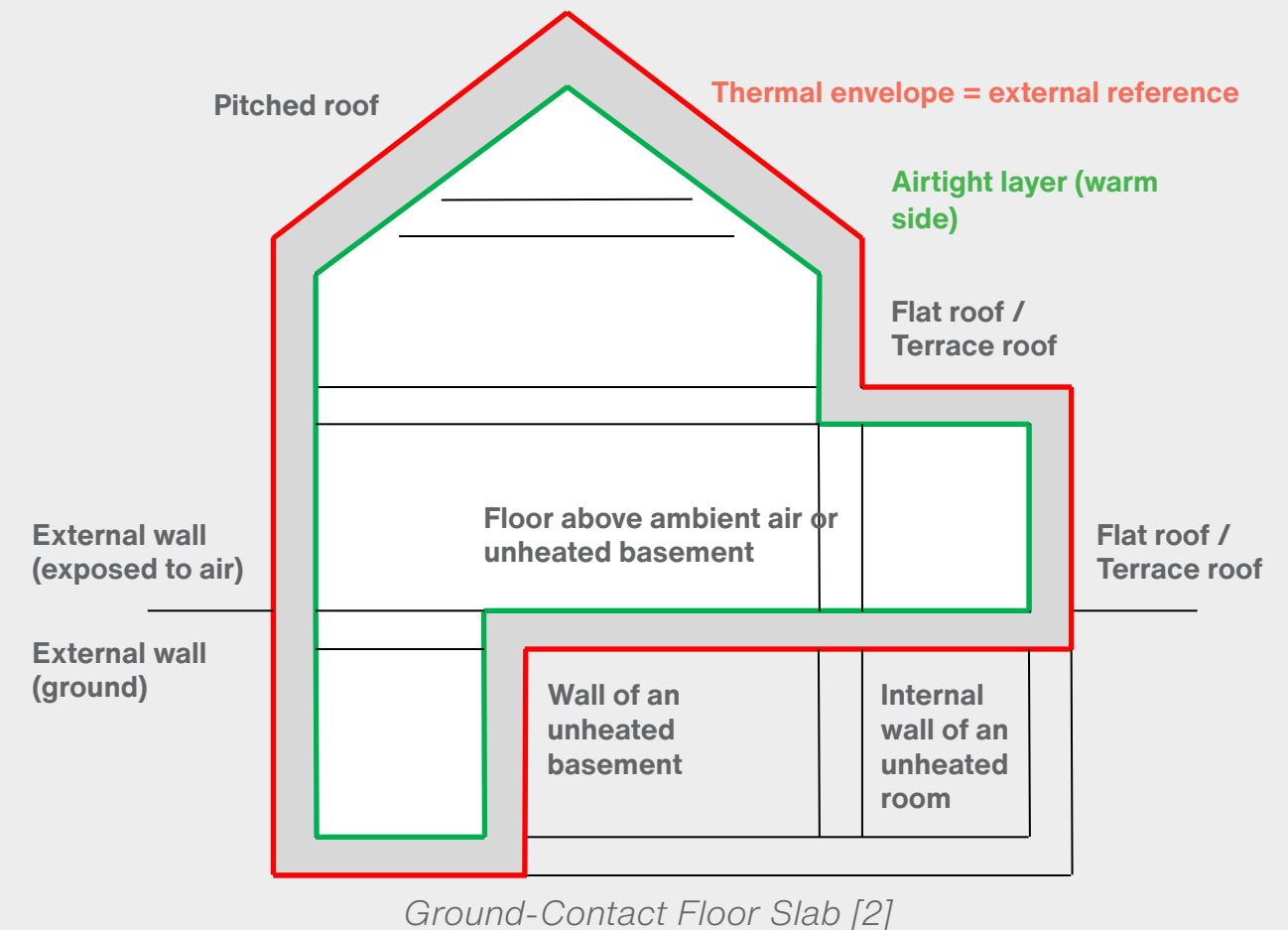
- **Stores Heat During the Day:** As sunlight enters through windows, materials with high heat capacity—such as concrete, stone, brick, or rammed earth—absorb the heat.
- **Releases Heat at Night:** As the air cools down, these materials gradually release the stored heat back into the interior, helping to maintain a stable indoor temperature.

2. Providing Cooling in Summer

- To prevent overheating during the day, thermal mass absorbs excess heat, thereby reducing indoor temperature peaks.
- At night, cool air is brought in through ventilation, and the thermal mass retains the coolness, making indoor spaces more comfortable during hot days.

3. Reducing Temperature Fluctuations

- Thermal mass prevents sudden temperature changes and helps maintain a more constant indoor temperature. This not only improves comfort but also reduces energy demand.



4. Recommendations for Proper Use

- **South-Facing Placement:** Surfaces with thermal mass (e.g., walls, floors) should be positioned to receive direct sunlight.
- **Support with Insulation:** Thermal mass is more effective when combined with insulation. Good insulation helps retain the stored heat for longer periods.
- **Control with Shading:** To prevent overheating in summer, sun-shading devices or shutters should be used on windows.

2.8. Moisture and Humidity Control

Moisture management in passive buildings is critical for comfort, energy efficiency, and the longevity of the building.

Importance of Moisture Management

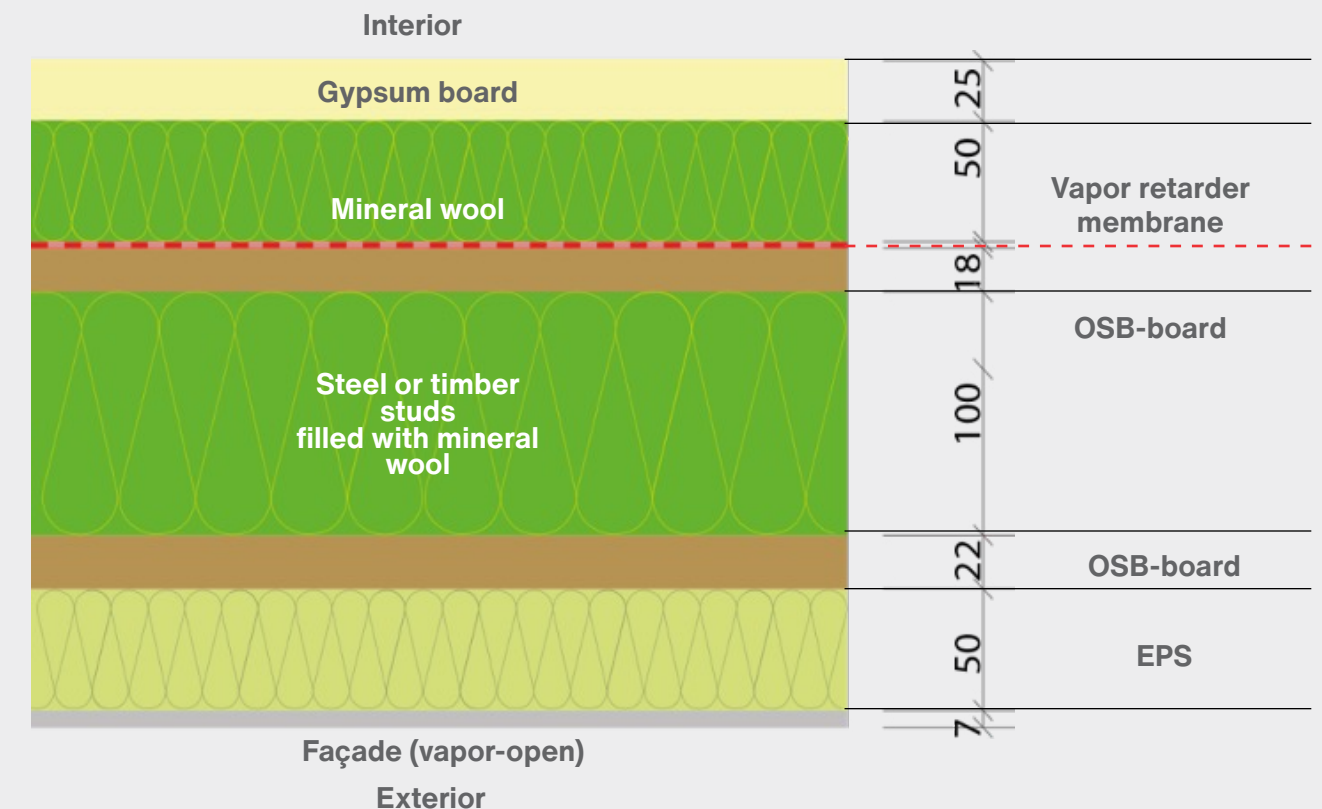
- **Ensures Comfort:** Optimal humidity levels (40–60%) improve indoor air quality.
- **Enhances Energy Efficiency:** Excess humidity can cause heat losses and increase ventilation demand.
- **Extends Building Lifespan:** Prevents condensation and mold growth, thereby protecting building components from damage.

Strategies for Preventing Condensation and Mold Growth

- **Airtightness:** Uncontrolled air leakage can lead to condensation; therefore, airtight construction is essential in Passive Houses.
- **Thermal Bridge Prevention:** Thermal bridges should be minimized to prevent condensation on cold surfaces.
- **Balanced Ventilation:** Heat recovery ventilation systems (HRV or ERV) should be used for effective humidity control.
- **Air Circulation in Enclosed Spaces:** Ensuring air movement behind closets, in basements, and in attic voids helps reduce the risk of mold growth.

Vapor Barriers and Vapor-Resistant Materials

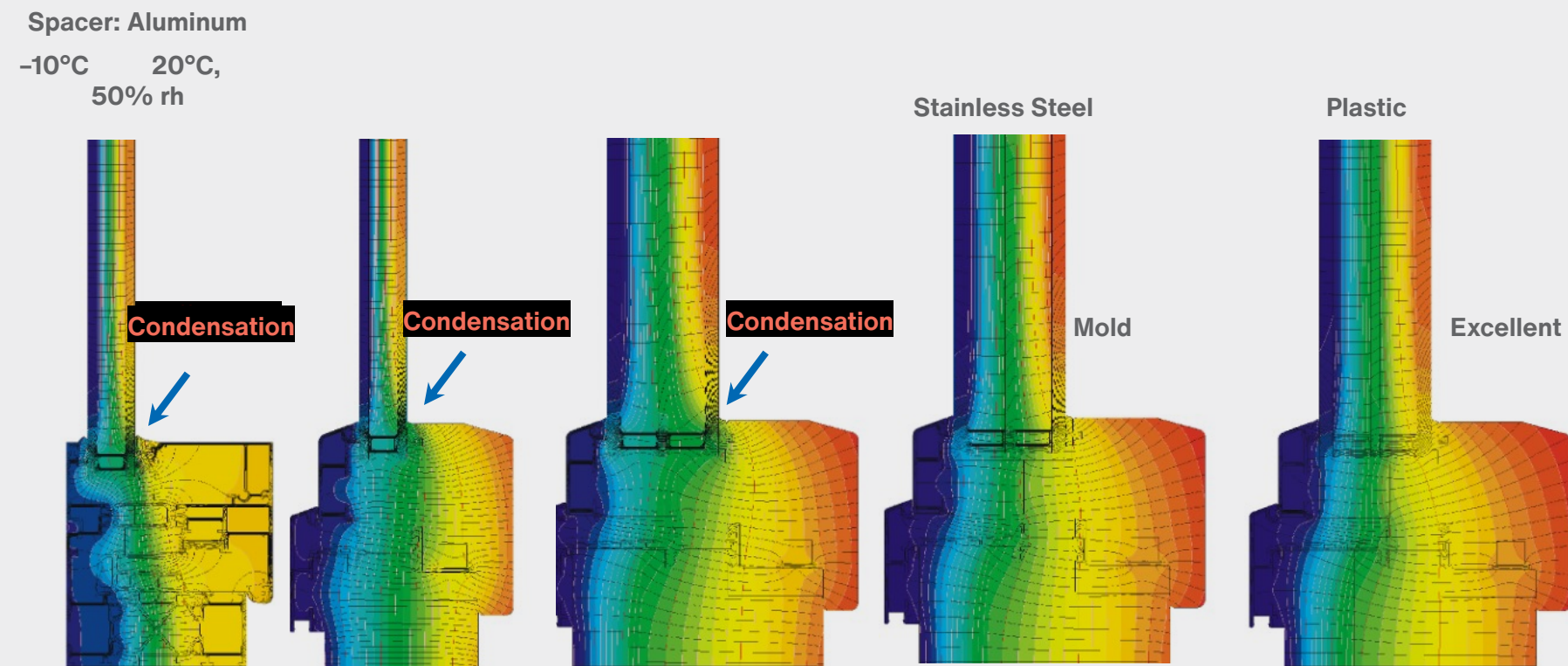
- **Vapor Barriers:** Typically applied to the interior side of walls to prevent water vapor from moving in undesirable directions (e.g., polyethylene (PE) membranes).
- **Vapor-Resistant Materials:** Materials that control moisture diffusion allow for a progressive increase in vapor permeability from the inside to the outside (e.g., smart vapor retarders).
- **Proper Layering:** The building envelope should be designed with decreasing vapor resistance from the inside to the outside to avoid trapping moisture within the structure.



Example of a Wall Section from a Warm Climate Region [2]

2.8. Moisture and Humidity Control

Window edges are the weakest point in terms of condensation. To keep the edge of the glass warm, appropriate materials—such as thermally broken edge spacers—must be selected. Many profile manufacturers have developed products made of materials that provide a high level of thermal separation for glass edge spacers (e.g., stainless steel foil or combinations of stainless steel and plastic). Unlike aluminum profiles, these spacers significantly reduce heat losses. In cool and temperate climates, mold prevention can only be reliably ensured by using plastic spacers.

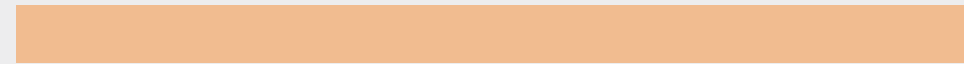


a_w	Maximum water activity	a_w [-]	1	1	1	0.83	0.74
f_{Rsi}	Glass edge temperature factor	$f_{Rsi}=0.20$ [-]	0.51	0.43	0.54	0.68	0.75
$\theta_{si,min}$	Minimum surface temperature	$\theta_{si,min}$ [°C]	7.73	5.84	8.53	12.00	13.61
Ψ_g	Thermal bridge value at the glass	Ψ_g [W/(mK)]	0.093	0.078	0.103	0.071	0.028



Section 3

ENERGY-EFFICIENT BUILDING SYSTEMS



3.1. Energy-Efficient HVAC Systems

HVAC (Heating, Ventilation, and Air Conditioning) systems are mechanical systems used to ensure indoor air quality and thermal comfort in buildings. These systems optimize indoor conditions by performing functions such as heating, cooling, ventilation, and humidity control.

OVERVIEW OF ENERGY-EFFICIENT HVAC SYSTEMS

Energy-efficient HVAC systems minimize energy consumption by meeting reduced heating and cooling loads in the most efficient manner. When integrated with good insulation, airtightness, and passive design strategies, these systems significantly reduce the energy demand of buildings. As a result, both the carbon footprint is lowered and long-term cost savings are achieved.

Energy-Efficient HVAC Solutions

- **Mechanical Ventilation with Heat Recovery (MVHR):** Saves energy by minimizing heat loss during ventilation.
- **High-Efficiency Heating Systems:** Heat pumps and condensing boilers deliver high performance with low energy use.

INTEGRATION OF HVAC SYSTEMS WITH PASSIVE DESIGN STRATEGIES

Integrating HVAC systems with passive building design significantly reduces a building's energy consumption. Passive design strategies minimize heat losses, enabling HVAC systems to operate at lower capacities, which in turn ensures energy savings.

In particular, MVHR systems help maintain optimal indoor air quality in passive houses with low air permeability while preventing heat loss. As a result, a stable and balanced indoor temperature is achieved, and the overall energy demand is kept to a minimum.

SAMPLE INTEGRATION SCENARIOS

- **Natural Ventilation + MVHR:** Passive methods such as cross-ventilation and the stack effect are combined with mechanical ventilation to reduce energy losses.
- **Thermal Mass + HVAC:** Materials with high thermal mass are used to decrease heating and cooling loads.
- **Solar Gains + Heating:** Passive solar heat gains are supplemented by low-energy heating systems such as heat pumps when additional heating is needed.

3.1. Energy-Efficient HVAC Systems

Traditional and many current HVAC solutions may fall short in terms of sustainability due to high energy consumption. However, HVAC systems supported by passive design principles can deliver maximum comfort with minimal energy use.

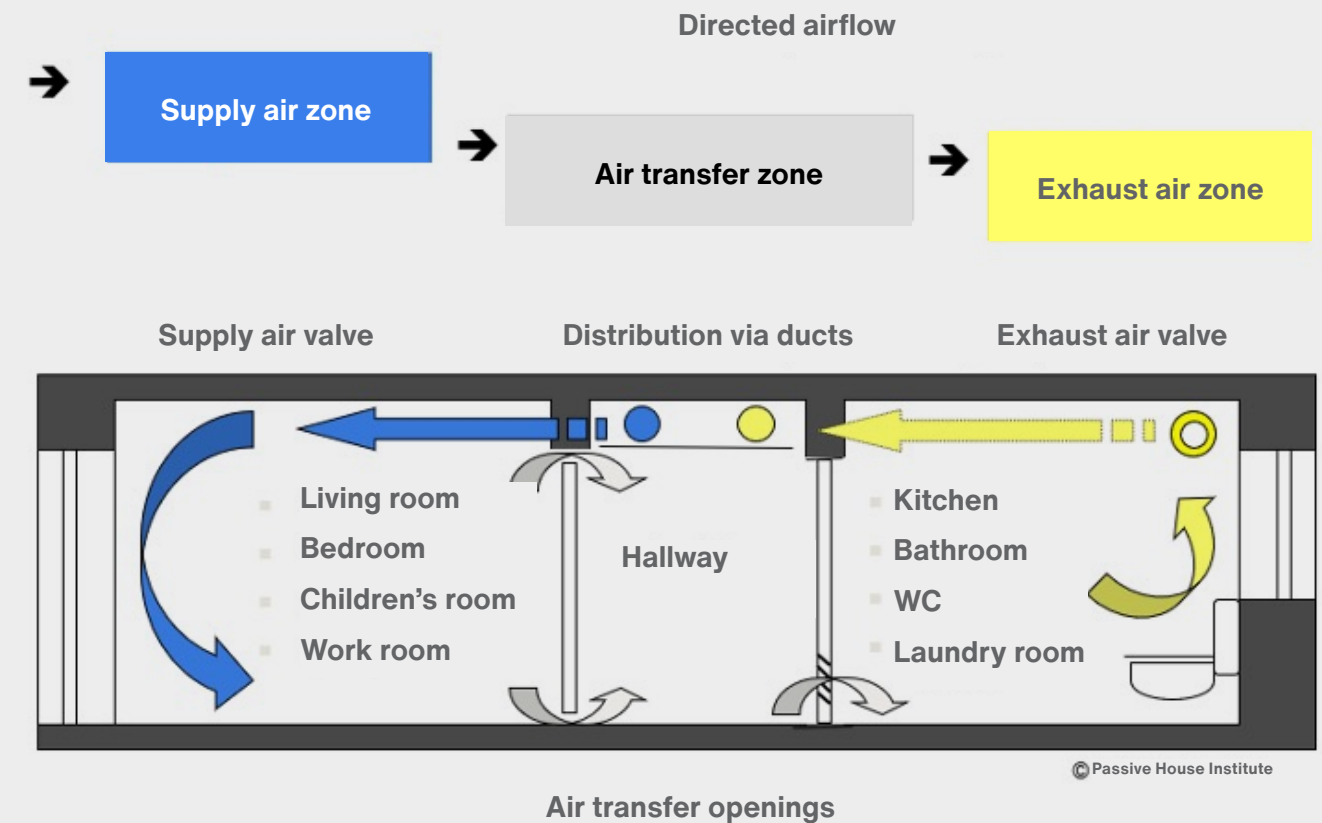
ZONING PRINCIPLE

When designing a ventilation system, spaces such as living areas, offices, or schools should be divided into zones to optimize airflow. In this system, supply air is directed toward the most frequently used rooms, while exhaust air is extracted from spaces with high humidity, odors, or emissions.

Priority should be given to supplying fresh air to rooms such as living rooms, bedrooms, or workspaces. This air should then pass through shared areas like hallways and be transferred to bathrooms, kitchens, or utility rooms, from where it is exhausted. These exhaust air rooms are defined as spaces containing moisture and odors that should not spread to other areas.

This zoning principle allows the reuse of air across several rooms, increasing air exchange efficiency in each space while minimizing the overall need for fresh air. In doing so, energy savings are achieved, and the system becomes more efficient.

The positioning of air ducts is also important. To avoid the need for long duct runs, suspended ceilings can be used in corridor areas to house ventilation ducts. Supply air valves can be installed on corridor walls to distribute air effectively. This provides efficient airflow without the need for costly and complex duct systems



© Passive House Institute

Additionally, to optimize airflow, exhaust valves should be placed as far from doors as possible. To ensure airflow is not blocked when doors are closed, sufficient clearance should be left between supply and exhaust zones. Special attention should be given to preventing furniture or carpets from obstructing airflow. [2]

3.2. Mechanical Ventilation with Heat Recovery (MVHR)

In non-residential buildings, the need for fresh air is generally higher compared to residential buildings. This is mainly due to the presence of more people in a shared space (e.g., classrooms or offices) and higher levels of air pollution (e.g., laboratories, restaurant kitchens, or cafeterias). In such cases, a mechanical ventilation system is not only advantageous but also necessary.

VENTILATION WITH HEAT RECOVERY – A PASSIVE HOUSE COMPONENT

In Passive House design, the ventilation system provides an integrated solution by considering all rooms within the thermal envelope of the building. An energy-efficient fan extracts used, humid air from exhaust air zones (e.g., kitchens, bathrooms, and storage rooms), while a second fan supplies fresh outdoor air to supply air zones (e.g., classrooms, offices, and living spaces).

These two air streams pass through a heat exchanger, enabling energy transfer. The warm exhaust air passively preheats the cold incoming air, providing energy savings and improved indoor comfort.

To ensure maximum energy efficiency and comfort, the system must have a heat recovery efficiency of at least 75%, and the specific electric power consumption of the fans should not exceed 0.45 Wh/m^3 .

BASIC OPERATING PRINCIPLE OF MVHR SYSTEMS

Mechanical Ventilation with Heat Recovery (MVHR) systems ventilate buildings by extracting polluted indoor air while recovering most of the heat from it. This process enhances indoor air quality with minimal energy loss.

- **In cold weather:** The heat from the exhaust air is transferred to the incoming fresh air, minimizing heat losses.
- **In warm weather:** The system can operate in reverse to prevent overheating by tempering incoming hot air.

Contribution to Energy Efficiency

- Compared to traditional ventilation systems, MVHR can reduce heat losses by up to 95%.
- Thanks to heat recovery, HVAC systems require less energy to maintain indoor comfort, reducing both energy consumption and operating costs. [2]



Image: © Aerex
Haustechniksysteme

3.2. Mechanical Ventilation with Heat Recovery (MVHR)

Ventilation systems must provide a sufficient amount of fresh air to occupied rooms and safely remove stale air. “Short-circuit” airflow must be avoided to ensure that air circulates effectively within the room before being discharged. The system should cause minimal disturbance to occupants and should not negatively impact indoor air quality. The formation of microbes, especially in filters and humid zones within the ventilation components, must be prevented. Additionally, the required airflow rate for hygiene purposes can assist in distributing warm or cool air effectively.

AIR QUALITY AND COMFORT

Mechanical Ventilation with Heat Recovery (MVHR) systems ensure a continuous circulation of clean air in passive buildings with high airtightness. They extract polluted indoor air while constantly supplying fresh air from outside.

Continuous fresh air flow helps balance carbon dioxide (CO₂) levels and enhances indoor air quality.

By controlling humidity, it prevents condensation and mold growth, promoting a healthier indoor environment.

Impact on Building Performance

- Thanks to heat recovery, MVHR systems significantly reduce the heating and cooling loads in passive buildings.
- They consume less energy, providing long-term energy savings and reduced operational costs.

Ductwork Used in MVHR Systems

- Simple and compact designs help avoid unnecessary investment costs.
- Sizing ducts strictly based on general rules is not always the most cost-effective solution.

Filter Class	Application Area	Type of Particles Captured
G4	Extract air (stale air)	Large particles (dust, insects, hair)
F7-F9	Outdoor air (fresh air intake)	Fine dust, pollen, some bacteria
EU10-17/HEPA	Special areas (hospitals, etc.)	Microorganisms, viruses, allergens

Filters Used in MVHR Systems

Filters should be replaced once a year. Otherwise, cleaning the system may become both time-consuming and costly.

- For outdoor air, filters rated at least F7, preferably F8 or F9, are recommended.
- For special environments (e.g., hospitals): High-quality aerosol filters (EU 10–17 or HEPA) are required.
- For extract air, a G4 filter should be used to protect the heat exchanger. [2]



Examples of supply and extract air nozzles attached to duct terminals



3.3. Energy-Efficient Lighting Systems

LED lighting supports passive design principles by reducing building energy consumption. Smart lighting systems automatically adjust light levels to prevent unnecessary energy use. By employing motion and daylight sensors, lighting is only provided in areas where it is needed, thereby improving energy efficiency.

ADVANTAGES OF LED LIGHTING

- **High energy efficiency:** Up to 80% more efficient than traditional incandescent and fluorescent lamps.
- **Long service life:** With an average lifespan of 50,000 hours, it significantly reduces maintenance and replacement costs.
- **Low heat emission:** Emits less heat, which lowers cooling needs and reduces the energy load on HVAC systems.
- **Environmentally friendly:** Contains no mercury and has low carbon emissions, making it safer for the environment.
- **Comfortable illumination:** Offers adjustable light in various color temperatures, providing both aesthetic and functional lighting solutions without straining the eyes.




SMART LIGHTING CONTROL SYSTEMS

- **Sensor-assisted lighting:** Lighting automatically switches on or off based on the presence of people or available daylight, using motion or daylight sensors.
- **Remote access:** Lights can be easily controlled through smartphone apps via Wi-Fi or Bluetooth.
- **Scheduling and scene settings:** Lighting can be programmed to turn on or off at specific times and customized for different scenarios (e.g., “movie mode” or “work mode”).
- **Dimming (light level control):** Adjusting brightness levels not only enhances visual comfort but also boosts energy efficiency.

3.3. Energy-Efficient Lighting Systems

APPLICATION AREAS

- **Home automation:** Smart LED lighting systems can be integrated with assistants like Alexa or Google Home to enhance comfort and energy savings at home.
- **Offices and commercial spaces:** Daylight-responsive systems automatically adjust indoor lighting, promoting both energy savings and improved employee productivity.
- **Smart city applications:** Street lighting systems can automatically adjust brightness based on surroundings and be managed remotely via centralized platforms.
- **Industrial facilities:** Sensor-based LED systems in factories and production facilities help prevent unnecessary energy use, yielding substantial energy savings.

SAMPLE PERFORMANCE TABLE FOR LIGHT SOURCES	Incandescent Bulb	Compact Fluorescent Lamp (CFL)	LED Bulb
			
Lamp Lifetime (Hours)	1,200	8,000-10,000	30,000-50,000
Economic Lifetime (Years)	1	3.5	10
Unit Price (TL)	2.5	6.3	21
Sensitivity to Frequent Switching	Low Impact	Shortens lifespan	No Effect
Instant Start	Yes	Delayed	Yes
Heat Sensitivity	Limited	Yes	No
Moisture Resistance	Limited	Yes	No
Harmful Materials	None	5 mg mercury/bulb	None
Replacement Frequency (for 50,000 h)	40+	5 times	1 time

[4]

3.3. Energy-Efficient Lighting Systems

Smart lighting management combines daylight and motion sensors to deliver the most energy-efficient lighting solution. This system can reduce energy consumption by 50–80%, significantly lowering operational costs. It also eliminates the need for manual control, offering a user-friendly and automated experience.

DESIGN STRATEGIES TO MAXIMIZE DAYLIGHT USE

- Building orientation and window design ensure maximum use of natural light indoors, reducing the need for artificial lighting.
- Light-colored interior surfaces reflect light better and make more effective use of daylight.
- Shading elements (e.g., pergolas, shutters, exterior architectural components) prevent excessive brightness and heat while preserving natural lighting.

Motion Sensors and Automatic Control Systems

- Motion and daylight sensors activate lighting only in needed areas, preventing unnecessary energy use.
- Timers and remote control systems allow lighting to operate in sync with daylight, avoiding unnecessary use throughout the day.
- With building management systems (BMS), lighting can be dynamically adjusted, improving energy efficiency and reducing operational costs.

INTEGRATION OF DAYLIGHT AND MOTION SENSORS

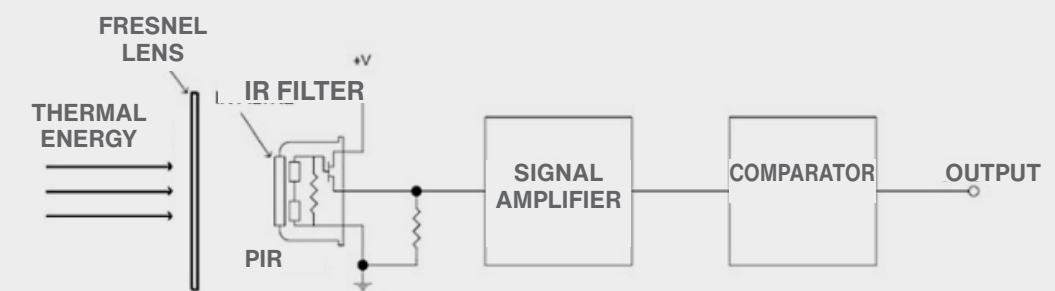
Working principle: Measures the natural light level in the environment and adjusts artificial lighting automatically.

Advantages: Ensures maximum daylight use and energy savings. Dims or turns off lights depending on brightness. Commonly used in offices, schools, and smart buildings.

Motion Sensors (PIR – Passive Infrared & Microwave Sensors)

Working principle: Detects human movement and turns lighting on or off accordingly.

Advantages: Prevents unnecessary energy consumption in unoccupied areas. Ideal for parking lots, corridors, and storage rooms. Can be integrated into security systems.



Lighting Motion Sensor [5]

3.4. Renewable Energy Integration

In recent years, commercial buildings have increasingly turned to the concept of Net Zero Energy Buildings, both to gain cost and competitive advantages and to comply with legal regulations. Moreover, this concept has begun to play a significant role in the short- and medium-term sustainability goals of many local governments.

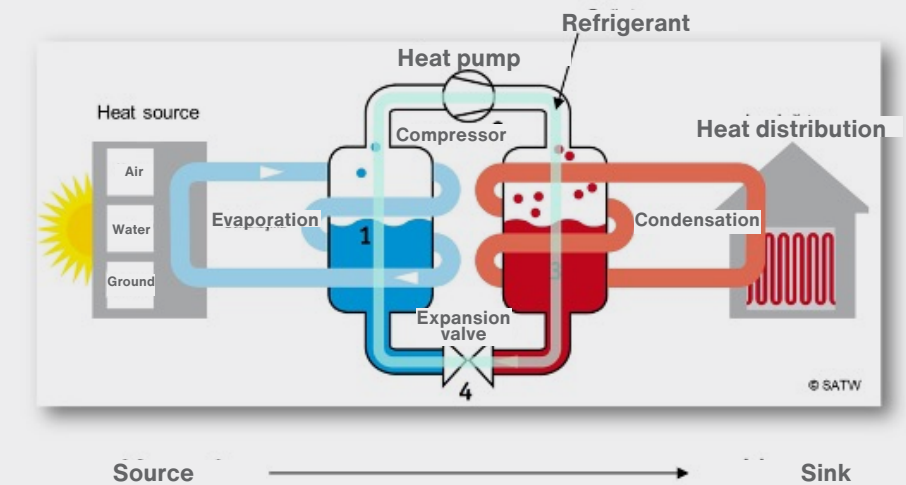
The primary purpose of a building is to provide a comfortable space for its users to live, work, rest, and take shelter. In the future, the main goal of buildings—especially in terms of photovoltaic systems—should not be solely to maximize energy production. Such an approach may lead to the widespread construction of uniform, single-story, windowless bungalow-like structures with wide overhangs facing the equator. However, these types of monotonous buildings do not offer a large-scale sustainable solution in terms of aesthetics, urban planning, or other architectural and cultural factors.

In addition, cities are largely already built up, and the rate of new construction is relatively low. It is not possible to apply renewable energy systems without limitation to both new and existing buildings. The main reasons for this include the fact that these technologies also consume natural resources and that there are practical limitations such as aesthetic and cultural-historical sensitivities, orientation, shading, and density.

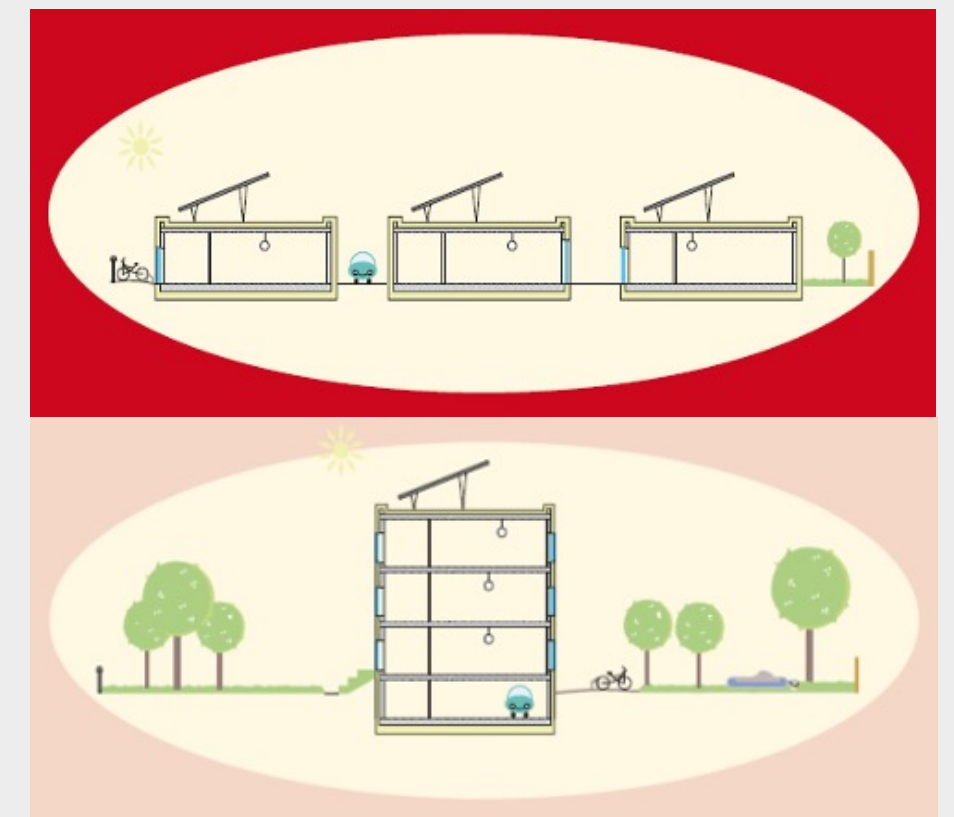
As buildings are responsible for approximately 40% of global carbon emissions, the integration of passive design and renewable energy systems is of great importance in achieving the Net Zero Energy Building target. First, buildings must reduce their energy consumption for heating, cooling, lighting, and other uses to the lowest possible level. Then, the remaining energy demand should be met by renewable sources, either on-site or remotely.

Relationship Between MVHR and Renewable Energy

- MVHR (Mechanical Ventilation with Heat Recovery) increases energy efficiency inside the building and, when integrated with renewable energy systems, minimizes total energy consumption.
- In passive buildings, MVHR can be supported by electricity produced from solar panels, allowing the system's energy needs to be met by renewable sources.
- When used in combination with geothermal systems, the energy required for ventilation and heating processes can be provided at lower cost. [2]



Selection of Heat pump [14]



Three single-family homes or one multi-family building [15]

3.4. Renewable Energy Integration

Renewable energy enhances energy independence by reducing external energy demand and fossil fuel consumption. By lowering carbon emissions, it contributes to environmentally friendly building design. In the long term, it reduces energy costs; although the initial investment is high, it is amortized over time and offers economic benefits.

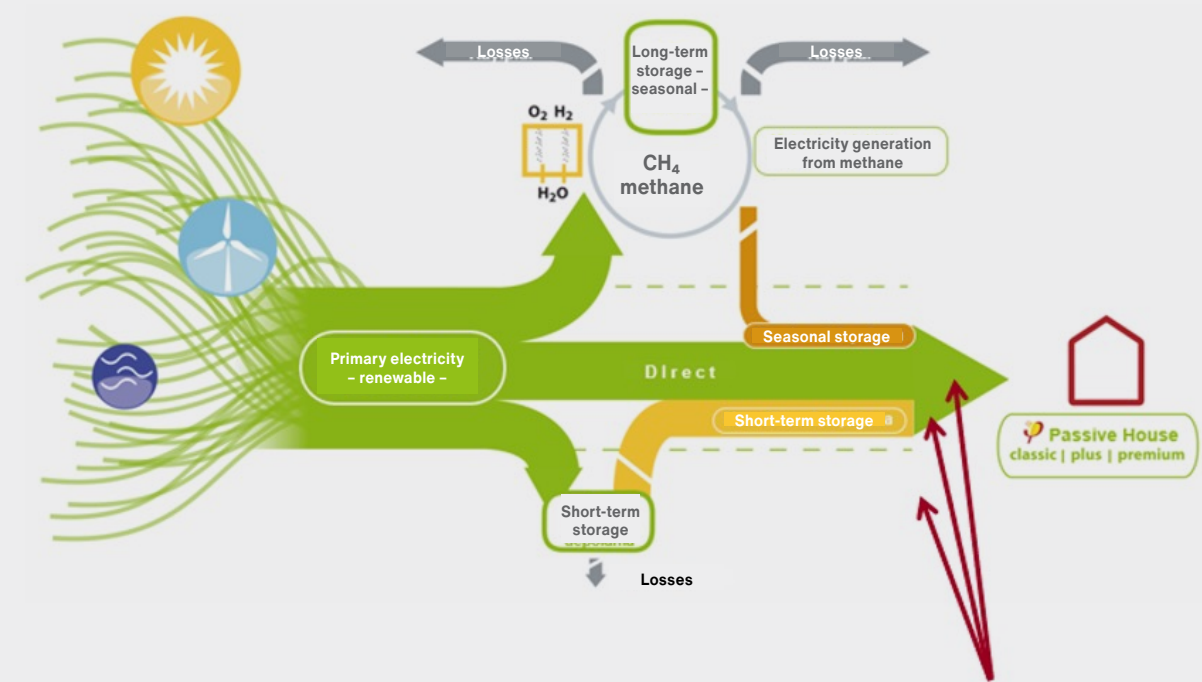
A large portion of renewable energy is generated as electricity from solar, wind, and hydroelectric sources. Most of the electricity produced can be used directly, and the most efficient solution is to ensure its direct use. However, to address short-term supply shortages (such as the absence of solar energy at night), electricity must be temporarily stored in short-term storage facilities.

On the other hand, long-term storage is required to meet extended energy needs, such as during the heating season. The most suitable method for long-term storage is to convert electricity into hydrogen through electrolysis and then add carbon to produce methane gas. Methane can be easily stored in underground caverns or dedicated storage facilities and can be converted back into electricity when needed via combined heat and power (CHP) systems.

Electricity use in buildings is supplied from three different sources:

- 1) Directly used electricity,
- 2) Electricity from short-term storage,
- 3) Electricity from long-term storage.

The primary energy demand of a building is determined by the ratio of the total amount of renewable primary energy required to meet the final energy need. This ratio is a significant metric for assessing the energy efficiency of buildings and the level of renewable energy use. [2]



$$\text{PER factor} = \frac{\text{Renewable energy generation}}{\text{Final energy}}$$

PER factor: Renewable Primary Energy Factor

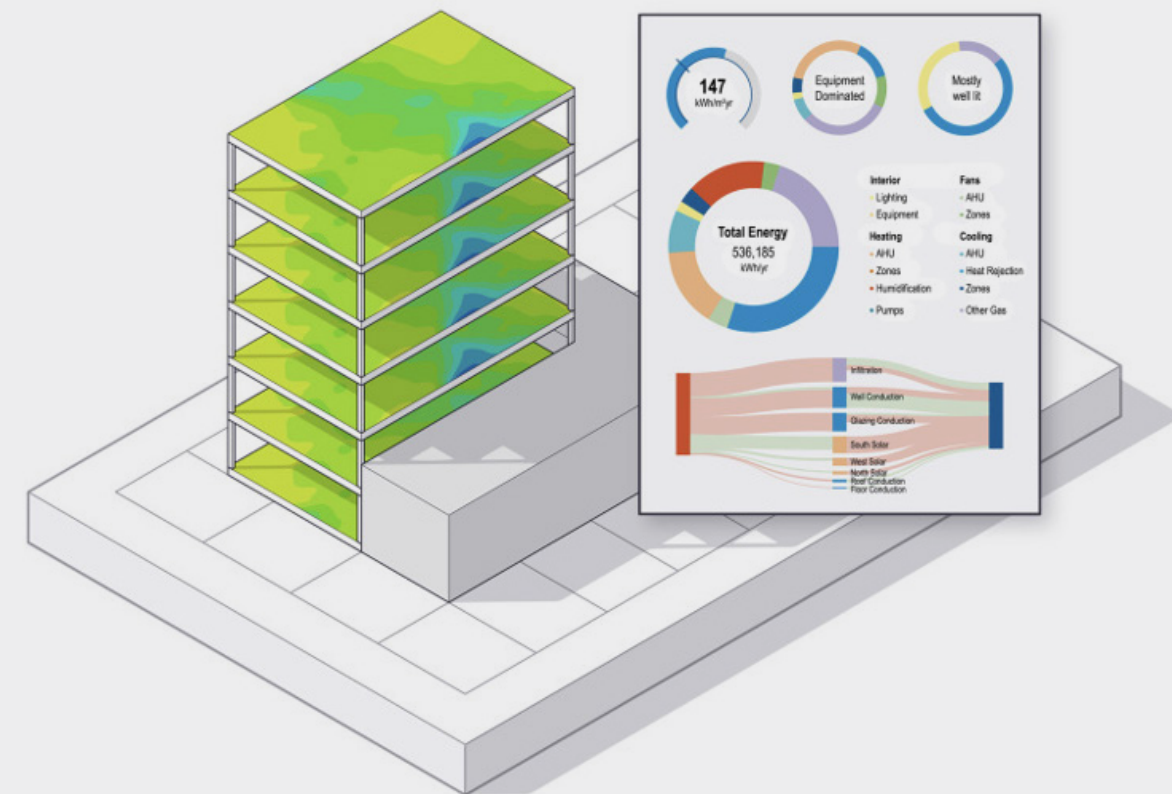
The composition depends on the area of energy use (heating, domestic hot water, etc.).

3.5. . Energy Modeling Tools

Energy modeling tools are used in early-stage design decisions to optimize building energy performance and identify the most efficient solutions. They provide guidance in material and system selection to reduce energy consumption and support sustainable building design. They are also used to improve the energy efficiency of existing buildings and to identify the most appropriate strategies in renovation projects.

WHAT IS ENERGYPLUS?

- An open-source energy simulation software developed by the U.S. Department of Energy.
- EnergyPlus is an energy analysis and thermal load simulation program that models heating, cooling, lighting, ventilation, and other energy flows in buildings. It features key simulation capabilities such as variable time steps, user-configurable modular systems, and zone simulation based on heat and mass balance. It also supports advanced features such as multizone airflow, thermal comfort analysis, and natural ventilation.
- With its advanced computational capabilities, it is frequently used in large-scale projects. [6]

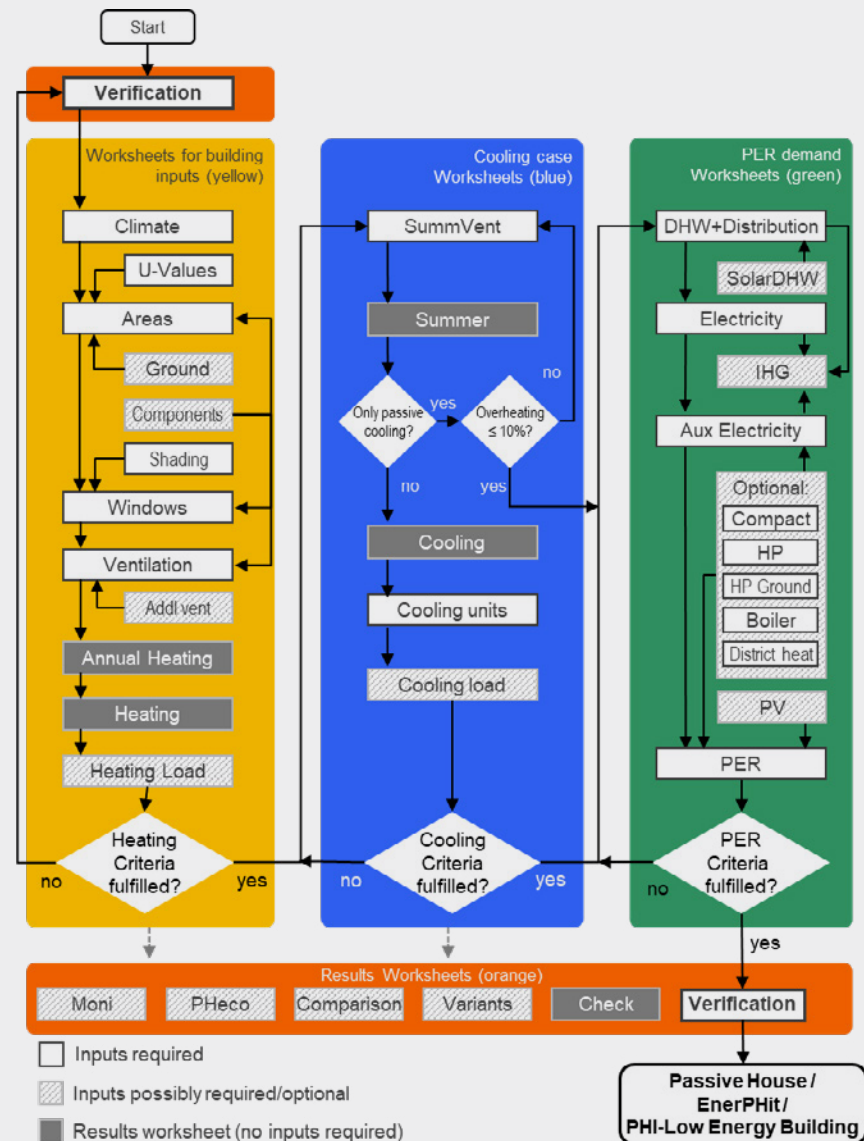


3.5. . Energy Modeling Tools

Developed for the planning and evaluation of buildings in line with the Passive House concept, the Passive House Planning Package (PHPP) offers both accuracy and practicality throughout the design process. Its Excel-based structure allows for easy analysis of energy consumption, heating demand, and other performance criteria.

WHAT IS PHPP?

PHPP is an Excel-based tool developed to enhance energy efficiency and optimize design processes. It is used as a verification tool for Passive House buildings and EnerPHit retrofits.



Key Features

Provides an easy-to-use interface for conducting energy calculations. Delivers calculation results tested and validated in accordance with Passive House standards. Offers more precise calculations and additional analysis options with updated versions. Allows integration with energy modeling and analysis software.

3D Data Entry Tool: designPH:

designPH is a 3D modeling and data entry tool developed for Passive House design. It analyzes building geometry, shading factors, and energy performance parameters to generate data sets compatible with PHPP (Passive House Planning Package). [2]

Specific building characteristics referenced to the insulated area						
				Criterion	Alternative criterion	Completed?
Area heating	Area within insulation ₁ m ²	156,0				
	Heating demand ₁ kWh/(m ² a)	13	≤	15	-	Yes
	Heating load ₁ W/m ²	10	≤	-	10	Yes
Area cooling	Cooling and dehumidification demand ₁ kWh/(m ² a)	-	≤	-	-	-
	Overheating frequenc (> 25 °C) %	1	≤	10	-	Yes
	Excessive high humidity frequency ₁ (> 12 g/kg) %	0	≤	20	-	Yes
Air tightness	Pressurization test result ₁ 1/h	0,2	≤	0,6	-	Yes
Fossil Primary Energy (PE)	PE demand ₁ kWh/(m ² a)	46	≤	-	-	-
Renewable Primary Energy (PER)	PER demand ₁ kWh/(m ² a)	37	≤	30	37	Yes
	Renewable energy production ₁ (projected based on building area) kWh/(m ² a)	176	≥	120	133	Yes

2 Empty fields: data missing; "-": Not required

I confirm that the values provided here have been determined following the PHPP methodology and based on the building's characteristics. PHPP calculations are attached to this confirmation:

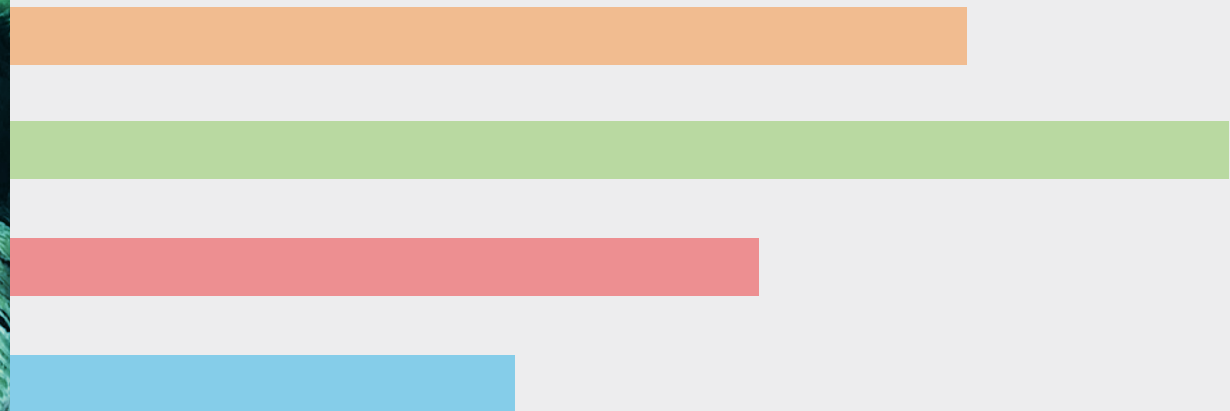
Task | First name | Last name | Passive House Premium? | Signature

© Passive House Institute



Section 4

PASSIVE HOUSE STANDARDS AND CERTIFICATION



4.1. Introduction to Passive House Standards

The Passive House standard is not a trademark; it can be applied to almost all designs, building typologies, and construction styles by anyone. Passive House buildings are designed in accordance with the European Energy Performance of Buildings Directive (EPBD), with an annual energy consumption for heating and cooling limited to a maximum of 15 kWh/m². Thanks to their low energy consumption, they offer long-term cost advantages.



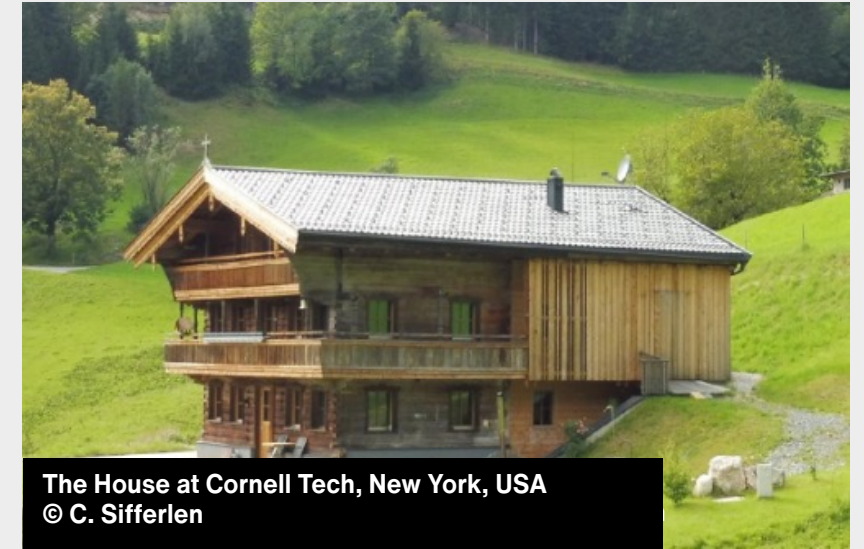
Goldsmith Street in Norwich | ID 6045 45
© Tim Crocker



Passive House Technology and Experience Center
Qingdao | ID 4674 © RoA - Rongen Tribus Vallentin



V. Senger School in Frankfurt, Germany
| ID 1955 © Mara Monetti Fotografie



The House at Cornell Tech, New York, USA
© C. Sifferlen

INTERNATIONAL DEFINITION OF PASSIVE HOUSE

A Passive House is a building type where thermal comfort is achieved by preconditioning the fresh air mass flow required for good indoor air quality through heating or cooling. This system, which combines energy efficiency and comfort, can be applied worldwide.

- Climate-independent and adaptable to all regions.
- Produces affordable, sustainable, and user-friendly solutions.
- Minimizes the need for separate heating and cooling systems, thus reducing energy consumption.

Advantages of the Passive House Concept

- **Affordable and Energy Efficient:** Significantly reduces heating and cooling loads through high insulation and airtightness.
- **High Comfort Standards:** Provides balanced indoor temperatures and a comfortable environment
- **Environmentally Friendly:** Can be integrated with renewable energy sources, reducing carbon emissions.

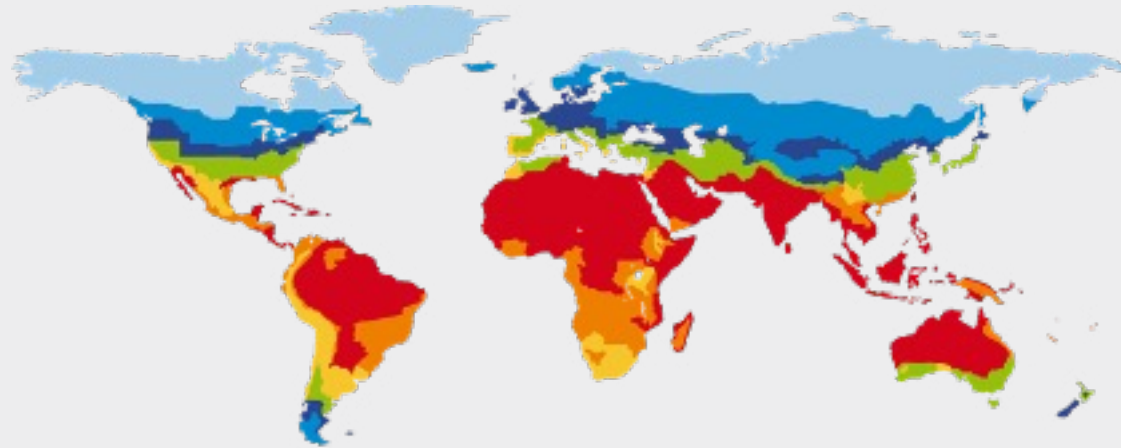
Global Applicability of Passive Houses

- Can be built with local materials and adapted to regional climate conditions.
- Longer lifespan, low maintenance costs, and sustainable building components.
- Serves as a model for future housing standards and is applicable worldwide.

4.2. Passive House Components

A Passive House compliant building component is a building material or system produced according to Passive House standards, characterized by high energy efficiency, tested and certified. These components minimize heat losses, improve building performance, and provide a comfortable, sustainable indoor environment.

<https://database.passivehouse.com/en/components/>



High-Performance Thermal Insulation

- High-value insulation is used in roofs, walls, and floors.
- U-value is minimized to ≤ 0.15 W/(m²K).
- Insulation thickness is typically between 250-300 mm.

Airtightness

- The building envelope is made completely airtight.
- Air leakage is measured with a Blower Door Test and must be $n_{50} \leq 0.6$ h⁻¹.
- Interior plaster, membranes, and wooden panels act as airtightness barriers.

High-Efficiency Windows and Doors

- Triple-glazed windows with low U-values (≤ 0.8 W/(m²K)) are used.
- Window frames are insulated to prevent heat loss.
- Glass optimized for solar gain provides heat gain in winter.

4.2. Passive House Components

Mechanical Ventilation with Heat Recovery (MVHR)

- Mechanical ventilation systems with over 75% heat recovery efficiency are used.
- Energy loss is minimized in both fresh air intake and exhaust air.
- Total electrical consumption of the ventilation system should not exceed 0.45 Wh/m^3 .

Thermal Bridge-Free Design

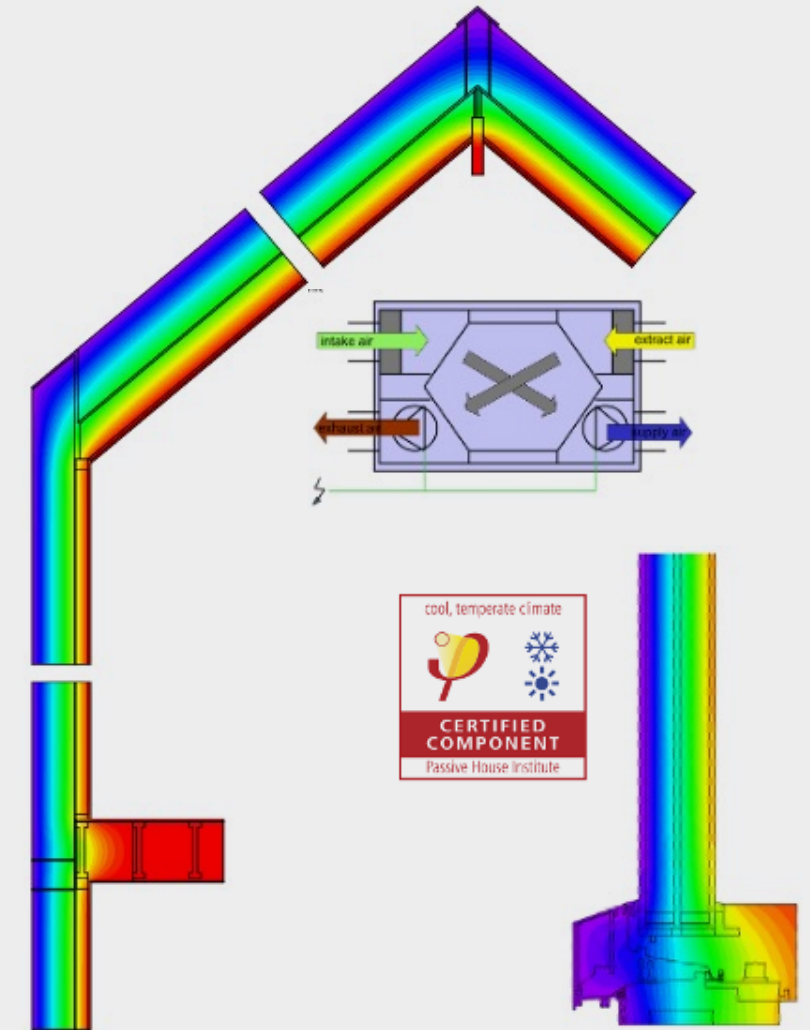
- Building components are detailed to avoid thermal bridges.
- Exterior joints, window edges, and structural elements are specially designed.
- Heat leaks are prevented to increase energy efficiency.

Solar Radiation and Shading Strategies

- Large glazed surfaces on the south facade increase solar gain in winter.
- East and west-facing windows are protected with external shading elements to prevent overheating in summer.
- Façade and roof design is optimized for both summer and winter conditions.

Low Energy Consumption Electrical Appliances

- Energy-efficient LED lighting and white goods are used.
- Energy consumption is optimized with smart building management systems.
- Electrical appliances should have an energy class of A++ or higher.



4.3. Passive House Design Process

Passive House buildings are characterized by their minimal energy consumption and exceptionally high thermal comfort. In general, the Passive House criteria are defined by the Passive House Institute and are particularly cost-effective for new buildings. Passive House certification can be achieved in the Classic, Plus, or Premium categories, depending on renewable primary energy demand and on-site renewable energy generation.

				Criteria ¹			Alternative Criteria ²
Heating							
Heating demand	[kWh/(m ² a)]	≤	15			-	
Heating load ³	[W/m ²]	≤	-			10	
Cooling							
Cooling + dehumidification demand	[kWh/(m ² a)]	≤	15 + variable allowance ⁴				
Airtightness							
Pressurization test result n ₅₀	[1/h]	≤	0.6				
Renewable Primary Energy (PER)⁵				Classic	Plus	Premium	
PER demand ⁶	[kWh/(m ² a)]	≤	60	45	30	±15 kWh/(m ² a) deviation from criteria... ...with compensation of the above deviation by different amount of generation ⁸	
Renewable energy generation ⁷ (with reference to projected building footprint)	[kWh/(m ² a)]	≥	-	60	120		

Explanatory notes on the criteria can be found in the Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard document.

Passive House Criteria [1]

4.3. Passive House Design Process

Passive House buildings are characterized by their exceptionally high thermal comfort levels while maintaining minimal energy consumption. To enable improvements and deep renovations within the existing building stock, the Passive House Institute has developed the EnerPHit / Energy Retrofit with Passive House Components criteria.

			Criteria ¹	Alternative Criteria ²	
Airtightness					
Pressurization test result n_{50}	[1/h]	≤	1.0		
Renewable Primary Energy (PER)³			Classic	Plus	Premium
PER demand ⁴	[kWh/(m ² a)]	≤	60 45 30 + allowance for larger heating/cooling demand (compared to Passive House)		±15 kWh/(m ² a) deviation from criteria... ...with compensation of the above deviation by different amount of generation ⁶
Renewable energy generation ⁵ (with reference to projected building footprint)	[kWh/(m ² a)]	≥	-	60	

RetroPhit Criteria [1]

Explanatory notes on the criteria can be found in the Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard document.

Q_H : heating demand

$Q_{H,PH}$: Passive House criterion for the heating demand

$f_{\emptyset PER, H}$: weighted mean of the PER factors of the heating system of the building

Q_C : cooling demand (incl. dehumidification)

$Q_{C,PH}$: Passive House criterion for the cooling demand

4.4. Passive House Certification Process

Passive House certification is a process that verifies a building's compliance with internationally recognized standards for energy efficiency and sustainability. It is assessed according to the criteria established by the Passive House Institute (PHI).

1. PRELIMINARY ASSESSMENT AND DESIGN PHASE

This phase includes the initial analyses conducted to determine whether the project is suitable for Passive House criteria.

- **Energy Modeling and Simulation**
 - The project is subjected to energy balance calculations using the PHPP (Passive House Planning Package) software.
 - Building orientation, insulation thicknesses, window performance, airtightness values, and HVAC systems are analyzed.
- **Material and System Selection**
 - High-performance insulation and windows with low U-values are selected.
 - Energy-efficient systems such as Mechanical Ventilation with Heat Recovery (MVHR) are chosen.
- **Pre-Certification Application**
 - Project-specific design documents are submitted to the Passive House Institute.
 - A preliminary review is conducted by PHI or authorized Passive House certification bodies.

2. IMPLEMENTATION AND QUALITY CONTROL PHASE

During this phase, quality assurance tests are performed while the building construction is ongoing.

- **Blower Door Test (Airtightness Test)**
 - The building is tested for airtightness.
 - The air change rate (n_{50}) must be $\leq 0.6 \text{ h}^{-1}$ (i.e., the building envelope must not exceed 0.6 air changes per hour).
- **Heat Recovery and Ventilation Systems Inspection**
 - The efficiency of the MVHR system is measured.
 - Sustainability of indoor air quality is assessed.
- **Insulation and Thermal Bridge Analysis**
 - Insulation applications are examined for compliance with the project.
 - The prevention of thermal bridges (heat losses) is checked.



3. CERTIFICATION APPLICATION AND APPROVAL PHASE

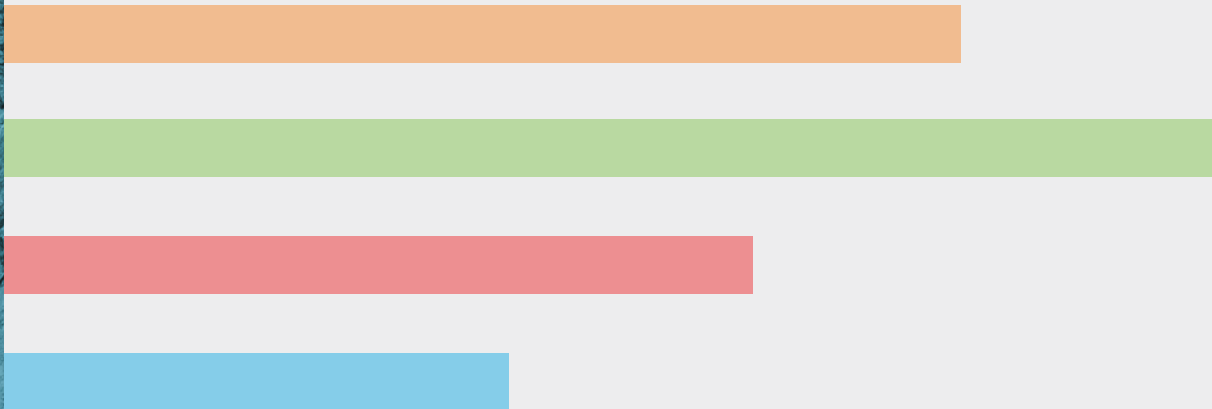
In this phase, after the building is completed, all measurements and documents are reviewed to finalize the certification process.

- **Preparation of the Final Report**
 - The completed building is submitted to the Passive House Institute or an authorized certification body.
 - PHPP analysis results, test reports, and energy performance data are evaluated.
- **Certification and Approval**
 - If the building meets all Passive House criteria, the Passive House Certificate is issued.
 - For non-compliant buildings, improvement recommendations are provided, and re-assessment is conducted after corrections are completed.



Section 5

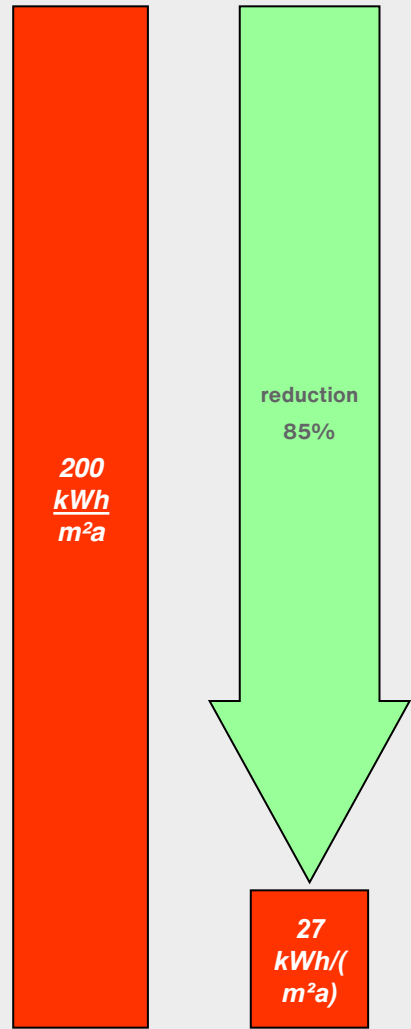
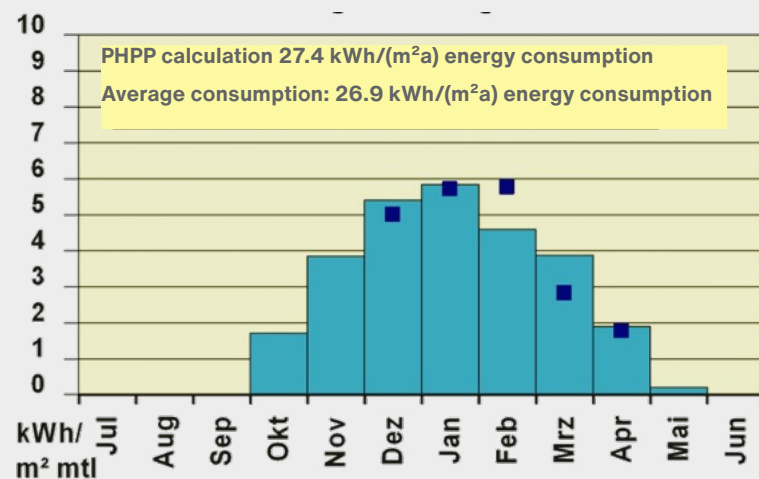
**ENERGY-EFFICIENT
RENOVATION OF
EXISTING
BUILDINGS**



5.1. Renovation Strategies and Their Importance

According to the International Energy Agency's 2022 Buildings Tracking Report, existing buildings are responsible for 40% of global carbon emissions. Through improvements such as thermal insulation, airtightness, and the use of energy-efficient systems, energy consumption is reduced and the carbon footprint is minimized. These renovations lower individual energy costs and contribute to societal savings. Energy-efficient renovation is a critical step toward achieving net-zero emissions targets by 2050. It supports the creation of environmentally responsible cities by minimizing fossil fuel use. Buildings integrated with renewable energy systems become more sustainable and low-carbon structures.

pre-renovation



Deep Renovation of an Existing Apartment Block

Location: Jean-Paul-Platz, Nuremberg

Architect: Schulze-Darup, Nuremberg

Scientific Assessment: Conducted by PHI Germany

Year of Construction: 1930

Building Details: Six apartments, each with an area of 149 m²

The energy consumption calculated after renovation closely matched the monitored actual consumption (refer to the graph at the bottom left). In this project, only necessary upgrades were implemented, with minimal changes made to the floor plans. [2]

post-renovation



- Basement insulation was applied
- External walls were insulated
- Windows compliant with Passive House standards were installed
- A high-efficiency heat recovery ventilation system was implemented

Photos and diagram: © Schulze-Darup

5.1. Renovation Strategies and Their Importance

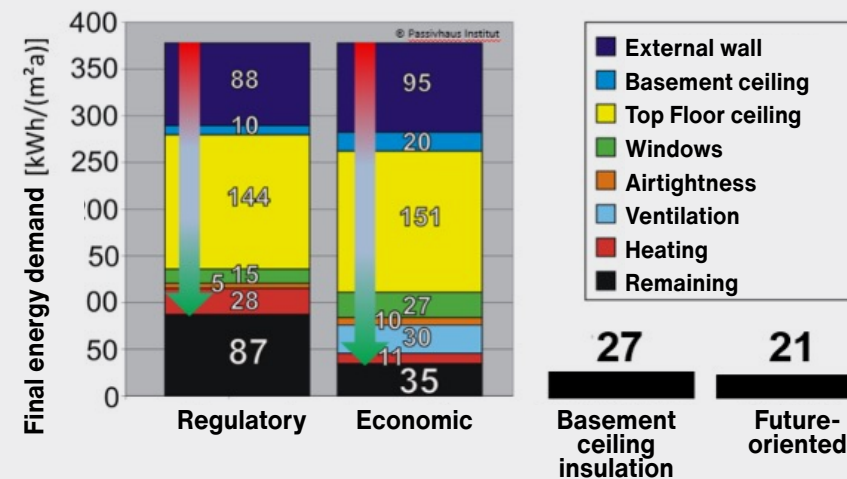
In existing buildings, structural constraints, high investment costs, limited access to financing, lack of awareness, and regulatory restrictions can hinder the transformation process.

Thanks to advancing technologies, more efficient insulation and HVAC solutions, government or international incentives, green building certifications, and long-term cost savings offer opportunities to create sustainable and comfortable living spaces.

FINAL ENERGY DEMAND FOR HEATING IN AN APARTMENT BLOCK BUILT IN THE 1950S IN GERMANY

The final energy demand for heating in an apartment block built in the 1950s in a cold-temperate climate was calculated to be approximately 380 kWh/(m²a) before renovation. The renovation process includes various scenarios for energy savings based on individual efficiency measures and different renovation standards.

Building code or economic optimization?



© Passive House Institute

Explanation of the Chart:

- The full height of the bar represents the pre-renovation final energy demand (~380 kWh/m²a).
- The colored sections show the energy savings achieved through individual renovation measures.
- The black bars represent the remaining final energy demand after renovation.

Two Different Renovation Scenarios:

1. Renovation According to Minimum Regulatory Requirements (Left Side)

- Involves renovating only individual building components to meet minimum energy efficiency standards.
- Although it provides a noticeable reduction in building energy demand, it still results in high

energy consumption (approximately 2.5 times higher energy demand).

2. Renovation According to Cost-Effective Energy Standards (Right Side)

- All building components are upgraded to provide the highest cost-benefit ratio over their life cycle.
- When optimal energy efficiency is achieved, the building's energy demand can be reduced to 35 kWh/(m²a).
- If insulation is added to the basement ceiling, the final energy demand can decrease to 27 kWh/(m²a).

Conclusion:

- The building renovated according to the cost-effective level has an energy demand at least 2.5 times lower than the one renovated to the minimum standard.
- Bringing all building components to optimal energy efficiency levels ensures maximum long-term savings and comfort.
- Additional insulation measures, such as insulating the basement ceiling, further reduce energy demand and offer cost-effective improvements. [2]

5.2. Deep Renovation Steps and Techniques

Upgrading the existing building stock for energy efficiency reduces carbon emissions, contributes to environmental protection, and lowers costs through energy savings. Improved insulation and efficient systems create comfortable and healthy living spaces. It increases energy independence, raises building value, and plays a critical role in ensuring a sustainable future in the long term.

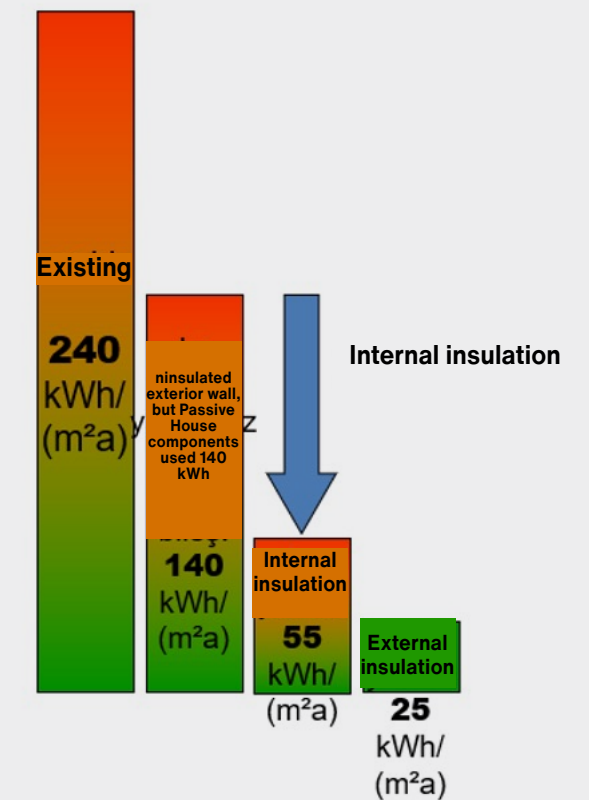
- **1. Assessment of the Existing Condition**
 - Analysis of the building's energy consumption
 - Identification of heat losses (thermal imaging, airtightness tests)
 - Evaluation of user behavior
- **2. Energy Modelling and Determination of Design Strategies**
 - Analysis through energy simulations
 - Passive design strategies: solar gain, natural ventilation, insulation improvements
 - High-efficiency HVAC and lighting systems
- **3. Key Considerations During the Implementation Phase**
 - Quality control in the integration of materials and systems
 - Building automation systems and smart control mechanisms
 - Detailed solutions that reduce thermal bridges
- **4. Passive House Techniques that Enhance Energy Performance**
 - Heat Recovery Ventilation ($\geq 75\%$ efficiency)
 - Low-Energy Ventilation ($\leq 0.45 \text{ Wh/m}^3$ – the electricity consumed by the mechanical ventilation system to move 1 cubic meter of air)
 - Optimal Heating Load ($\leq 10 \text{ W/m}^2$)
 - High-Efficiency Electrical Appliances & Lighting
 - Overheating Prevention (10% limit, PHPP analysis) - The number of hours per year during which the indoor temperature exceeds 25 °C must not exceed 10% of the total annual hours.
- **Passive House Components**
 - High-Quality Thermal Insulation ($U \leq 0.15 \text{ W/m}^2\text{K}$)
 - Double or Triple Glazed Windows with Low U-Values ($U \leq 1 \text{ W/m}^2\text{K}$)
 - Prevention or Minimization of Thermal Bridges
 - Airtight Layer & Pressure Testing ($n_{50} \leq 0.6/\text{h}$)
 - Use of Solar Energy & Proper Façade Planning

5.2. Deep Renovation Steps and Techniques

In many historic buildings, external insulation cannot be applied; therefore, internal insulation should be taken into account.

THE IMPACT OF INTERNAL INSULATION ON HEATING DEMAND

- Although internal insulation is less efficient than external insulation, it significantly reduces heating demand.
- In uninsulated older buildings, heating demand is around 240 kWh/(m²a), which can be reduced to 40–60 kWh/(m²a) with internal insulation.
- With external insulation, this figure can be reduced to 20–30 kWh/(m²a), resulting in approximately a tenfold decrease in heating demand.
- In renovation projects, even if external insulation is applied, the Passive House standard (15 kWh/(m²a)) is generally not achieved due to thermal bridges and building orientation.
- The effectiveness of internal insulation has been proven in many projects.
- Dynamic simulations are critically important for assessing moisture and thermal risks.
- EnerPHit-certified solutions are tested and approved by the Passive House Institute. [2]



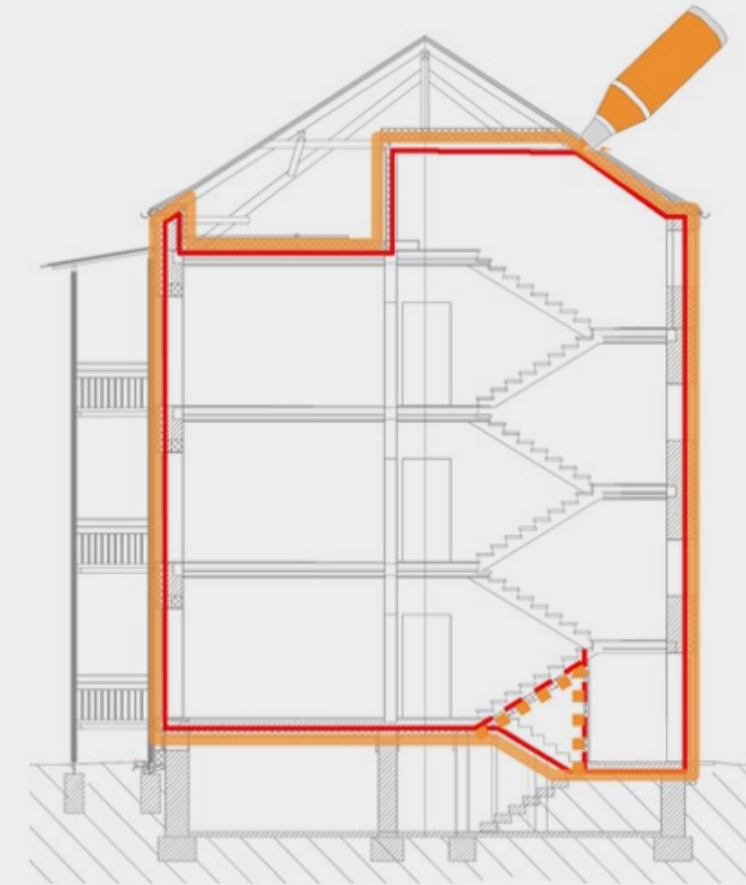
5.2. Deep Renovation Steps and Techniques

CHALLENGES IN THE RENOVATION PROCESS

- Structural condition of existing buildings and technical constraints
- High initial investment costs and limited access to financing
- Lack of awareness and user resistance to renovation projects
- Difficulties in regulatory and permitting processes

OPPORTUNITIES FOR ENERGY-EFFICIENT RENOVATION

- More efficient insulation and HVAC solutions enabled by advancing technologies
- Incentives through EU- and government-supported financing programs
- Long-term cost payback through green building certifications and energy savings
- Potential to create sustainable and comfortable living spaces



- **Continuity Rule:** The thermal envelope should be as continuous and uninterrupted as possible.
- **Contact and Penetration Rule:** If interruptions or penetrations in insulation are unavoidable, materials with the lowest possible thermal conductivity must be used.
- **Connection Rule:** Different insulation layers must be joined tightly without gaps.



5.2. Deep Renovation Steps and Techniques

EXAMPLES OF THERMAL BRIDGE-FREE CONSTRUCTION IN RENOVATION PROJECTS

1. Preventing Thermal Bridges:

- Eliminating or Redesigning Protruding Building Elements
 - Attach balconies/canopies using structurally independent supports
 - Alternatively, integrate balconies into the thermal envelope
- Including Cold Areas Within the Heated Space
 - Convert unheated attic spaces into living areas to ensure insulation continuity
 - Remove interior basement walls to allow uninterrupted basement ceiling insulation

2. Reducing Thermal Bridges:

- Additional Insulation on Walls in Contact with Cold Areas
 - Use side insulation on load-bearing walls in contact with cold basements or attics
 - Separate these walls with materials of low thermal conductivity, such as porous concrete or foam glass
- Ensuring Continuous Thermal Insulation
 - Integrate windows into the insulation layer
 - Ensure continuity in basement and roof insulation

3. Maintaining Continuity of the Thermal Envelope:

- Insulating Unheated Basements
 - Define the boundaries between heated and unheated zones at stairs, doors, and walls
 - Insulate basement walls and floor slabs
- Insulation Measures for Adjacent Buildings
 - Insulate walls and building elements facing unheated neighboring structures
 - Analyze the existing structure before the planning phase [2]

5.3. . Upgrading HVAC and Lighting Systems

Heat recovery units can be integrated into suspended ceilings, walls, or storage spaces; unused chimneys may also be utilized for this purpose. Even in older buildings with low ceilings or ground-level applications, suspended ceiling solutions are feasible. Flat air ducts can perform similarly to round ducts in terms of cost and pressure loss. Core drilling reduces dust and noise. Thanks to simplified duct enclosures, these systems can be easily applied in existing (occupied) buildings.

HVAC SYSTEM RENOVATION

- **High-Efficiency Heating Systems:**
 - Condensing boilers, heat pumps, and district heating systems should be preferred.
 - Radiant heating and low-temperature heating systems offer energy savings.
- **Energy-Efficient Cooling and Humidity Control:**
 - Variable refrigerant flow (VRF) systems and high-efficiency air conditioning units should be used.
 - Passive cooling methods (natural ventilation, night cooling, etc.) should be applied.
- **Heat Recovery Ventilation (HRV) Systems:**
 - Ventilation units with heat recovery efficiency above 75% should be used.
 - Humidity control should be ensured to improve indoor air quality.
- **Integration of HRV Systems**
 - Indoor air quality should be improved with filtration systems.
 - Bidirectional ventilation units should provide both heat and humidity control.
 - Moisture should be effectively removed from wet areas such as bathrooms and kitchens.
 - The air exchange rate should be optimized to minimize energy losses. Excessive air change rates may lead to overly dry indoor conditions. [2]



HRV unit installed **inside a wardrobe**



HRV unit installed inside a **kitchen cabinet**



HRV unit installed on **exterior wall**



© Nilan Comfort CT150



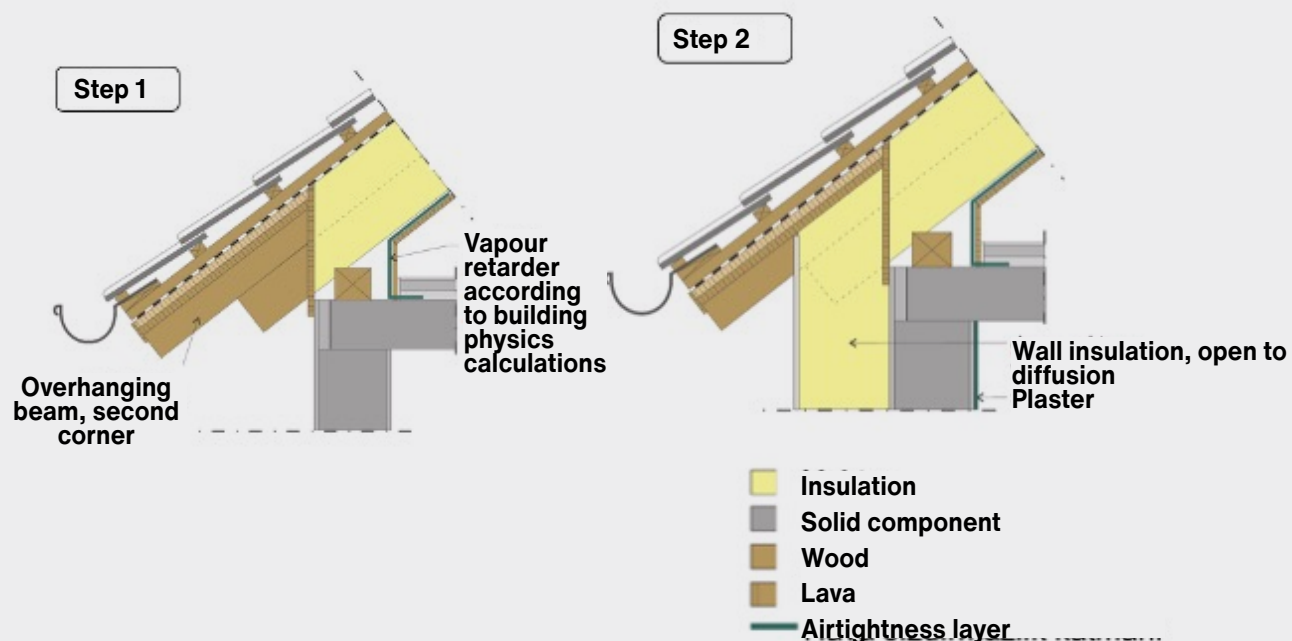
Installed in a **service wall** (HRV unit depth: 20 cm)

5.4. Renovation Methods

Deep retrofit projects can be implemented using either a holistic or a step-by-step approach. Both methods have their own advantages, and the choice depends on factors such as budget, building condition, and user needs. A holistic deep retrofit ensures that the entire process is completed at once, while a step-by-step approach allows for a more flexible financial plan by spreading the costs over time.

There are two pathways to obtain the EnerPHit certification:

- 1. According to Certified Passive House Components Criteria:** Each building component must meet the specified limit values. These limits are based on the certification requirements for Passive House components.
- 2. According to Energy Demand Criteria:** In some cases, the energy renovation may result in a sufficiently low heating demand (e.g., below 25 kWh/(m²a) in a cool-temperate climate). In such cases, if the improvement over the previous energy performance is significant, full compliance of all building components with the certified criteria is not required. The same principle applies in warm climates where the cooling demand meets Passive House standards.



© SEPEV



When Deep Retrofits Are Carried Out Step-by-Step:

- The remaining service life of existing building components is fully utilized.
- Investment costs can be spread over time, offering financial flexibility.



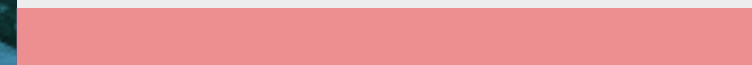
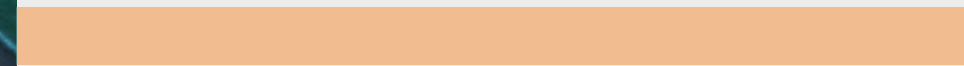
When Deep Retrofits Are Carried Out in One Phase:

- Construction site setup, scaffolding, and planning are required only once.
- Occupants are affected by the renovation only once.
- Intermediate stages do not require additional safeguarding.



Section 6

CASE STUDIES AND BEST PRACTICES



6.1. Passive Building Design in a Mediterranean Climate

ŞİLE ATLI HOUSE

Atlı House is the world's first mixed-use Passive House Plus certified building comprising both residential and restaurant functions. It is located in Şile, Istanbul.



The building has a total enclosed area of 820 m² and consists of a three-story Block A (residence) and a single-story Block B (industrial kitchen). There is no partition door between the two blocks. The southeast and east façades continue with walls. In the façade design, the window openings on the building envelope are planned to maximize daylight utilization.

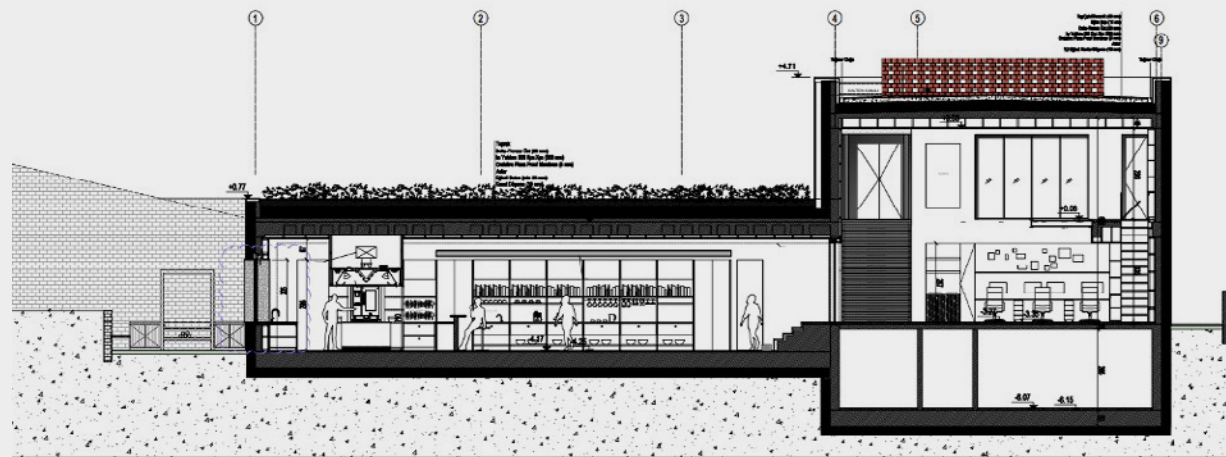
The wide openings on the south façade allow solar radiation into the interior during winter, contributing to heat gain and efficient use of daylight. There are no openings on the north façade, and since the structure consists of only one floor above ground, heat loss is minimized.

The building envelope is wrapped externally from beneath the foundation with XPS thermal insulation boards in varying thicknesses (15–30 cm) on the ground-contacting surfaces and roof. On other walls, 20 cm thick stone wool insulation has been applied. Thermal breaks are used at the connection points between the mechanical façade system and the reinforced concrete structure to prevent heat transfer.

The building meets all its electricity needs—excluding the kitchen—through approximately 10 kW photovoltaic panels installed on the roof and a vertical-axis wind turbine located in the garden. To minimize heat loss, triple-glazed window systems and thermally insulated frames are used.

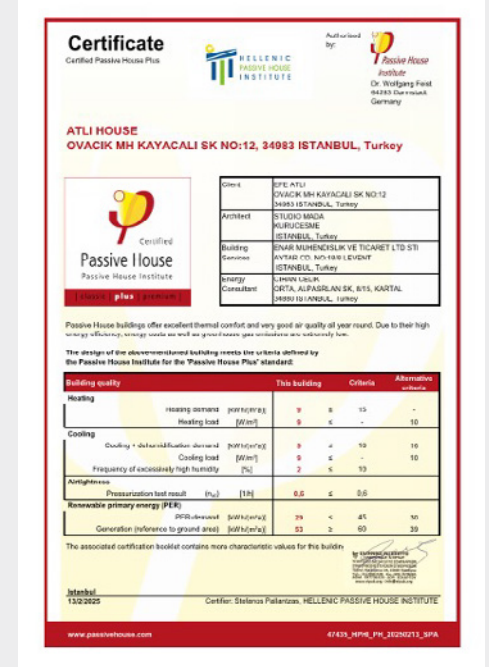
Fresh air for the building is supplied via pipes installed underground and through heat recovery units. The air drawn from outside is directed into the building, utilizing the coolness of the soil in summer and the warmth of the soil in winter. For heating and cooling, an air-to-air heat pump, which is an alternative energy source, is used.

Thanks to the installed building automation system, the energy consumption of all systems is monitored daily. Greywater is treated and redirected to toilet tanks to reduce water consumption. Rainwater is collected in a tank with a total capacity of 450 m³, treated with an ozone system, and converted into potable water.



6.1. Passive Building Design in a Mediterranean Climate

ŞİLE ATLI HOUSE



The green roof system implemented on the building's roof contributes to thermal insulation and helps reduce carbon emissions. The plants used in the green roof and landscaping were selected from among endemic species that are suited to the region's climate and require low water and maintenance. During summer, the water needs of the plants are met through a drip irrigation system. The materials used in the building were sourced locally and selected in accordance with sustainability principles.

Heating demand	9 kWh/m ² year
Cooling demand	9 kWh/m ² year
Renewable energy generation	53 kWh/m ² year
External wall U-value	0.102 W/m ² K
Ground floor U-value	0.110 W/m ² K

Roof U-value	0.113 W/m ² K
Window U-value	0.8 W/m ² K
Heat recovery efficiency	86 %
n50 pressure test	0.6 h/1

6.1. Passive Building Design in a Mediterranean Climate

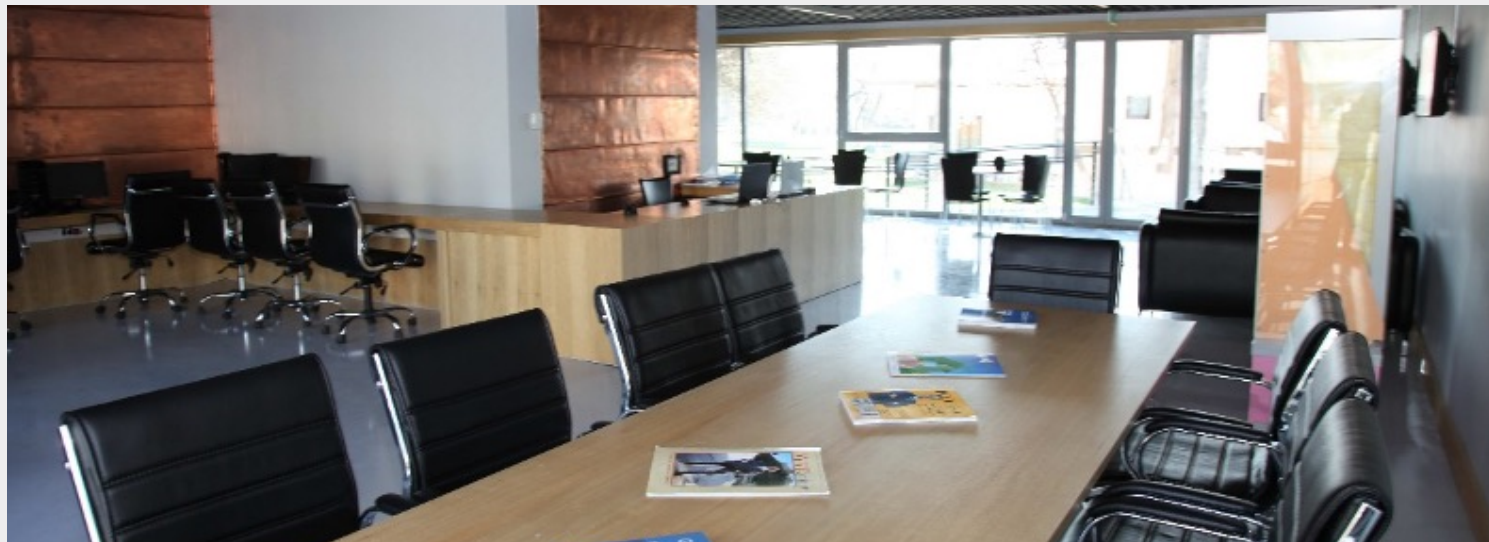


GAZİANTEP ECOLOGICAL BUILDING

Gaziantep Ecological Building is the first Passive House certified building in Türkiye in the new building category. It has also achieved LEED Platinum certification, awarded by the U.S. Green Building Council.

With a total indoor area of 325 m², the building operates as an information center on environmentally responsible construction. Managed by the Gaziantep Metropolitan Municipality, the building hosts awareness-raising and educational activities on ecological balance for approximately 25,000 people annually.

The building includes a 60-seat conference hall designed for sharing and developing ideas related to energy efficiency and sustainable energy sources. At the entrance, there is an information and research area intended for both tourists and students, followed by a flexible space designed for resting, waiting, or exhibitions. The building systems are introduced to visitors through informational videos and building system models.



6.1. Passive Building Design in a Mediterranean Climate

GAZIANTEP ECOLOGICAL BUILDING

Designed and constructed according to its specific needs, the Gaziantep Ecological Building was built to prevent resource loss and waste generation. Its compact architectural design helps minimize unnecessary energy consumption. A variety of systems were implemented to ensure minimum energy use and low carbon emissions, tailored to the building's functional requirements.

- Compact architectural design
- Location that supports public transportation and pedestrian access
- Green roof system
- Green landscaping area
- Architectural layout optimized for natural daylight
- Triple-glazed window systems and thermally insulated frames
- Highly insulated building envelope
- Ventilation system with heat and humidity balance
- Water-based heating and cooling system
- Rainwater harvesting system
- Greywater treatment systems
- Low-energy LED lighting
- Photovoltaic energy system



Heating demand	9 kWh/m ² year
Cooling demand	9 kWh/m ² year
Renewable energy generation	96 kWh/m ² year
External wall U-value	0.092 W/m ² K
Ground floor U-value	0.111 W/m ² K
Roof U-value	0.101 W/m ² K
Window U-value	0.74 W/m ² K
Heat recovery efficiency	75 %
n50 pressure test	0.51 h/1



6.2. Energy-Efficient Renovation in a Cold Climate

DUBLIN SEMI-DETACHED HOUSE

This semi-detached house is the first EnerPHit Passive House building completed by Dublin City Council in 2018.

Originally, the building was used as a 22-bedroom residential unit. Through the renovation, it was converted into eleven one-bedroom apartments designed for elderly residents. The average floor area of the ground-floor apartments is 57.3 m², while the first-floor units measure 58.9 m². Both floors follow the same layout plan. The living and bedroom areas are oriented to the southwest. The existing structure consisted of a robust frame

made of concrete, blockwork, and brick.

The buildings were reconstructed to meet high building standards while maintaining the original architectural form. To eliminate the risk of major thermal bridging, certain concrete eaves and projections were removed. Due to height constraints and the need to preserve minimum ceiling height, only limited insulation could be added to the ground floor.

The external walls were insulated from the outside using rock wool, chosen for both thermal

performance and fire safety. Attic spaces were generally insulated with conventional mineral wool. The front and rear eaves were also reinforced with insulation to reduce thermal bridges and meet design targets.

This project served as a pilot study under Dublin City Council's Deep Retrofit strategy. Given the large number of similar buildings across the city, the model offers high replicability. As a result of the retrofit, energy consumption and carbon emissions were reduced by over 80% compared to the building's previous performance. [10]



Passive House Database [10]

6.2. Energy-Efficient Renovation in a Cold Climate

DUBLIN SEMI-DETACHED HOUSE



Certificate
Passive House Suitable Component
 For cool temperate climates, valid until 31. December 2016

Category: **Compact Heat Pump System**
 Manufacturer: **Nilan A/S**
 8722 Hedensted, DENMARK

Product name: **Compact P (92 m³/h)**

This certificate was awarded based on the following criteria (limit values*):

Thermal Comfort: $t_{supply,air} \geq 16,5^{\circ}C$
 Heat Recovery of ventilation system: $\eta_{HRC,air} \geq 75\%$
 Electric efficiency ventilation system: $P_{el} \leq 0,45 Wh/m^3$
 Air tightness (internal/external): $V_{Leakage} \leq 3\%$
 Total Primary Energy Demand (**): $PE_{total} \leq 55 kWh/(m^2a)$
 Control and calibration (*)
 Air pollution filters (*)
 Anti freezing strategy (*)
 Noise emission and reduction (*)

Measured values to be used in PHPP (set point 92 m³/h) useful air flow rates 52 to 120 m³/h

	Test point 1	Test point 3	Test point 3	Test point 4	
Outside Air Temperature	T_{out}	-7,0	2,1	7,1	°C
Thermal Output Heating Heat Pump	$P_{th,HP}$	0,49	0,62	0,67	kW
COP number Heating Heat Pump	COP _{HP}	2,43	2,55	2,78	-
Maximum available supply air temperature with Heat Pump only(*)		33,6			°C

	Test point 1	Test point 3	Test point 3	Test point 4		
Outside Air Temperature	T_{out}	-6,9	1,9	7,2	20,2	°C
Thermal Output Heat Pump for heating up storage tank	$P_{th,HP,heating up}$	0,51	0,72	0,89	1,02	kW
Thermal Output Heat Pump for reheating storage tank	$P_{th,HP,reheating}$	0,54	0,71	0,83	0,94	kW
COP Heat Pump for heating up storage tank	COP _{HP,heating up}	2,11	2,40	3,08	3,38	-
COP Heat Pump for reheating storage tank	COP _{HP,reheating}	1,94	2,50	2,80	3,05	-
Average storage tank temperature		50,5			°C	
Specific storage heat losses		1,83			W/m³	
Exhaust air addition (if applicable)					W/m³	

(*) detailed description of criteria and key values see attachment.
 (**) for heating, domestic hot water (DHW), ventilation, auxiliary electricity in the reference building, explanation see attachment.

www.passivehouse.com 0390ch03

Passivhaus Institut
 Dr. Wolfgang Feist
 64283 Darmstadt
 GERMANY

Heat Recovery
 $\eta_{HRC,air} = 77\%$

Electric efficiency
 0.43 Wh/m³

Air tightness
 $V_{Leak, internal} = 1.0\%$
 $V_{Leak, external} = 1.1\%$

Frost protection
 down to -7 °C

Total Primary Energy Demand ()**
 54.1 kWh/(m²a)

CERTIFIED COMPONENT
 Passive House Institute

St. Bricin's Park, Block 2 is a two-storey residential building designed to accommodate elderly residents. As part of the project, eleven one-bedroom apartments were created by combining adjacent single rooms. These units were planned to comfortably house one or two people. Originally, this building was one of the standard single-bedroom accommodations constructed across Dublin in the early 1970s for individual residency.

To improve energy efficiency and indoor comfort, external wall insulation was applied to the building envelope, and both the roof and floor were insulated, significantly reducing thermal bridging throughout the structure. Additionally, high-performance windows and external doors were installed to minimize energy loss.

All these upgrades were supported by enhanced airtightness, elimination of thermal bridges, and the integration of mechanical ventilation with heat recovery (MVHR) systems in each apartment.

This exemplary retrofit project was overseen and approved by MosArt Ltd. [10]

Heating demand	11 kWh/m²year
Cooling demand	9 kWh/m²year
External wall U-value	0.145 W/m²K
Ground floor U-value	0.349 W/m²K

Roof U-value	0.098W/m²K
Window U-value	0.78 W/m²K
Heat recovery efficiency	75.4 %
n50 pressure test	0.55 h/1

6.3. Practical Recommendations for Designers and Developers

SOME KEY INSIGHTS AND PRACTICAL SUGGESTIONS TO COMPLY WITH PASSIVE DESIGN PRINCIPLES:

- 1. Insulation:** External façade and roof insulation should be at the best possible level appropriate to the climate zone. Thermal bridges should be avoided, and continuous insulation should be provided between building components.
- 2. Correct material selection:** High-performance materials such as mineral wool, cellulose, and polyurethane should be used.
- 3. Airtightness:** Vapor barriers and airtight layers should be applied correctly. Junctions of doors and windows should be carefully sealed. Airtightness should be tested with a blower door test.
- 4. Highly Insulated Building Envelope:** Materials such as concrete, stone, and compressed earth should be used in the interior to prevent temperature fluctuations. Shading elements should be placed in front of glazed surfaces on the south façade. Thermal storage and delayed release strategies should be applied.
- 5. Natural Ventilation:** Fresh air circulation should be ensured through cross-ventilation strategies. Passive ventilation solutions such as solar chimneys and wind deflectors should be considered. Controlled air

exchange should be provided by using HRV or ERV systems.

- 6. Lessons Learned from Real Projects and Common Mistakes:** Successes: Up to 90% heating energy savings can be achieved through proper orientation and solar gain. Cooling needs in summer can be eliminated thanks to a highly insulated building envelope and ventilation strategies. Mistakes: Reduced energy efficiency due to inadequate airtightness. Overheating or insufficient daylight due to incorrect window

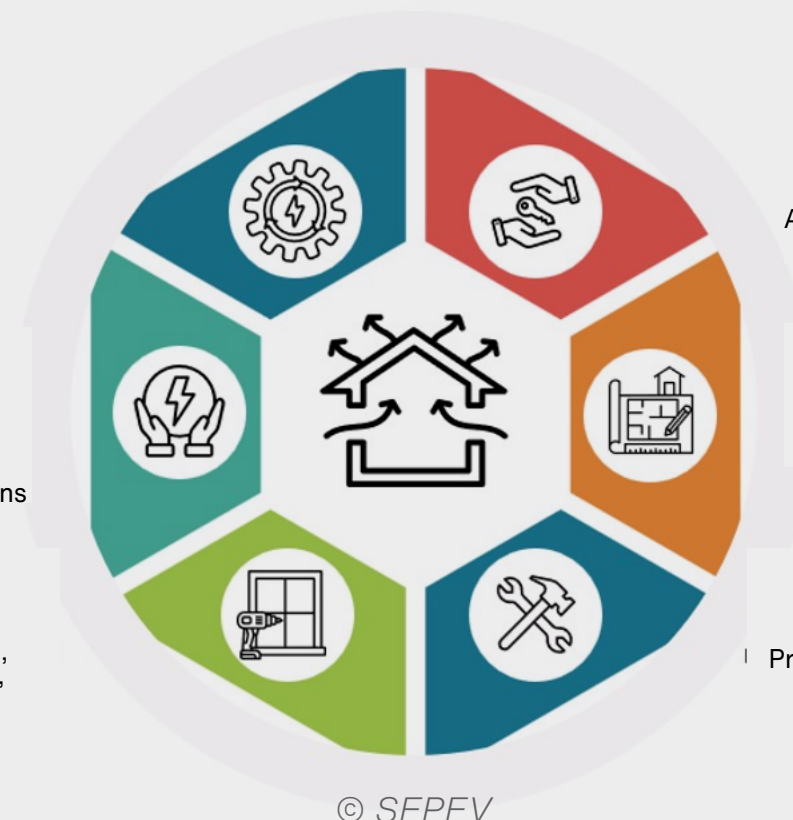
placement. Inappropriate insulation and overlooked thermal bridges.

- 7. Regulations and Certification Processes:** The airtightness and energy consumption criteria defined for Passive House buildings should be considered. Compliance with local regulations should be ensured, and design should be carried out by taking regional climate conditions into account. Building efficiency should be pre-tested through energy performance simulations.

ELECTRICITY GENERATION
Solar/wind energy systems are required to achieve the "Passive House Plus" level.

ENERGY DESIGN
Design in accordance with Passive House criteria
PHPP software
Consultancy
Energy efficiency calculations

BUILDING SYSTEMS
Installation of mechanical systems
Ventilation, heating, cooling, domestic hot water, lighting, elevator, etc.



OWNER
Financing provider
Decision-maker
Auxiliary electricity consumption
Monitoring the funding process

ARCHITECT
Thermal envelope design
Insulation
Window placement and energy efficiency

CONSTRUCTION
Construction process
Thermal bridge management
Proper construction techniques to minimize heat loss

References

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CONGRATULATIONS!

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Module 9. Now, reinforce your learning by
taking the test and challenging yourself*

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