Active for more comfort: The Passive House

Information for property developers, contractors and clients

International PASSIVE HOUSE Association iPHA

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International Passive House Association
Rheinstraße 44 | 46
D-64283 Darmstadt
Tel.: +49 (0) 6151 | 82699-55
Fax: +49 (0) 6151 | 82699-34
info@passivehouse-international.org
www.passivehouse-international.org

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Passivhaus Dienstleistung GmbH
(Passive House Services)
Rheinstraße 44 | 46
D-64283 Darmstadt
Tel.: +49 (0) 6151 | 399499-0
Fax: +49 (0) 6151 | 399499-11
post@passivhaus-info.de
www.passivhaus-info.de

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We are very grateful to all participants, designers, property developers, workers and visitors who have contributed towards the success of the International Passive House Days and supported us in the preparation of this brochure.

Foreword

The Passive House has become the internationally acknowledged standard for sustainable architecture, and by now this pioneering achievement is well known all over the world.
It was originally developed in Germany. In central Europe, where over 20,000 living units have already been realised, this building standard is quickly spreading to all other continents. So far, Passive Houses have been constructed in Europe, North and South America, Africa and Asia.

The Passive House standard is a unique solution for sustainable buildings:

- The standard is clearly defined, and the know-how needed for its implementation is available to everyone.
- Thorough scientific investigation has been carried out in hundreds of existing Passive Houses, including detailed measurements and time-resolved thermal simulations. The results confirm that the heating (and cooling) energy consumption in Passive Houses really is over 80 % lower than in conventional buildings – regardless of the regional climate. Thus, the Passive House has proven to be an efficient and reliable building standard.
- The Passive House is a cost-efficient solution. Most people are surprised how simple the principles are and how low the additional investment is. Most importantly, any extra expenses incurred are an investment in quality, because achieving the Passive House Standard means getting a better building and a truly sustainable solution.

The Passive House offers a realistic option for a cost-efficient building that provides a high level of living comfort while using very little energy for heating and cooling. In times of rapidly increasing energy prices, this also makes the Passive House an economically attractive option.

This first English edition of the brochure "Active for more comfort: The Passive House" (now in its 6th German edition) provides an overview of the basic functions and features of a Passive House and explains the principles to be observed during design and implementation. The supplementary documentation of 5 projects shows the variety of possibilities this standard offers regarding use, architecture, construction mode and technical systems.

Most Passive Houses that have been realised so far are new residential homes. Today, more and more people are becoming aware of the advantages the Passive House standard offers for other building types as well: offices, schools, kindergartens, gyms or even for indoor swimming pools. What is more, Passive House components that have proven to be effective in new buildings will also increase energy efficiency significantly when used to modernise existing buildings. As we all know, this is the part of the building industry that will be most important for construction companies, residents and other users of buildings in the near future.

At the International Passive House Conference held every spring, experts from all over the world meet to scientifically discuss issues regarding the latest questions about – and solutions for – Passive Houses.

"Open Passive House Days" take place every year in November and offer the chance to experience Passive Houses with all five senses. Once people have actually gotten a feel for Passive Houses, they understand that these buildings not only save energy, but provide an extremely high level of living comfort as well. Typical questions like, "Will it really be warm enough during winter?" or "What happens if I open a window?" can be answered more convincingly by an actual resident than by scientific data.

We would like to thank all those who have contributed to making the "6th International Passive House Days" a successful event, and we hope you enjoy reading this publication.

Yours sincerely, Univ. Prof. Dr. Wolfgang Feist

International Passive House Association,
University of Innsbruck, Austria and
Director of the Passive House Institute, Darmstadt, Germany

www.passivehouse-international.org

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BASIC INFORMATION

The Passive House... What's that?

More living comfort, less energy

A Passive House combines high-level comfort with very low energy consumption. Passive components like thermal windows, insulation and heat recovery are the key elements. Each Passive House is an active contribution to climate protection. On the outside, Passive Houses are no different from conventional buildings, because the term "Passive House" describes a standard and not a specific construction method.

What's so special about a Passive House?

It's all in the details:

1. Exceptionally high level of thermal insulation
2. Well-insulated window frames with triple low-e glazing
3. Thermal-bridge-free construction
4. Airtight building envelope
5. Comfort ventilation with highly efficient heat recovery

Built for the future

The Passive House concept is a low-energy building standard that has been consistently refined. Good planning and the careful implementation of details are essential. It is so well thought out, planned and executed that what little extra heat is needed can, for example, be supplied by the comfort ventilation system. The amount of heating power required is so small that a 20 m² room can be heated using 10 tea lights or the body heat of four people, even in the middle of winter. In reality, Passive Houses are heated not with tea lights, but by an efficient and comfortable heating system. The total heat consumed is very low.

Adapted to the local climate

The Passive House concept can be implemented all over the world; the general approach is always the same. Depending on the local climate, the quality requirements of individual components will vary. In hotter climates additional focus will lie on passive cooling measures, such as shading and window ventilation, to ensure comfort in summer. Any Passive House's individual characteristics should be optimised for the local conditions.

Rongen Architekten GmbH | Single-family house | Selfkant-Großwehrhagen

1.5 litre/m² heating energy per year!

In facts and figures, for the homeowner this means:

A Passive House uses no more than about 1.5 litres of heating oil or 1.5 m³ of natural gas (equivalent to15 kWh) per year and square metre of living space. This means a saving of more than 90% in relation to the average consumption in existing buildings. In comparison, a new construction built according to legal standards in Germany still requires six to ten litres of oil per square metre of living space.

"The heat losses of the building are reduced so much that it hardly needs any heating at all. Passive heat sources like the sun, human occupants, household appliances and the heat from the extract air cover a large part of the heating demand. The remaining heat can be provided by the supply air if the maximum heating load is less than 10 W per square metre of living space. If such supply-air heating suffices as the only heat source, we call the building a Passive House."

Univ. Prof. Dr. Wolfgang Feist
Head of Energy Efficient Construction/Building Physics
at the University of Innsbruck, Austria and
Director of the Passive House Institute, Darmstadt, Germany

"Low heating costs and a pleasant indoor climate year-round make the Passive House the building concept of the future."
Karl Kiggenberg, Law firm in Wassenberg

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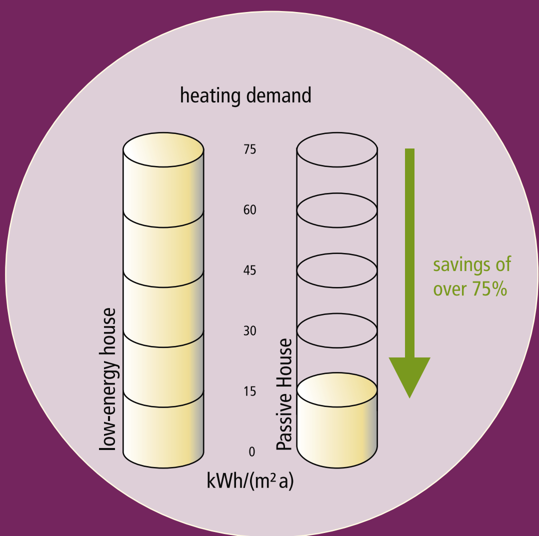
DECISIVE ADVANTAGES:

1. High level of comfort
2. Fresh air in all rooms year-round
3. Proper assembly consistent with building physics: no increased humidity, free of mould
4. Extremely low heating costs – even with rising energy prices
5. Radical environmental relief



Let the facts convince you!
A Passive House is...

... comfortable.

As if covered with a down sleeping bag, a Passive House is enclosed in a very well-insulated thermal envelope to ensure that the heat stays in the house. This means:

- Evenly warm surfaces in the room
- Uniform and constant indoor climate
- No fluctuations in temperature and no draughts

The comfort ventilation continuously provides clean, pleasantly warm and fresh indoor air.

... sustainable.

- High energy efficiency radically reduces CO_2 emissions.
- The Passive House standard significantly contributes to climate protection and helps preserve limited resources such as gas and oil.
- The remaining energy demand in Passive Houses can be completely covered by renewable energy sources.

... efficient.

- It requires very little heating energy.
- It automatically provides perfect air quality with minimal technical effort.

... innovative.

The Passive House concept is a modern building standard that opens up completely new perspectives for architects and engineers. The construction industry is developing highly efficient products and offering them on the market. Innovative building services systems that are compatible with the Passive House standard complete the range. The investment in comfort and efficiency adds value and creates additional employment nationally.

... tried and trusted.

- Several hundred Passive Houses have been scientifically monitored and rigorously tested. The consistently positive results are very convincing!
- Thousands of Passive Houses have already been built, occupied and proven efficient.

... energy-efficient and provides a good quality of life.

... uncomplicated.
The Passive House doesn´t require anything out of the ordinary from its occupants. On the contrary, by its very design it provides consistently pleasant indoor and surface temperatures. There aren't any draughts anywhere, and there is no need to worry about airing the rooms. And all this requires no complicated technology.

User friendliness is built in, so you can benefit from the extra time you gain!

... distinct.
The Passive House standard is not a building regulation. The benefits of a Passive House are convincing. Everything that is needed is available to anyone: experience, construction products, planning tools. Every property developer can make a contribution to climate protection and sustainability, without cutting back on comfort!

Go for it!

... eligible for funding.
Passive Houses are environmentally friendly. That is why they are subsidised in many countries and regions. In Germany, for example, the KfW bank offers low-interest loans in sums of up to 50,000 Euros per dwelling unit in Passive Houses.

Refurbishments using Passive House components are also often subsidised.

Certification requirements for Passive Houses: The space heating demand must not be more than15 kWh per square metre of living space per year. Alternatively, the heating load must not exceed 10 W/m^2. If active cooling is required to ensure comfort in summer, the energy demand for this is also limited to 15 kWh/(m^2a). The building´s airtightness must be verified with an independently administered pressure test that confirms an n_{50} value of less than 0.6 air changes per hour (ACH). The primary energy requirement for the total amount of domestic hot water, heating, cooling, auxiliary and household electricity must not exceed 120 kWh/(m^2a). All calculations are based on the Passive House Planning Package PHPP.

Please contact your local authority or energy agency to find out about Passive House grants available in your country.

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Information about example projects that have already been built can be found at:

www.passivhausprojekte.de
or
www.passivehousedatabase.com

You have questions?
Here are the answers!

What is passive about a Passive House?

The heating system. A Passive House doesn't need to be heated actively, because it essentially uses passive heat gains to heat itself. This way, only a minimal amount of additional heat needs to be supplied. This concept is based on excellent thermal insulation and a highly efficient heat recovery system. The heat stays inside and doesn't need to be provided by an active system.

The "passive" principle is well known in engineering; it is an effective strategy to securely, reliably and efficiently achieve a goal. "Passive security", "passive filters", "passive cooling" and "Passive Houses" are examples of the successful implementation of this principle.

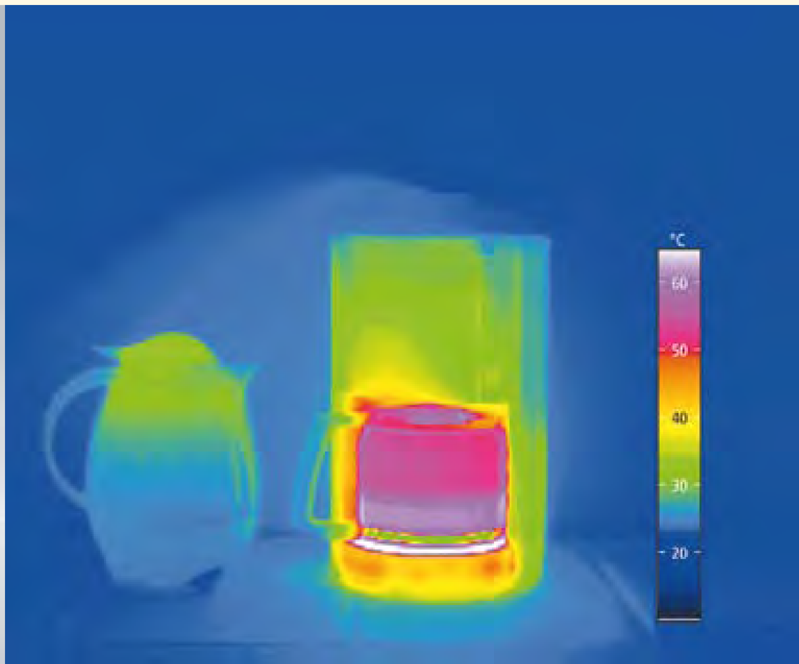
Of course, all these technical applications are not exclusively "passive" in the proper sense of the term; minor intervention is inevitable for directing the respective processes towards the desired course. It's not about "letting it happen", but rather about controlling processes in such a way that a certain goal is achieved with minimum effort, as if it were happening all by itself.

Why should buildings be airtight? Doesn't a house need to breathe?

Air infiltration through cracks and joints – or draughts – is not a reliable way of ensuring healthy indoor air quality. It is therefore essential to ventilate the building, traditionally by opening the windows.

In the Passive House, a comfort ventilation system provides sufficient fresh air to all rooms and transports used air towards the outside.

An airtight building envelope prevents moist indoor air from leaking through cracks. Cracks would permit the air to cool down, making the humidity in the air condense and putting the building at risk of becoming moist and growing mould. This will not happen in a Passive House!



Am I allowed to open the windows in a Passive House?

Yes! But it's not necessary. Traditional ventilation through windows requires constant attention and intervention on the part of the occupants. Due to the continuous development of odours and moisture (e.g. from towels, plants, wet clothes, etc.), windows need to be opened and shut regulary, even at night and during absences. This is simply not possible and as a matter of fact, most homes are not sufficiently ventilated.

In a Passive House it's different. The ventilation system constantly provides good quality indoor air; it automatically extracts moisture and clearly improves living comfort. There are no draughts, no cold corners in the house, and fresh air is constantly available. Fine filters keep out dust, pollen and other particulate materials – an invaluable advantage for people who suffer from allergies. The windows can be opened if desired, for example to let in cool air on hot summer nights.

What's so special about Passive House windows?

Windows create a connection to the outside world and let daylight enter the rooms. They also function as "passive" solar panels that let the energy of the sun into the house. In central Europe Passive Houses have triple-glazed windows and the frames are equally well insulated. In winter, the high-quality windows facing south allow for so much of the sun's energy to enter the building that it more than makes up for any heat that may be lost through them.

In most climates, large glazing areas should ideally be oriented towards the equator; windows facing east or west can more easily lead to overheating and provide less solar gains during the heating period. Windows need careful planning and, where necessary, appropriate sun protection. The window specifications needed to achieve the Passive House standard depend on the local climate conditions.

What are the advantages of highly efficient comfort ventilation?

Passive Houses have a ventilation system with highly efficient heat recovery, which directly draws away exhaust air from the kitchen, bathroom and other rooms where unpleasant odours may occur (e.g. smoking rooms). The heat contained in this air is used to warm the fresh air coming in from the outside, which is then supplied to the living room and bedrooms. Passive House ventilation systems are low-energy devices and have low levels of sound emission.

These are the benefits you can enjoy:

- Fresh air at all times of the day
- Clean air thanks to fine filters
- Supply air of a comfortable temperature
- Air in living rooms and bedrooms untainted by air from rooms with odour and moisture issues
- A constant supply of fresh air, ensuring very low levels of air velocity and no draughts or discomfort
- Energy savings of between 75% and 90%, thanks to the heat-recovery system

Innovative building services

The remaining required heating energy can be supplied with any traditional heating system and any energy source. (Purely electrical direct heat generation should, however, be avoided.) Since the requirements for heating in a Passive House are much lower than for a conventional building, any major investment would not be worthwhile. Appropriate heating systems make good use of this system advantage.

A conventional distribution of heat using radiators is always an option, but not essential. In the Passive House, the required heat can generally also be provided by the supply air from the ventilation system. The seasonal energy demand for heating is less than that needed to provide hot water all year round. Heating the living area can thus become a convenient side effect of the hot water supply.

An investment that pays off!

Are Passive Houses more expensive than conventional buildings?

Passive Houses have already been built at costs no higher than those for conventional constructions built according to present standards. As a general rule, however, additional costs of three to eight percent may be incurred. In order to offset these costs, the construction of Passive Houses is often financially assisted – and reduced energy costs more than compensate for a great part of the additional expenditure. And Passive Houses are high-quality products. Passive House comfort levels, freedom from concerns about structural damage, and very low energy costs all increase the value of the property.

If you wish to build a Passive House, from the very outset you should coordinate planning accordingly. Thicker insulation layers may cost a bit more (in order to build suitable walls, for example), but the price for additional materials is usually quite low, and installation costs do not increase significantly.

Basically, Passive Houses aren't necessarily more expensive than conventional houses. These days, in terms of the total cost burden of a household, Passive Houses can be more cost efficient than average new buildings. You can find a sample calculation in the second part of this brochure.

"Within only three weeks, 95 % of the 55 flats in the 'Campo am Bornheimer Depot' project were sold or booked."
"The 111 owner-occupied Sophienhof flats were sold in record time."
Frank Junker, Director of ABG FRANKFURT HOLDING GmbH, housing company and developer

FAAG TECHNIK GmbH | Apartment block Sophienhof | Frankfurt am Main

Turning the idea into reality

Who can provide support for the construction of a Passive House?

The International Passive House Association

The network for communication, quality information and professional training offers support and advice for architects, engineers, manufacturers, builders, property developers, construction companies and research institutes interested in the construction of Passive Houses.

>> www.passivehouse-international.org

The Passive House Institute

Here you can find literature on the Passive House. The Passive House Planning Package (PHPP) is an indispensable tool for calculating energy balances and designing buildings. It is published as a spreadsheet by the Passive House Institute.

>> www.passiv.de or
>> www.passivehouse.com

"20 years ago, we did not even dream that one day we would be able to reduce energy consumption for heating to around 15 kilowatt hours per square metre of living space per year – a development which is now standard. By that I mean the Passive House. This is a great prospect, and I will do everything within my power to promote it."
From the government declaration by Dr. Peter Ramsauer, Minister of Transport, Building and Urban Affairs
Berlin, 11th November 2009

Certified Passive House Designers / Consultants

Are you looking for a competent partner for planning your Passive House? Certified Passive House designers possess well-grounded, expert knowledge that they have acquired in professional training courses or through practical experience. This is then tested in an examination or proven by the certification of a Passive House of their design.

>> www.passivhausplaner.eu

The "Component Suitable for Passive Houses" Certificate

High-quality, reliable information about the characteristics of important components such as windows, doors, glazing, and ventilation systems provides assistance for the realisation of Passive Houses.

>> www.passiv.de

The "Quality Approved Passive House" Certificate

To make sure that your building really is a Passive House you can apply for certification. Certified Passive Houses will be awarded with a certificate and a Passive House Plate that can be attached to the building. A list of all accredited certifiers can be found on

>> www.passiv.de

Direct link:
http://www.passiv.de/03_zer/Zertifizierer/Zertif-PHI_F.htm

Technical questions?

We will be happy to assist you!
Simply send an email (Subject: Technical question) to:
info@passivehouse-international.org

Interested?

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WOULD YOU LIKE TO FIND OUT MORE?

In the following part of the brochure you will find further information, tips and technical information that will provide valuable assistance for the planning of your Passive House.

02 DETAILED INFORMATION

From the vision to the Passive House

In the beginning... was an idea.

Is it possible to achieve a building that is highly energy-efficient, provides good thermal comfort, has good indoor air quality, is economically attractive and at the same time easy on natural resources? Dr. Wolfgang Feist and Prof. Bo Adamson first addressed this problem in May 1988, with the Passive House Research Project. Using a Passive House that was built as a demonstration model and then occupied as of 1991, they proved that extremely low energy consumption is possible. The energy consumption measured in this Passive House in Darmstadt Kranichstein amounts to less than 15 kWh/m² of living space per year – and has consistently done so over the last 18 years.

Recent projects

Since that time, more than 13,000 Passive Houses serving various functions have been built in Germany alone, including single-family and multi-family houses, schools, kindergartens, office buildings, senior residences, swimming pools, etc.. More recent projects clearly show the progress that has been made over the last few years. Especially in the construction of multi-storey buildings, the Passive House concept displays its advantages. With its 354 accommodation units, the "Lodenareal" building in Innsbruck is the largest Passive House construction in the world. Today, Passive Houses are no distant vision any more: they have become an affordable investment for building constructors. A large number of Passive House projects have been realized all over the world. These projects can be found in the Passive House database at www.passivhausprojekte.de or www.passivehousedatabase.org.

Of course, the design and construction of a Passive House places high demands on the people involved. To get you started we have compiled the most important information for you. Numerous specialists can provide assistance for further planning.

architekturwerkstatt din a4 | team k2 architekten | Apartment block Lodenareal | A-Innsbruck

Less energy – more comfort!

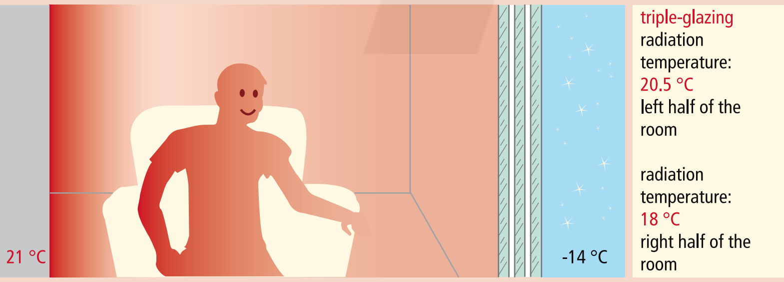
The general principle of the Passive House is **energy efficiency**. Excellent thermal protection, innovative window technology, an airtight construction, highly efficient building services for ventilation, heating and hot water as well as electricity-saving household appliances are essential for achieving this principle. The Passive House technology not only reduces energy consumption but also increases thermal comfort and improves the building's protection.

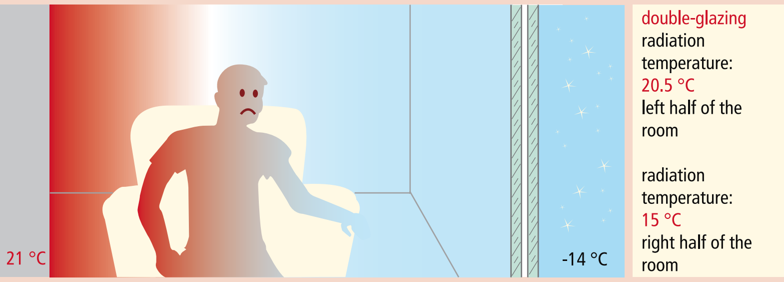
The improved thermal **insulation** in Passive Houses reduces heat losses and leads to higher indoor surface temperatures in the winter and to lower temperatures in the summer. They hardly differ from the ambient temperature, providing for a pleasantly warm, uniform indoor climate without any cold corners or risk of condensation. **All constructions** – whether solid, timber, steel or mixed – can be implemented with highly insulated building envelopes.

Comfortable in the summer, too!

In Passive Houses during the summer, high temperatures can be prevented to a great extent. The good insulation protects not only against the cold but against heat as well, provided that not too much heat is already present indoors. During the winter months, the sun's free warmth is of course desirable. Windows that face south are ideal, because during the winter, the sun is low in the sky and can shine directly into the house. In summer, the sun is high in the sky and fewer of its rays can enter southern windows.

Effective shading must be provided in particular for windows that face west and east. The house can also be ventilated through the windows in the hot months. A calculation sheet for planning good summer temperature values is available in the Passive House Planning Package. The tool can be used to estimate summer temperatures and plan suitable protective measures against summer heat.





It is the well-insulated window which so improves thermal comfort, because it keeps the average inside surface temperatures above 17 °C. Even in severe winter, there is no perceptible drop in window-surface temperatures.

Thermal bridge free and airtight

Prevention of **thermal bridges** is one of the most efficient savings measures, as experience with Passive House construction has shown. Building envelopes consist not only of standard construction elements like walls, roof and ceilings, but also include edges, corners, connections and penetrations. The heat loss at these points is generally higher (thermal bridges). Observing some simple rules helps to reduce losses caused by such thermal bridges.

For example: A balcony slab which is part of the concrete ceiling inevitably leads to additional heat losses, because it penetrates the insulation and conducts heats towards the outside. The use of a thermal break element must be planned to minimize these losses. A good solution, for example, is to position the balcony in front of the facade and provide separate supports.

The Passive House concept aims at a "thermal-bridge-free" con-struction, reducing thermal bridges so much that they do not have to be taken into account in calculations.

Specific information concerning this issue and many specially developed products are now available to designers and manufacturers.

Ensuring that the building envelope is **airtight** reduces the risk of structural damage. Achieving an airtight construction requires careful planning and execution. An airtight building can be effectively achieved, for example, by full plastering on the inside, sheeting, reinforced building paper, or wood composite boards. Quality workmanship and the proper installation of all airtight building materials and products (e.g. windows and doors) are also important. The Passive House Institute provides planning tools for durable, exceptionally airtight constructions.

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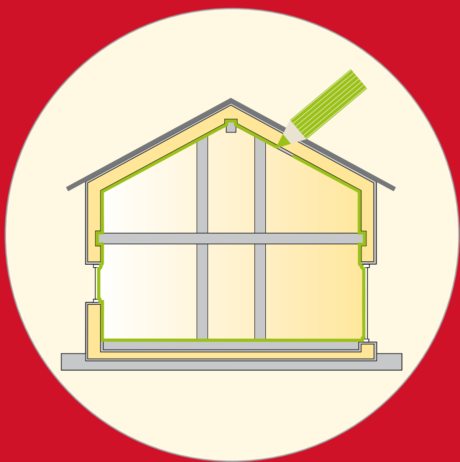
The airtight layer in a Passive House (green line) seamlessly encloses the heated space; it should be possible to follow the line with a pencil without any interruption. For each detail, the materials to be used and the connections to be made should be defined during planning.

A similar pencil rule should also apply to the thermal-bridge-free insulation layer (yellow). Unavoidable penetrations should consist of components with minimal thermal conductivity.



Draughts, cold feet, structural damage due to cracks – Passive Houses make these things of the past!

The air should not flow randomly through the walls (building envelope), driven by the wind and temperature differences. These types of air flows are not sufficient to provide **consistently good air quality.** They are uncomfortable (at times too much air, often too little air) and can cause structural damage as leaks in the building envelope allow warm moist air to flow from the inside towards the outside. The air cools down, condensing the moisture and causing mould and rot. Poor sound protection and significant heat losses are further disadvantages of leaking houses. Therefore, every building should be airtight! In the Passive House, a ventilation system provides for sufficient and lasting fresh air.

With careful planning, it is possible to construct buildings in an airtight way. Property developers and architects with Passive House experience know exactly how to do it. For each Passive House, a building airtightness test (the so-called "Blower Door" pressure test) is carried out at a suitable point in time to make sure the **stringent quality requirements** are met. The test is performed by creating positive-pressure followed by negative-pressure, and measuring the total leakage. Any leaks detected can then be sealed.

An airtight house has many advantages: it is free from draughts, prevents structural damage, improves sound protection, saves energy and is comfortable.

"We have an exceptionally good indoor climate in our house. I'm very sensitive to draughts. Here there aren't any; that's why I feel the cold even more when I'm staying somewhere else."
Dr. Wilma Mohr has lived in a Passive House since 1991.

Fan for pressure test

Passive House windows

Insulated window frames and low-e triple-glazing

High-quality windows are essential components for Passive Houses. The stringent thermal protection requirement (U-value less than 0.85 W/(m²K)) for the fitted window is determined by the demands for thermal comfort in living spaces. The average temperature of the internal window surfaces on winter days may not fall below 17°C, without radiators under the windows. This way, optimum thermal comfort is provided even near the windows. The window frame plays a particularly important role, because for typical window sizes, the frame accounts for between 30 and 40% of the total window area.

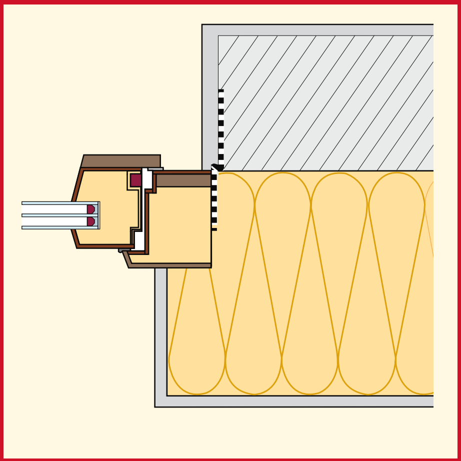
Heat losses from conventional window frames (U-value 1.5 – 2.0W/(m²K)) are twice as great as the heat losses through an insulated frame with a U-value of 0.8 W/(m²K).

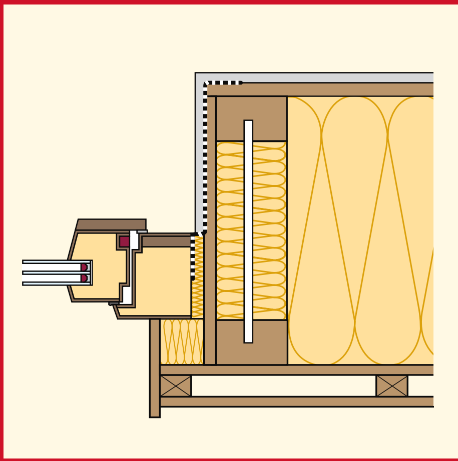
The additional heat losses at the edges of the glass are also considerable in conventional window frames. They can be greatly reduced if a thermally improved edge seal is used. Therefore a well-insulated window frame is essential for high-quality glazing (triple-pane low-e glazing or equivalent).

Triple low-e glazing and an insulated frame, as per the above specifications, are required in the cool temperate, e.g. central European, climate. In warmer climates a window with double low-e glazing and a moderately insulating frame would be sufficient, whereas in colder climates even quadruple glazing and further improvements in frame insulation may be required.

>> Minimizing thermal bridges when installing the windows in the insulation layer of the external walls is of great importance. Additional insulation covering the window frames reduces heat losses even more.

Cross section: solid construction | timber-frame construction





Maximum comfort

Preventing thermal bridges at the window

Significant thermal bridges can occur if a window is incorrectly installed in the wall. In Passive Houses windows are skilfully incorporated into the insulation layer of the external building elements. This generally includes extending the insulation so that it overlaps connections in the window frame in order to prevent heat losses and raise internal surface temperatures at these junctures. Certified windows also need to provide for these installation details, so that everything fits together perfectly during construction.

Use of solar energy

Solar radiation enters the room through the glazing and acts as passive solar heat gain. Heat losses can be prevented to a great extent by good levels of insulation. The amount of passive solar gain depends on the building location as well as the distribution and orientation of the glazed areas.

Experienced designers have realised Passive Houses even in locations that receive little sunshine. The passive use of solar energy not only leads to savings in energy and costs but also provides attractive and healthy living conditions.

The illustration shows a cross-section of one side of a window.

"What is the best feature of your Passive House?" "The large window areas; it's as if we are living outdoors."
"Is your Passive House living up to your expectations, or did you have to accept compromises?"
"We have our dream house, no compromises!"
The Schwally family lives in a Passive House in Ulm.

Insulated window frames that are suitable for Passive Houses are available in many different materials so that everybody´s preferences can be met.



Comfort ventilation:

In the Passive House the home ventilation system plays a key role. It provides **clean, pollen-free, dust-free air** and eliminates moisture and odours where they occur. Opening windows to achieve this would result in heat losses greater than the total energy demand.

That is why heat recovery from exhaust air is indispensable in the Passive House. It reduces ventilation heat losses considerably because inside the heat exchanger, heat from the warm exhaust air is passed on to the cold fresh air. Depending on the efficiency of the heat exchanger, over 90% of the heat from the exhaust air can be passed on, which brings the incoming air almost up to room temperature.

High quality systems ensure that the exhaust air ducts and supply air ducts in the heat exchanger are leak-proof, so that the fresh air and exhaust air are not mixed.

These high-quality ventilation systems use much less energy than the amount they are able to save by preventing heat loss. The ventilation system as a whole needs to be carefully designed and laid out.

Air flows (imperceptibly) into the living room and bedrooms of the house and is extracted through the kitchen, bathroom and WC. These two areas are connected by so-called transferred air zones (e.g. hallway) that direct the air flow through the home and allow the fresh air to be used several times.

Clean air, pleasant climate

To ensure that closed doors do not hinder the air flow, appropriate air transfer openings (e.g. covered panels with acoustically optimised vents) are installed above the door frame. A high-quality Passive House ventilation system is super silent, in Passive Houses the maximum sound level is 25 dB(A). To comply with this limit, the supply and exhaust air ducts are fitted with silencers that prevent sound transmission between the rooms.

Operating and maintaining a comfort ventilation system with heat recovery is very easy. For reasons of hygiene (prevention of contamination), the system must be fitted with high-quality filters in the fresh air inlet and coarse filters in the exhaust air valve. These filters should be replaced regularly (one to four times a year). Experts and specialised companies are at your disposal for planning and installation information, advice and support. User information can be downloaded free of charge from the Passive House Institute website at www.passiv.de.

Even a Passive House requires some heating, but the heating demand is so small that the ventilation system can also be used to distribute heat in the house. Heater coils heat the incoming fresh air. Compact heat pump units have been approved for this purpose, because they combine all the building services functions (ventilation with heat recovery, heating, hot water supply and storage) in one unit. These space-saving devices are industrially manufactured and optimised and are easy to install.

Other solutions are also available – the Passive House is flexible. Gas, oil, district heat or wood can be used for heating and hot water. Active application of solar energy, using solar collectors to provide hot water for household use, is an interesting option that can reduce energy consumption even more.

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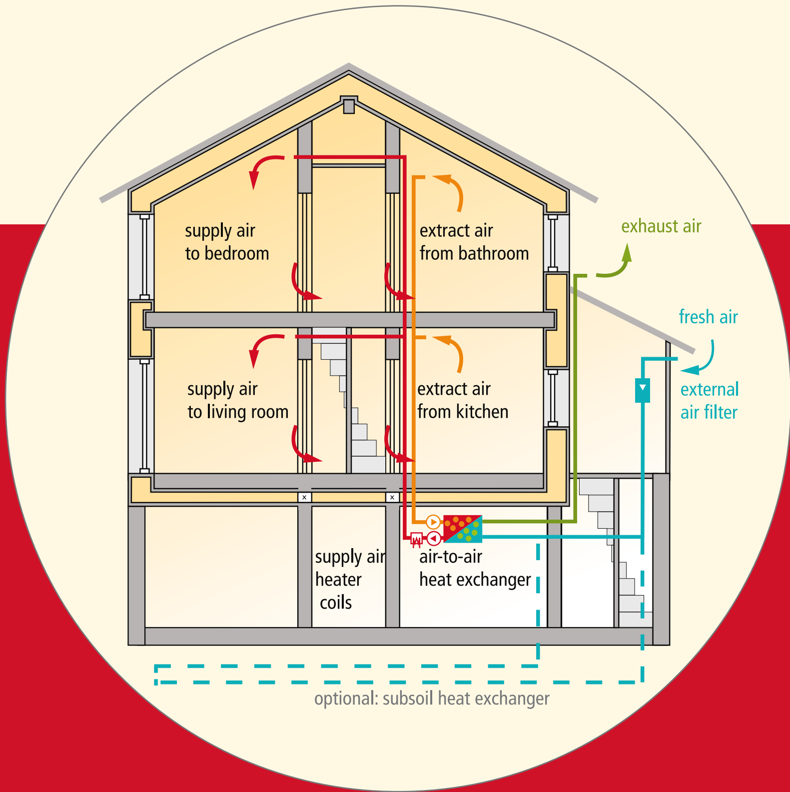
The basic principle of the Passive House ventilation is this: Moist air is extracted from the kitchen, bathroom and WC. Fresh air flows into the living areas. As a result, the hallways are automatically ventilated as well.
As a general rule, the ventilation system should be designed to provide 30 m³ of fresh air per person every hour. For a living space of 30 m² per person, this is equivalent to a supply air quantity of 1 m³/(m²h). Since the maximum temperature of supplementary heating is limited to less than 50°C, a maximum heating load of 10 W/m² is the result. This can easily be met by the supply air.



Old buildings can become Passive Houses too!

Why refurbish?

In Germany, less than 1% of the existing buildings are newly constructed. Most people in Germany will continue to live and work in older buildings over the next few decades. Because such buildings use even more energy than the average new construction, they offer an even greater potential for energy savings. What works for new buildings cannot be wrong for existing ones. On the whole, the refurbishment of older buildings is financially profitable – and also reduces the economy's dependence on energy imports.

Costs and benefits...is it worthwhile?

To be cost-efficient, it is crucial to optimise the modernisation measures that are necessary anyway. The additional expense for components that meet Passive House standards is small, and the value of the building increases considerably. A house that has been refurbished in a consistently energy-relevant manner, with a high level of comfort and low running costs, is significantly more attractive for tenants. The chances for successfully renting out the property improve considerably.

Since optimally refurbished older buildings not only ease the personal financial burden, but also the environmental impact, financial-assistance programmes are available. The German KfW bank programme supports energy-efficient refurbishment by offering low interest loans (detailed information at: www.kfw-foerderbank.de). The somewhat higher investment costs are worthwhile not only because of the savings in energy costs; the property developer's initial outlay is reduced as well.

Refurbishment of older housing is the order of the day!

The fact that it is possible to successfully equip existing buildings with Passive House components has often been demonstrated and is well proven.

Almost all the advantages of a newly built Passive House can be effectively applied in existing buildings as well.

"Anything worth doing is worth doing well."

Whenever a building component needs to be modernised, the materials used and the workmanship involved should be of the highest quality possible. If you use Passive House components for each modernisation measure, step by step you will arrive at an optimum level of energy conservation, maximum user satisfaction and the best economic results.

This is better than making several half-hearted attempts to modernise all at once, which would compromise any future efforts to achieve low energy consumption.

Detached house | Refurbishment of an older building with certified Passive Houses components | Darmstadt

The advantages of Passive House components

Saving a lot on energy is only one of the many benefits of a Passive House, but a very important one. In times of high running costs that constitute a significant burden and are often referred to as "the second rent", Passive House components reduce energy consumption in existing buildings by 75% as a rule, and often by up to 90%. Even more significant is the fact that the building substance of older constructions is considerably improved. For example, due to the excellent insulation level, the risk of mould growth is practically eliminated. Passive House windows are so warm on the inside that condensation does not occur. The living area can be fully utilised, because furniture can be positioned near external walls, without fear of mould.

How thick should the insulation be?

In the central European climate, the economic optimum for external wall and roof insulation is currently about 220 mm at a thermal conductivity of 0.04 W/(mK). Using a future-oriented insulation thickness of 320 mm is equally cost-efficient, because it saves even more energy and provides even greater independence from energy prices. High-quality insulation is an economical form of insurance in times of energy-prices crises.

Older building before refurbishment | Frankfurt am Main

EQUIVALENT COST OF THE ENERGY SAVED

If a building element needs to be renovated (e.g. because the exterior plaster is cracked), an additional investment for insulation would be small. Once the costs for the scaffolding and improvement of the facade (which would be incurred either way) are deducted, only the costs for the energy-relevant refurbishment remain. The same principle applies to the refurbishment of the roof, the windows and the basement ceiling. The additional costs for improved thermal protection are amortised by the equivalent energy costs saved.

Does insulation change the appearance of a house?

Applying insulation to the external walls increases their thickness. If the windows are renewed at the same time, they should be fitted in the insulation level in front of the window reveal, so that thermal bridges are avoided and window reveals don't appear to be deeper than before refurbishment. When additional insulation is applied to an existing facade, the design options are almost limitless. For ornate 19th-century facades or valuable brickwork facades, it may be better to apply insulation on the inside.

What if external insulation is not possible?

We recommend examining any possibility to improve the external insulation for this is always the best solution. Even if a building can only be insulated on the inside, however, it is better than no insulation at all. An interior insulation must be competently planned and carried out. In contrast to external insulation, there are many problems associated with interior insulation, and they can have serious consequences. It must be sealed and airtight inside every room and all thermal bridges must be reduced as much as possible in order to eliminate cold areas that could lead to moisture damage.

"Would you move into a Passive House again?"
"Yes, by all means – especially because it feels so good to live here. When we returned from a 4-week holiday, we immediately noticed how fresh the air in our home was."
A family in a Passive House in Wiesbaden (EB 2/2000)

»

The equivalent cost is between 1 and 4.6 Eurocents per kilowatt hour saved, even for insulation thickness levels suitable for Passive Houses, depending on the building element and type of construction (see Final Report: Evaluation of energy-relevant requirements in view of increasing energy prices for EnEV and KfW funding, PHI June 2008). Considering current energy prices of 8 to 9 Eurocents per kilowatt hour of energy from oil or gas, it quickly becomes clear that you could hardly make a better investment.

Faktor 10 | Older building after refurbishment

What doors and windows are suitable?

Many windows still have poorly insulating double glazing; single glazing can even sometimes still be found in older buildings. Modern double glazing that has a thermally protective coating and is filled with inert gas is also energy saving, but you should always bear in mind: "Anything worth doing is worth doing well." If windows need to be replaced anyway, well-insulated Passive House windows should be installed. For the central European climate this means a window with an insulated frame and triple low-e glazing. In southern Europe a window with double low-e glazing and a moderately insulating frame would be sufficient, whereas in colder climates even quadruple glazing and further improvements in frame insulation may be required.

If the facade is newly insulated or the front door needs to be replaced, it makes sense to install a door that meets Passive House standards. It is an essential component that can also serve to prevent unnecessary heat losses due to poor insulation or connections that are not airtight.

What are the limits of refurbishment?

In new constructions, supplementary insulation is applied under the floor slab. This is naturally not feasible for an existing building. An alternative would be to apply insulation to the surface of the floor slab and/or use a so-called insulation apron, an external insulation covering the entire external wall all the way down to the foundation.

Installing a thermal barrier in existing basement walls in order to minimise thermal bridges is also rather uneconomical. Instead, a "flanking insulation" can be applied along basement walls that penetrate existing insulation (e.g. where they join the basement ceiling), to help reduce heat losses through thermal bridges and raise the interior surface temperatures of the rooms above.

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You wish to replace old windows with new ones. There's no doubt that this will be expensive. You will have to reckon with around 250 Euros per square metre of window area for conventional windows, plus the costs for the disposal of the old windows. That's why windows are not replaced every year; the new windows should do their job for at least twenty years. That's how long the house owner and users will have to live with these windows – good grounds for choosing the windows on the basis of their ability to stand up to future conditions and requirements.

Windows that meet these demands are already available today: Passive House windows prevent heat losses much more efficiently than new conventional windows. Their inner surfaces are uniformly warm, and there are neither any disturbing drops in temperature nor any surfaces that radiate cold. In view of the unavoidable investment costs for new windows, the extra cost for Passive House quality is low.

Depending on the type of window, the extra cost amounts to 80 to 180 Euros per square metre of window area (30% to 70% of the inevitable costs). And you can have the window of the future today!

How can an older house be made airtight?

In buildings with brickwork and solid ceilings, the interior plaster can provide an airtight seal if damages are repaired and the plaster directly joins the unfinished floor. Timber-beam ceilings make it more difficult to guarantee continuous airtightness at the joists in the external wall. If thermal insulation is applied to the facade, it may be expedient to apply the necessary adhesive evenly over the entire surface, in order to create an airtight layer at the level of the original external wall covering.

In the roof or on the uppermost ceiling, the vapour barrier sheet, necessary to keep the building damage free, can also serve as the airtight layer. Depending on the position of the insulation, the basement ceiling or reinforced concrete floor slab could form the lower boundary of the building. If the basement ceiling is not airtight, a crack-free screed could serve as the airtight layer. New windows can be equipped with a plastered-in sealing sleeve.

Does airtightness increase the risk for mould growth?

An airtight building envelope prevents warm air from escaping and stops cold air from entering which also protects the building from damage. If warm, damp indoor air flows into the walls or roof through cracks, it condenses on the colder, more external building layers, causing mould and structural damage. Every refurbishment should, however, also include the installation of a ventilation system to prevent excessive moisture accumulation in the air and on the surfaces of building elements.

Does insulation lead to mould growth?

External insulation is the best way to prevent mould, because it increases the temperatures on the inner surfaces of the walls, roof and basement ceiling, so that moisture in the air can no longer condense. Condensation at the points of any remaining thermal bridges is also reduced. Increased surface temperatures perceptibly improve comfort.

Thermographic image after (left) and before (right) refurbishment.

Is a ventilation system really necessary?

In a new house as well as in an existing building, the ventilation system transports unpleasant odours and unhealthy, polluted air out of the house – around the clock. Even the most dedicated fans of window airing can't accomplish that. Measurements confirm that good air quality can hardly be achieved by ventilating through windows alone. The windows would have to be opened all the way every four hours, and the air in the rooms would have to be replaced completely each time. In an airtight building it is all the more important to ventilate continuously and remove moist air from the kitchen, bathroom and toilet. Ultimately, this serves to improve health and avoid building damage. A Passive House ventilation system constantly provides for excellent air quality – and also saves energy through heat recovery.

Doesn't the ventilation system use more energy than it saves?

When heat recovery ventilation systems are properly installed, the ratio of electricity required to heat loss prevented is 1:10 or better. This means that the ventilation system saves more than 10 times the energy it requires for operation.

Where is the ventilation system located?

Heat-recovery ventilation systems are not very large; they can even be placed in a storage room. If there is not enough space, flat devices can also be integrated into a suspended ceiling or a wall. Ventilation systems can be installed in a centralized or decentralized fashion.

Do I need new interior doors?

For the home ventilation system to function properly, air from the living areas needs to be able to flow through the hallways into the kitchen and bathroom. To assure air flow even when doors are shut, there should be a gap of at least 10 mm between the bottom of the door and the floor. If this is not already the case, doors can be shortened without much effort, or an opening for transferred air can be created.

How much does a heat-recovery ventilation system cost?

For the purchase and installation of a controlled ventilation system with heat recovery, you should reckon with 40 to 90 Euros per square metre (net), depending on the size of the house and the type of unit. For maintenance and operation, another 20-80 Eurocents/m² per year should be calculated.

Since older buildings are much more airtight after refurbishment, we strongly recommend the installation of a simple exhaust air system as the minimum standard. The extra expense of an energy-efficient ventilation system with heat recovery will also pay off due to the additional savings in energy costs.

What should I do with the old heating system?

Old heaters and pipes can often still be used after an energy-oriented renovation. Since less heating power is needed now, the water in the heater can be kept at a lower temperature and the heating system can work more efficiently. In most cases the boiler itself is then too large and can be replaced by a smaller, much more efficient heat generator.

"We know from calculations that we had 5% additional costs and that these would be amortised in a few years due to the energy savings."
Dr. R. Köppler, Mayor of Günzburg/Germany

Ventilation unit with heat recovery

Supply air duct during construction

Where to begin?

In what order should refurbishment take place?

In energy-relevant refurbishment, it is always best to begin with the building element that most needs to be renewed. If the facade plaster is falling to pieces and needs to be replaced, thermal insulation of sufficient thickness can be applied at the same time, at little extra cost. The additional investment is well worth it in any case, thanks to the heating costs saved. Renewing building elements that will still be serviceable for a long time, simply in order to improve thermal protection, may not always prove economical. You may, of course, still want to consider replacing them to enhance comfort or to prevent structural damage.

With each thermal protection measure you undertake, you should bear in mind how to simultaneously create the best possible conditions for later improvements. If the roof is being renewed and insulated, for example, the roof overhang should also be enlarged to an extent that will provide enough space for the later addition of thermal insulation on the external wall.

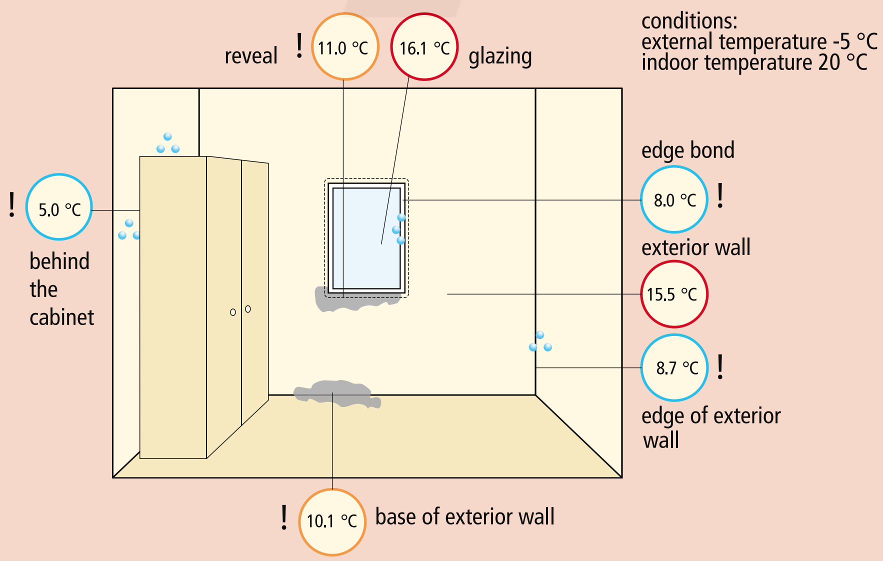
Which comes first, the insulation or the heating?

By consistently renovating with Passive House components, the heating demand and the required heating power are drastically reduced. Existing heat generators are then clearly too large. Cost-efficient retrofitting should therefore begin with optimising the thermal protection of the building envelope and installing a heat recovery ventilation system. Later, the heating can be economically replaced with a low-power heating system that better conforms to the new, reduced level of need.

If the heating system is defective and needs to be replaced first, however, it is essential to install the most efficient system possible, e.g. a condensing boiler with low standby losses which will still produce heat efficiently once the thermal protection has been improved.

>> Further information on the refurbishment of older buildings can be found in the Passive House Institute protocol literature, vol. 24, 30, 32 and 39 (in German only). Also see www.passiv.de or www.passivehouse.com.

Old situation: Cold surface temperatures can lead to humidity-related damage



The walls of older buildings are usually poorly insulated. The temperatures of the interior surfaces drop and humidity rises – often so much that mould growth occurs. Good insulation on the exterior can prevent this from happening.

Is it possible to live in the house during renovation?

Conscientious planning reduces the time required for the installation of the ventilation system to four or five days, and to one day for fitting the windows. During this time there may be some inconvenience, but you won't have to leave the house.

How much will it cost?

The additional expenses for a refurbishment using Passive House components naturally differ from house to house. For a multi-family home, a ventilation system and Passive House windows can cost a good 120 Euros extra per square metre of living space, compared with a conventional refurbishment according to German legal standards. For a single-family house these costs are slightly higher due to the less favourable geometry. Taking into account the savings in energy costs and the subsidies granted for energy-efficient construction, however, refurbishment with Passive House components is currently just as economical as conventional retrofitting.

In addition, the residents benefit from optimum living comfort and extremely low heating costs, even with rising energy prices.

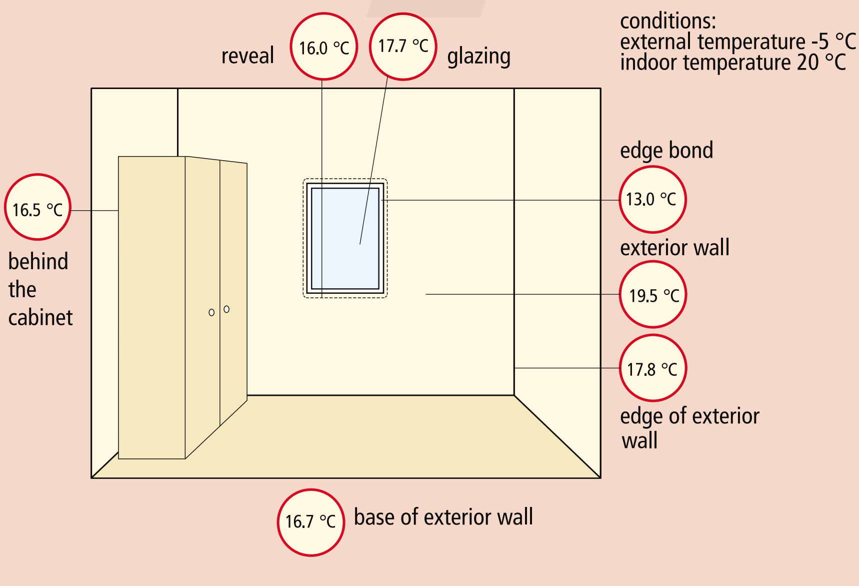
Where can I apply for a subsidy for my refurbishment project?

Please contact your local authority to find out about possible subsidies. As an example, the German KfW bank provides low interest loans for property developers. The higher the level of energy efficiency aimed for, the more favourable the conditions of the loan. In Germany, the Federal Office of Economics and Export Control (BAFA) also grants subsidies for refurbishment measures. You may benefit from regional funding programmes offered by some local authorities, as well. It pays to be informed!

Is there a Passive House certification for energy retrofits?

The PHI has recently developed the "EnerPHit" certification for quality-approved energy retrofits with Passive House components. At the time of printing, the pilot phase with selected renovation projects had already started (certification criteria: www.passiv.de).

New situation: Refurbished with Passive House components



» **The same living room after modernisation (200 mm insulation on the external walls, new Passive House windows). Almost all the surface temperatures are above 16 °C – even at the skirting board and in the corner behind the cabinet. The moisture level remains low and there is no risk of mould.**

The Passive House

Building a Passive House means saving energy costs – and investing in better building quality.

Can a Passive House pay for itself through energy savings alone? That of course depends on future energy costs. It's very likely that energy will continue to get more expensive. The total annual expenditure for a Passive House can already be lower than that of a new construction built according to conventional regulations – thanks to its extremely low energy demand and the low interest loans offered in many countries and regions. For instance, the loan offered by the German KfW bank (50, 000 Euros at a rate of 2.45 to 3.05% p.a. as of 07.02.2010) can be granted to anyone who builds a Passive House, regardless of personal income.

Rule of thumb:

For small buildings like detached or semi-detached houses, Passive-House construction will incur additional expenses of about 10%, for terraced and multi-family houses 8%. Additional costs will amount to approximately 5% for large office buildings or schools. These extra costs will continue to decrease as architects and building engineers gain more experience in the construction of Passive Houses.

Since only the energy-relevant improvements of certain construction details incur higher investment costs (and these additional costs are minor), the total expenditure is not governed by these improvements but rather by the individual building design.

EXAMPLE:

A German family builds a detached house with 140 m² of living space. The optimised insulation, thermal-bridge-free construction, Passive House windows and heat recovery ventilation system add up to an extra investment of 13,000 Euros, compared with a standard house. Despite this additional initial investment, the family ends up paying 340 Euros less per year than they would for a house built according to regulations only. What appears to be a contradiction can be easily explained:
The family takes on a mortgage at the current interest rate of 4.3%. Over a period of 30 years they will have to pay back about 700 Euros per year, plus 70 Euros per year for the electricity used by the ventilation system, adding up to 770 Euros per year on the costs side. On the credit side, the Passive House saves 540 Euros on heating costs per year in terms of fuel, this means about 850 litres of heating oil or 850 m³ of gas saved every year.

The family also profits from a low-interest Passive House loan from the KfW bank. The interest rate is considerably lower than the market rate, so the family saves another 570 Euros per year (based upon a 50,000 Euros loan, payable over a period of 30 years, interest rate 3.05%, fixed interest period of ten years*). The total annual savings of 1,110 Euros now far outweigh the additional annual costs of 770 Euros. Each year the family saves 350 Euros.

(based on an energy price of 64 Eurocents/litre heating oil or m³ gas on average over the next ten years) Credit repayment can be deferred by up to five years to further reduce the financial burden during the critical initial years.

*As of 07.02.2010. Current conditions at www.kfw-foerderbank.de, "Energy-Efficient" Construction programme.

An attractive investment

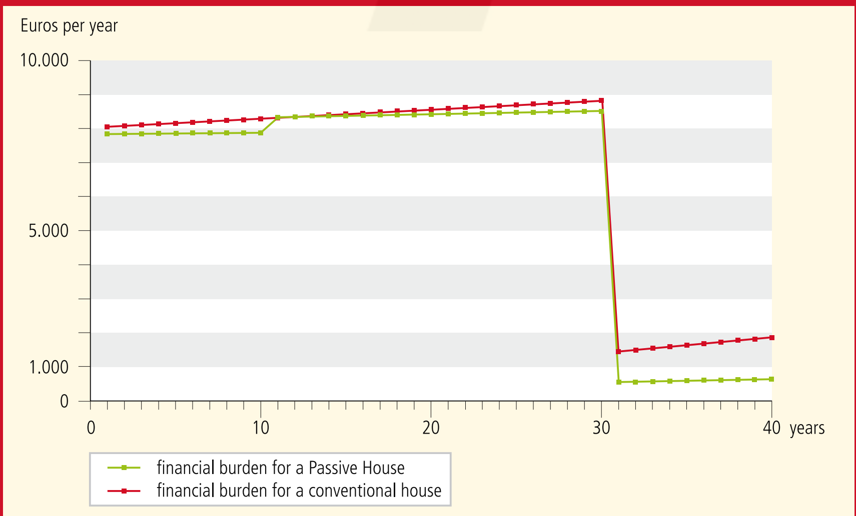
1. Optimal Insulation

The insulation layers for all external building elements – floor slab or basement ceiling, external walls and roof – are thicker than required by building codes. With competent planning, the construction costs hardly change; the only additional costs are for the larger quantities of insulation material and amount to approximately 0.40 to 1.20 Euros per 10 mm of extra insulation per square metre of construction element area. This investment pays off from the very beginning – even at today's energy prices.

2. Thermal-bridge-free building envelope

Small and middle-sized Passive Houses must be thermal bridge free. This will incur almost no additional costs because experienced architects know which details are most cost effective. Certified building products already come with exact illustrations of the most important details. In large-volume buildings, achieving a thermal barrier for load-bearing construction elements can be a very complex task, so a certain amount of thermal-bridge effect is acceptable here. Somewhat better insulation of other building parts can make up for these thermal bridges and allow for a good energy balance, because these buildings have a favourable surface-to- volume ratio (A/V ratio). On the whole, the cost-benefit ratio for thermal bridge reduction is excellent.

The cost burden of a house built according to the German regulations (EnEV 2009) [red] compared with that of a Passive House [green]



What happens when the fixed interest period of the loan expires? The interest rates could adjust to the market rate, just like those for regular mortgages, but thanks to energy savings, the total costs for a Passive House are still lower than those for a standard building. The illustration shows a model calculation, assuming constant capital market conditions and a real energy price increase of 2% per year (based on 58 Eurocents per litre of heating oil or m³ of natural gas).

3. Airtight building envelope

Improving a building's airtightness helps prevent structural damage and increases the level of comfort. Building structures that are not airtight always end up being more expensive than using conscientious construction methods from the very outset. Having to repair any damage or improve the building envelope at a later stage is more complex and ultimately leads to higher costs. That's why you should always demand a building envelope which is as airtight as that of a Passive House.

Seen objectively, there aren't any additional costs here; on the contrary, you avoid potential repair costs.

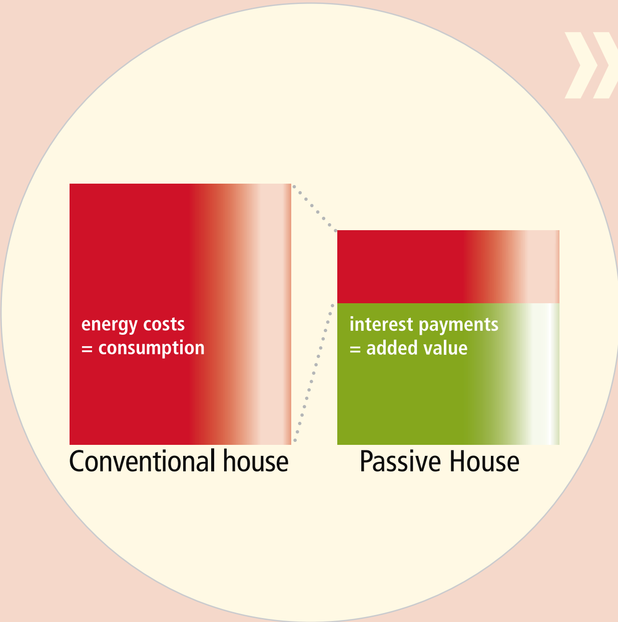
4. Passive House windows

Passive House windows must fulfil high requirements, and many of the products available on the market today do so. Better quality has its price of course – the additional costs for Passive House windows are definitely noticeable. But while the energy savings achieved by Passive House windows alone may not make up for the (unsubsidised) extra costs, they are indispensable. They help reduce other costs as well: thanks to lower heat losses, the costs for heating and air conditioning are reduced. As an additional benefit, these windows greatly enhance comfort.

Viewed as a whole, the investment in quality Passive House windows is definitely worthwhile.

>> Learn more about cost calculations from the Passive House online course: www.passivhauskurs.de

Investing in adding value instead of in energy consumption



5. Heat recovery ventilation system

The home ventilation system is essential for good health and should be installed in every new construction and during every renovation. Reducing levels of indoor air pollution improves the health of occupants so drastically that this alone makes investing in a good ventilation system worthwhile.

We have nevertheless chosen to calculate the full costs for it as extra construction expenses. These expenses amount to between 40 and 90 Euros per m² of living space, accounting for 3 to 6% of the average total construction costs.

6. Some costs can even be reduced.

Since a Passive House requires much less energy for heating, less money needs to be invested in the heating system. Radiators don't have to be positioned at the external walls, distribution pipes are shorter and thinner, and heat generators have smaller dimensions. Chimneys, fuel tanks and tank rooms are no longer required.

These savings can amount to up to three percent of the total construction cost. Given the extra investment of 3 to 8 % for a Passive House, they are definitely worth noting.

"How do you feel at home on sunless winter days?"
"We have never had temperatures below 20°C. When it was at the most minus 10°C outside, we measured a temperature of 23°C in the house, without having to use any heating."
Family Stiegeler lives in a semi-detached Passive House near Freiburg., Germany

SAVING COSTS THROUGH ENERGY EFFICIENCY – FOR THE DURATION

In the long run, energy efficiency is the main factor that contributes to lightening your financial load.

- **Building a Passive House today means making a sensible and effective long-term investment.**
- **The risk is lower than for a normal building, and the "total investment value" of the house is increased.**

Learn more about economic-efficiency calculations in the Passive House internet course at: www.passivehouseconference.com

RISK INSURANCE
After 30 years, the Passive House has been paid off and the family in our example on page 34 is now saving even more due to the extremely low energy requirements of the Passive House.

The risk of increasing energy prices doesn't concern the Passive House occupant; it does, however, affect those people who don't have Passive Houses. In the property business, the focus is on security. An investment like the construction of a house shouldn't be a high-risk endeavour, especially since there are alternatives. The Passive House is a secure investment.

EVERYONE BENEFITS FROM THE PASSIVE HOUSE BECAUSE:

- **everyone is less dependent on external energy supplies.**
- **innovative products create employment and added value within the country.**
- **the climate, the environment and health are protected.**

Quality is the top priority.

The Passive House concept far exceeds existing regulations. Certified Passive House designers and consultants have the experience and knowledge necessary to ensure this level of quality. In addition, qualified service providers offer assurance of quality.

Planning

The Passive House Planning Package (PHPP) is available as a planning tool. It is a calculation procedure developed specifically for Passive Houses and can be used for the following purposes:

- to prepare energy balances
- to calculate heating loads
- to determine the dimensions of ventilation systems
- to monitor comfort conditions
- to draw up verification for Passive House financial support

Certification bodies authorised by the Passive House Institute offer **independent review and certification** of plans. Any property developer can take advantage of this option.

Implementation

Certified building products like

- facade systems
- insulation systems
- construction systems
- Passive House windows
- glazing
- connection details
- heat recovery units

ensure secure implementation. Renowned companies offer high quality products for Passive Houses and are competent partners during the building process. An airtighness check is obligatory for each Passive House.

Huke-Schubert Berge Architekten | Mixed-use apartment building on Erdmannstraße | Hamburg, Germany

Passive House user experiences

The very first Passive House (in Darmstadt, Germany) was not only a research project for checking the technical operation of Passive Houses, people also lived there. From the very beginning, the occupants were questioned about their experiences, just like in later Passive House projects. Social science investigations were carried out in several terraced housing estates and multi-storey buildings. The results were overwhelming: in terms of comfort, Passive Houses consistently performed very well. This showed that the residents were not passionate penny-pinchers willing to suffer freezing conditions just for the sake of saving energy. After all, they could keep their house comfortably warm with no costly heating bills and no bad conscience!

People appreciate the ventilation system in particular, because it provides fresh air continuously and reliably.

Most of the occupants feel that life in a Passive House is "completely normal". There are some differences, of course:

- You don't have to worry about the ventilation, because it works automatically.
- There are no great temperature fluctuations in the winter or summer.
- It is not necessary in a Passive House to reduce the temperature at night or during absences constant comfort is affordable since almost no costs are incurred.
- It is easy to keep the Passive House pleasantly cool in the summer, as the positive reactions of guests show.
- Ventilation through windows is no longer needed. In houses without ventilation systems, the windows in bedrooms have to be tilted open – but that doesn't guarantee good air quality.
- The occupants of a Passive House have to replace the filters in the ventilation system regularly, but it´s so easy that they can do it themselves.

"We walk around the house barefoot or with socks all year long. Even in the basement our feet never get cold."
Family Zielke, residents of a Passive House in Darmstadt

»

Windows can of course be opened in a Passive House, too. It's just that in winter, it's no longer necessary to worry about airing on a regular basis. Users of existing Passive Houses have different habits, depending on their individual preferences.

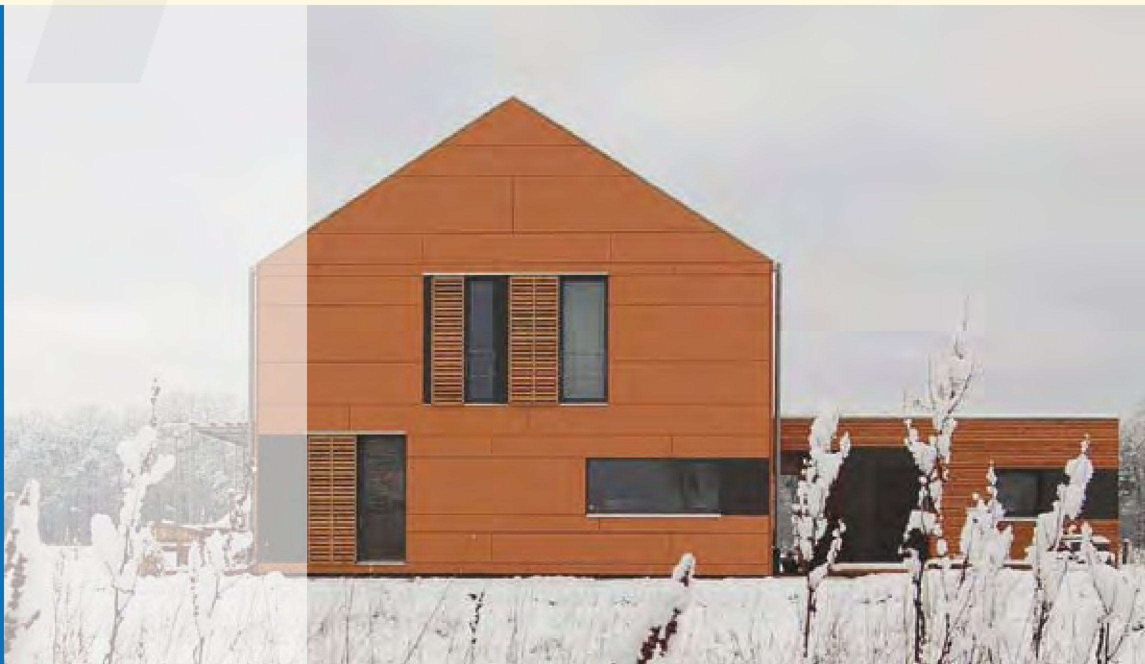
In the scientifically monitored projects, there was apparently no need for excessive ventilation through the windows; all Passive Houses that were monitored functioned as expected. Where windows were opened frequently, energy consumption was somewhat higher than the average for Passive Houses, but it was still much lower than in any conventional new building.

In the summer and in the transitional period it is obviously reasonable and sometimes even necessary to open the windows more often, in order to get rid of any excessive heat. External shading attachments are particularly important at this time of year. When it is really hot outside, it is best to keep the windows closed and rely upon the ventilation system.

03

PASSIVE HOUSE PROJECTS

Five projects:



Inspired by the aesthetics of traditional architecture

The Passive House in Bessancourt | France

The town of Bessancourt lies about 28 km northwest of Paris. An intact, historic town centre with narrow alleys, courtyards and small houses surrounds the church, which dates from the 12th-13th century. The urban planning regulations of such a town made it necessary to keep the cubature of the Passive House simple. Its fine and airy covering of bamboo poles creates a sculptural form; the transparent outside layer disperses the mass, lends a feeling of weightlessness and creates depth. The light is broken up by bamboo poles attached at intervals, and a special atmosphere is created inside, ever changing with the position of the sun.

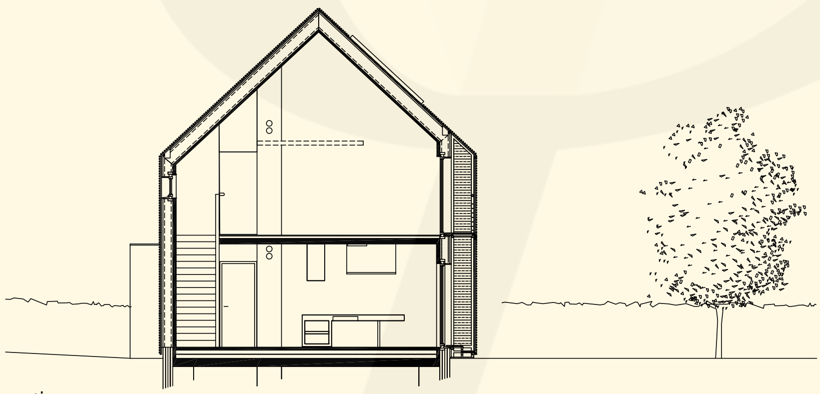
A very important element of the design is the „spine". It consists of wooden discs 600 mm wide, arranged at intervals of 900 mm, and divides the floor plan into two parts, at a ratio of 1:2. The larger part is situated on the southern side and contains the living and sleeping areas; the smaller part is on the northern side and accommodates the sanitary and service/utility rooms. The division of the rooms is clear, the distances are short, and the materials are natural and untreated. Even the lighting follows a clear principle: the energy-saving fluorescent tubes and technical cables run along the spine and are visible in places.

Some parts of the spine serve as load-bearing supports and accommodate the technical installations. This central element, which is sometimes closed and sometimes open, is accessible from both sides and serves as a cabinet, shelf or partition. It forms the walls of the kitchen and the bathroom, and it houses the lighting and ventilation ducts. The latter are partially visible as part of the aesthetic concept and make the ventilation system clear and easy to understand.

Along the southern facade, there is a walkway of metal grating that serves as a balcony and as the mounting support for folding shutters. The space that it creates lends additional depth to the interior.

The house was built using mainly natural materials – wood panels for the construction, cellulose and wood fibre for the insulation, and plasterboards and bio paints for the finishing of the interior. The photovoltaic panels on the roof make this house an Energy Plus House, according to French standards.

This house has attracted the attention of the media in France due to its architecture, energy efficiency and consistent method of realisation.



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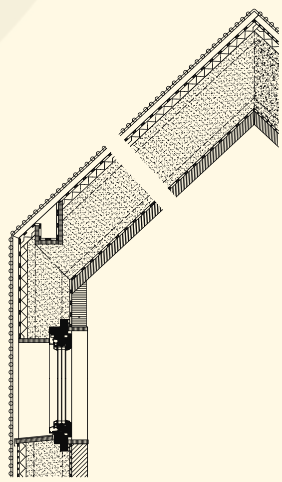


detail section

Project information

Certified single-family house
New construction | 95550 Bessancourt, France
Living area (Treated floor area) according to PHPP: 161 m²
Year of construction: 2008
Project database: ID 1125

Property developers

Mischa Witzmann | Milena Karanesheva

Architects

karawitz architecture, Paris

Photographs

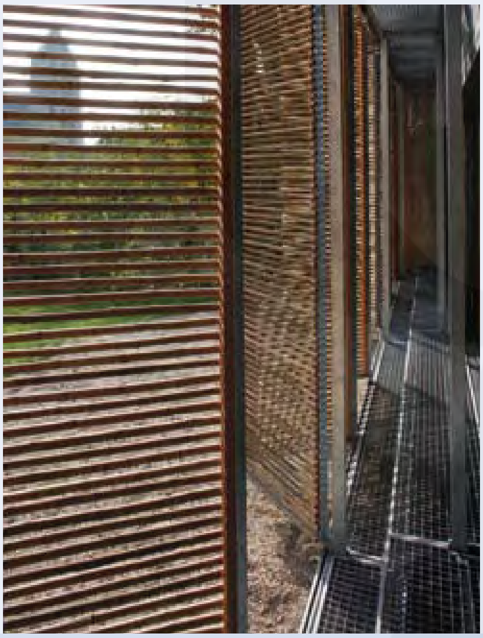
Hervé Abbadie

Construction

External wall: cross-laminated timber | airtight steam brake | 240 mm I-joists with cellulose | wood-fibre insulating board | under-roof membrane | bamboo
Roof: cross-laminated timber | airtight steam brake | 300 mm I-joists with cellulose | wood-fibre insulating board | under-roof membrane | bamboo or PV module
Floor slab: screed | 200 mm EPS | concrete slab

U-values

External wall: 0.14 W/(m²K)
Roof: 0.12 W/(m²K)
Floor slab: 0.17 W/(m²K)



Windows
Wooden frame with aluminium cover strip, overlapping insulation at the wall connection
$U_{w,installed}$ = 0.80 W(m²K)
Triple glazing with low-e coating and Argon filling
U_g = 0.60 W(m²K) | g-value = 50%

Ventilation | heating | hot water
Compact heat pump unit with cross-counterflow heat exchanger, η_{HR} = 76% | external air suction through subsoil heat exchanger | thermal solar plant | photovoltaics

Airtightness of building
n_{50} = 0.48/h

Heating demand (calculated according to PHPP)
11 kWh/(m²a)

Primary energy demand (calculated according to PHPP incl. the total electricity demand without taking solar electricity into account)
90 kWh/(m²a)

Construction costs (for construction and building services)
2,153 Euros/m² including VAT (19,6%)

Living and Learning in the Waldsee BioHaus

Concordia Language Villages | Bemidji | Minnesota, USA

The BioHaus at German Village Waldsee serves as a residential facility for students of the German language, from all over the world. As an educational facility for environmental studies and a model for sustainable building construction in the USA, it serves as a home for 28 people for two weeks at a time and provides room for language study and learning about sustainable activities. Every year, over 1,500 young people from the ages of 7 to 18 take part in these immersion programs at Concordia Language Villages.

Compared with buildings in Germany, the BioHaus is exposed to extreme climatic conditions. The region of Bemidji has 5700 heating degree days (HDD) – in contrast with 3500 heating degree days in Germany. This application of the German Passive House standard in Minnesota is unrivalled; the BioHaus requires 85% less energy than the maximum allowed by the current energy regulations of the state of Minnesota.

The Waldsee BioHaus design combines two key functional elements (see picture below):

1. Private areas containing dormitories and apartments – the basement and rear of the building, with blue stucco walls that have a very solid feel to them;
2. Public areas for gathering, playing and learning – the upper part of the building, with its lightweight design, reflective-aluminium siding and lots of high-quality windows to let in light.

As an environmental living centre, the BioHaus demonstration project exhibits the latest technologies for sustainable building standards: a building envelope and ventilation system that meet Passive House standards, an extensively planted roof, toxin-free building materials, conservation of resources, simple building-service engineering, windows that act as heaters, vacuum insulation panels, the application of renewable energies through the use of solar collectors, as well as the use of energy-efficient electrical appliances and water-saving faucets. The building is also equipped with a monitoring system that interactively demonstrates the building's performance to the students and makes it possible for them to compare it to other German and American buildings.

section

site location plan

Project information
Educational facility with dormitory
Bemidji | MN 56601 | Minnesota, USA
Useable area (Treated floor area) according to PHPP: 401 m²
Year of construction: 2006

Property developer
Concordia Language Villages | Concordia College

Architects and Engineers
Intep - Integrated Planning LLC, Minneapolis, Stephan Tanner |
Intep - Integrated Planning GmbH, Munich, Thomas Rühle

Photographs
Stephan Tanner, AIA | Edwin Dehler-Seter, Concordia Language Villages |
John Gregor, Coldsnap

Construction
Wall: gypsum board | wood structure with insulation 290 or 140 mm | OSB | EPS insulation 200 mm or vacuum insulation 50 mm
Roof: gypsum board | wood structure with insulation 300 or 500 mm | structural insulation 200 mm or vacuum insulation 50 mm | plywood sheathing
Floor slab: concrete | rigid insulation 360 mm

U-values
Wall: 0.08 – 0.09 W/(m²K)
Roof: 0.06 – 0.08 W/(m²K)
Floor slab: 0.11 W/(m²K)

Windows
Insulated wood profiles with larch exterior
$U_{w,\ installed}$ = 0.86 W/(m^2K)
Triple glazing with low-e coating and Argon filling
U_g = 0.60 W/(m^2K), g-value= 52%

Ventilation | heating | hot water
Supply-exhaust system with counter-flow heat exchanger, earth-to-air heat exchanger, ground source heat pump for heating and hot water generation, heat distribution through in-floor radiant heating, solar thermal energy 20 m^2 for hot water generation and supplemental heating

Airtightness of building
n_{50} = 0.18/h

Heating demand (calculated according to PHPP)
14 kWh/(m^2a)

Primary energy demand (calculated according to PHPP incl. total electricity requirement)
83 kWh/(m^2a)

Construction costs (for construction and building services)
2,410 Euros/m^2 useable area

Sustainable Housing in Tyrol

Multi-storey building | Innsbruck | Tyrol, Austria

The "Lodenareal" project perfectly combines the climate-protection goals of the project sponsor, the Austrian state of Tyrol, with the "Neue Heimat Tirol (NHT)" construction company's objective to guarantee the region affordable and sustainable housing of the highest quality standard. The success of the project has led to a Passive House boom in Austria that has made Tyrol (like Vienna) a driving force for multi-storey constructions.

Due to the high demand for social housing in Innsbruck, an architectural competition was organised in 2006 to find the best, most compact way to use the inner-city industrial wasteland of a former textile factory for residential purposes. The four 6-storey L-shaped buildings, with a total of 354 accommodation units, are situated above a communal underground garage with 405 parking spaces. Two L-shaped buildings are arranged to form a large, thematically designed inner courtyard with views of the surrounding mountain panorama. Each accommodation unit includes a private area for use either as a garden or a balcony, depending upon what floor it is on.

Each open-plan apartment of 2-4 rooms extends across one whole side of the building, and the units are divided by a central kitchen area. All feature generous windows and oak flooring throughout, which visually enlarges the living area to include the balconies. Glass screens that provide privacy and wind protection extend even further past the building facade and are decorated with patterns like those on the balcony balustrades.

NHT project managers' optimised basic concept is what made achieving the Passive House standard possible, because it followed the fundamental principles of energy efficiency – from the planning phase through the supervision of construction and all the way up to how the apartments would later be used and managed. Since then, this concept has become the standard for all Passive House projects undertaken by the NHT.

With the help of dynamic building simulations it was possible to reduce the costs, for example by optimising the summer heat protection of the various building zones.

Central heat generation using a wood-pellet heating system and a large solar-collection system ensures that regenerative energy can almost completely fulfil the heating demand.
The heat is distributed by a supply-and-return heat circulation network that decentrally supplies hot water to heating surfaces, as well as to the transfer stations that heat water for household use. Heating and ventilation take place separately and can be regulated individually. Each of the 18 stairwells has its own ventilation centre, combined with a groundwater heat exchanger for frost protection.

section | elevation | Architekturwerkstatt din a4 | Innsbruck

Project information

Certified Multi-storey Building
New construction | A-6020 Innsbruck | Tyrol
Living area (Treated floor area) according to PHPP: 27,804 m²
Year of construction: 2009 | Project database: ID 1225

Contractor

Neue Heimat Tirol Gemeinnützige WohnungsGmbH

Architects

architekturwerkstatt din a4 | Messner-Prackwieser-Zobl
team k2 architekten | Ewerz und Gamper

Passive House Consulting

Herz & Lang GmbH | Airoptima
Member of the IG Passivhaus Deutschland

Fotos

Christof Lackner | Günter Richard Wett

Construction

External wall: interior plaster | reinforced concrete wall 180 mm | insulation EPS 240-300 mm | exterior plaster
Roof: plastering | reinforced concrete ceiling | EPS insulation 300-400 mm | roof seal | extensive planting
Ceilings of basement and underground garage: coat of paint | bonded rock wool panels 260 mm bonded | reinforced concrete ceiling | infill and soundproofing insulation 100 mm | cement screed | parquet/tiles

U-values

External wall: 0.13 W/(m²K)
Roof: 0.11 W/(m²K)
Ceiling of basement/underground garage ceiling: U = 0.13 W/(m²K)

Windows

Windows and balcony doors $U_{w,installed}$ = 0.78 W/(m²K) | Triple glazing with low-e coating, filled with Argon | U_g = 0.60 W/(m²K) | g-value = 51% | Wood/aluminium window system, U_f = 0.96 W/(m²K) | full overlapping of frame insulation done on site

Ventilation | heating | hot water

18 central ventilation systems (one device per stairwell), with cross-flow heat exchanger (η_{WRG} = 82% according to PHI testing procedures), frost protection by means of groundwater heat exchanger, regulation of air quantity for each apartment | Central heating for the whole complex: pellet stove 300 kW and peak-load gas-condensing boiler 326 kW, solar heating system 1,050 m² (3 m²/unit) | 11 buffer storage units 2,500 l each, supply-and-return heat distribution network with heat transfer stations in apartments for heating and decentralised hot water provision, underfloor heating in parts

Airtightness of building

n_{50} = 0.18/h

Heating demand (calculated according to PHPP)

14 kWh/(m²a)

Primary energy demand (calculated according to PHPP incl. the total electricity demand) : 117 kWh/(m²a)

Primary energy demand for heating | ventilation | hot water

(calculated according to PHPP, but based on EnEV useable area)

27 kWh/(m²a)

Construction costs (cost category 300 + 400)

1,536 Euros/m² useable living space inc. VAT (20%)

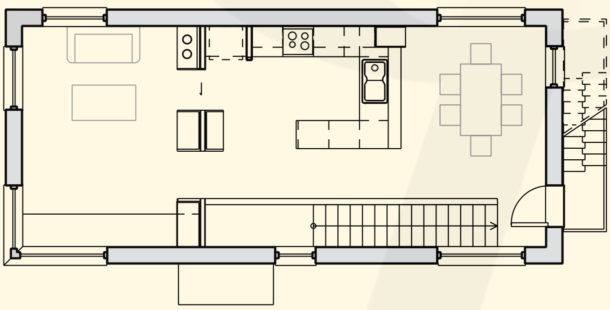
Less is more – the first Passive House in Japan

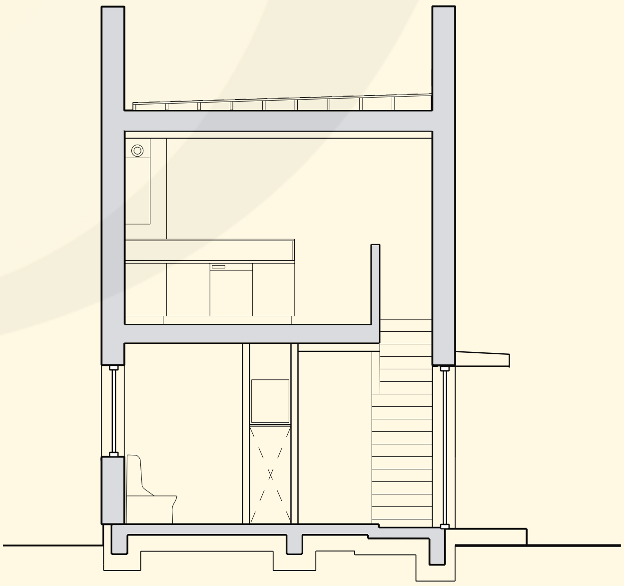
A small detached house in Kamakura, Kanagawa | Kanto, Japan

The design approach was to create a simple, two-storey unit that would fit into a mature neighbourhood. After you have taken off your shoes in the entrance area essential to any Japanese house, a spacious staircase leads up to a living-dining area on the first floor, which is designed open plan in order to make the best use of daylight. The well-positioned windows frame nice views over the river and the hills of Kamakura.
The site does not have enough private open space at the ground-floor level. To overcome this problem, the architects designed an access from the dining space to a roof garden.
The building itself had to be constructed within a very limited budget due to the high purchase price of the site (approx. 2,500 Euro/m²).

The house was built using the Canadian 2/6-inch timber-frame construction method and insulated with wood-fibre insulation. The wood-aluminum composite windows with triple glazing were shipped over from Germany, as windows with such high energy performance are not yet produced in Japan. To match the surrounding environment, charcoaled cedar panelling was chosen as the external wall finish. This is a very traditional construction material in Japan, because it is known to be highly durable against moisture and insects, an issue relevant to the local climate.
There is currently no minimum energy-efficiency requirement for new residential buildings in Japan; a house with single-glazed windows and no insulation is still acceptable.
KEY ARCHITECTS tried to find a comfortable balance between summer and winter by applying the Passive House principle.
In such a humid sub-tropical climate, reducing the dehumidification and cooling demand during summer is more difficult than reducing the heating demand in winter.

Another conflicting issue involved the strict earth quake requirements for Japan, which require rigid load-bearing walls instead of diffusion-open walls that prevent condensation within the external walls during both summer and winter months.


first floor plan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Project information

Certified detached house
New construction | Kamakura Kanagawa, Japan
Living area (Treated floor area) according to PHPP: 78 m²
Year of construction: 2009
Project database: ID 1718

Architects

KEY ARCHITECTS, Japan

Photographs

KEY ARCHITECTS, Japan

Construction

External wall: plasterboard | battens with service cavity | moisture-adaptive vapour barrier | stud frame with wood-fibre insulation 140 mm | timber board | wood-fibre insulation 100 mm | permeable membrane | ventilated rain screen
Roof: plasterboard | battens with service cavity | moisture adaptive vapour barrier studs with wood-fibre insulation 290 mm | timber board | stud frame with wood-fibre insulation 100 mm
Floor slab: XPS insulation 100 mm | concrete | screed | timber floor finish

U-values

External wall: U = 0.16 W/(m²K)
Roof: U = 0.10 W/(m²K)
Floor slab: U = 0.22 W/(m²K)

Windows

Thermally insulated wood aluminium composite windows, triple glazing with low-e coating and Argon filling

$U_{w,installed}$ = 0.85 W/(m²K)

U_g = 0.64 W/(m²K) | g-value = 51%

Ventilation | heating | hot water

Ventilation: supply and exhaust air with counter-flow heat exchanger | summer bypass | heat pump for heating, cooling / dehumidification and domestic hot water provision | heat distribution using air-conditioners

Airtightness of building

n_{50} = 0.14/h

Heating demand (calculated according to PHPP)

15 kWh/(m²a)

Cooling demand (calculated according to PHPP)

15 kWh/(m²a)

Primary energy demand (calculated according to PHPP incl. the total electricity demand)

113 kWh/(m²a)

An ambassador – in the form of a building

The Austria House, Whistler | British Columbia, Canada

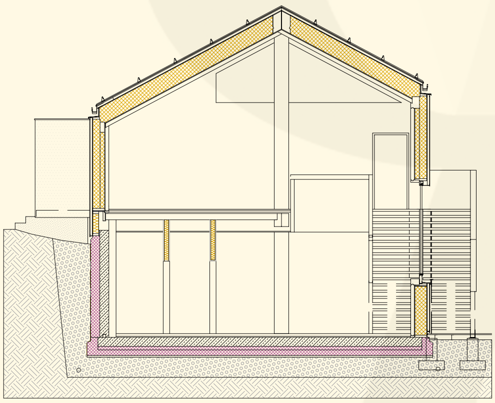
At the 2010 Olympic Winter Games, the Austria House was a popular meeting place for people from all over the world. With representatives of sports, the media, industry and politics gathering within its rooms, the building assumed the role of an ambassador as the first "Olympic House of Nations". The Austria House is also the most energy-efficient building ever built for the Olympic Games. Its construction epitomises how the issues of energy conservation can be actively solved.

The design is a modern interpretation of traditional construction in alpine regions: a compact structure with a double-pitched roof and with its large glazing areas oriented towards the south.

The ground floor is open to the public and features a bar and restaurant area as well as a terrace in front, providing a large venue with both indoor and outdoor areas. A continuous row of windows leads to the upper floor, further opening up the building to its natural surroundings and creating a visual contrast to the upper floor, which is used for other purposes.

The television studio on the upper floor can be reached via two staircases running parallel on the inside and outside of the building. Ample glazing offers an unimpeded view of the Blackcomb and Whistler Mountains – the two venues used for the alpine skiing events. A balcony at the front connects the studio with the outdoor area. In the private area of the upper floor there is a lounge and VIP area with only a few, well-placed windows. Having two entrances to the upper floor allows separate access to the TV studios and the VIP lounge.

The building was developed by the Austrian Passive House Group (APG), together with the Municipality of Whistler, and designed by Treberspurg & Partner Architekten, Vienna. The issue of subsequent use and durability was an important consideration so that after the Games, the community of Whistler can use the building as a cross-country skiing centre in winter and a mountain bike centre in summer.



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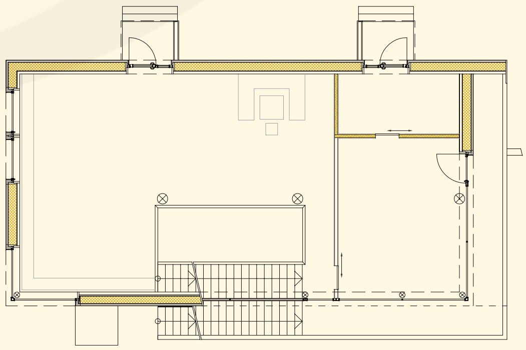


ground floor plan

Project information

Certified Leisure Facility
New construction | CA-1B7 Whistler | British Columbia, Canada
Useable area (Treated floor area) according to PHPP: 248 m²
Year of construction: 2009
Project database: ID 1750

Contractor

Austrian Passive House Group

Architects

Treberspurg & Partner Architekten ZT GmbH, AT - Vienna

Photographs

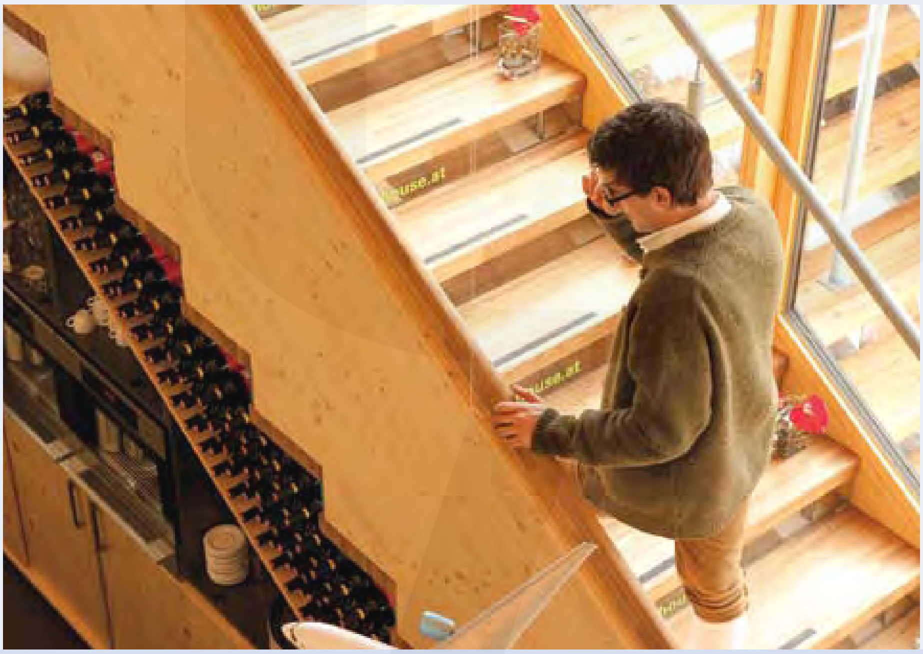
Ira Nicolai

Construction

External wall: triple-layer-panelling | wood frame and wooden beams with 320 mm mineral wool | vapour-permeable insulating panels | shingle facade
Roof: triple-layer-panelling | laminated rafters with 440 mm mineral wool | full cladding | covered with shingles
Floor slab: screed | sound-proofing insulation | reinforced concrete | 250 mm perimeter insulation

U-values

External wall: 0.14 W/(m²K)
Roof: 0.11 W/(m²K)
Floor slab: 0.12 W/(m²K)



Windows
Insulated wooden profiles with aluminium cover strip
$U_{w,installed}$ = 0.86 W/(m²K)
Triple glazing with low-e coating and Argon filling
U_g = 0.74 W/(m²K) | g-value = 52%

Ventilation | heating | hot water
Compact heat pump unit for ventilation, heating and hot water provision in combination with a brine heat exchanger and water-based low-temperature heating circuit

Airtightness of building
n_{50} = 0.28/h

Heating demand (calculated according to PHPP)
15 kWh/(m²a)

Primary energy demand (calculated according to PHPP incl. total electricity requirement)
67 kWh/(m²a)

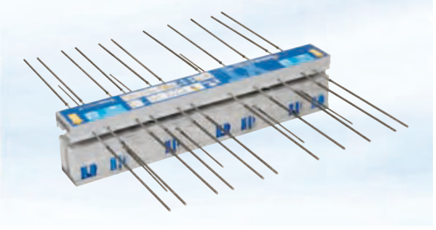
Construction costs (for construction and building services)
2,160 Euros/m² including VAT (20%)

Free cantilevered balconies in a passive house design

For a long time free cantilevered balconies represented a weak point in the building envelope of a passive house, because no certified solution was available for this thermal bridge. The balcony architecture was therefore usually subject to limitations. The problem was solved by using balconies with separate supports.

However, these days balconies not only form part of the expected living standard in new buildings - particularly in multi-storey houses - they are also an architectural design features. In addition, separate balcony supports are undesirable, since in many cases there isn't enough space for adequate foundations.

As a solution for this problem Schöck developed the Isokorb® XT as a load-bearing thermal insulation element that is compliant with the passive house standard. Thanks to its optimised materials and an insulation thickness of 120 mm, compared with the conventional Isokorb® with an insulation thickness of 80 mm the new product range represents a significant thermal improvement. Balcony connections insulated with standard Isokorb® XT types meet the criteria for low thermal bridges specified by the Passive House Institute.



Isokorb® XT suits as low thermal bridge constructions for free cantilevered balconies in passive house design.

In passive house designs free cantilevered balconies and balconies that are only supported at the front can thus be realised without problem. In addition, the minimal thermal bridge design has lower heat loss via the thermal bridge, which is limited to reasonable levels. The design specification requires the increase in the mean U value of the opaque façade caused by the thermal bridge to be limited to $\Delta U_{TB} = 0.025\,W/(m^2K)$. The heat loss coefficients depending on the balcony slab thickness and the Isokorb® XT load-bearing level can be found in the corresponding certificates at www.schoeck.de or www.passiv.de

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