auf Basis einer Zuarbeit von Dipl.-Ing. Dieter Brandt (Passivhaus-Berater)

A Passive House Standard in the Interest of the General Public and of Private Households

1 What are Passive Houses?

Passive Houses are buildings with

- walls, windows, roofs and floors which are not only well **insulated**
- but which are also so well **sealed** (against convection and not against diffusion!)

so that their energy requirements tend to go towards zero **(<15 kWh/m²*a),**

whereby the **passive** energy input through

- the heat emission of the residents,
- the solar energy entering through the windows, and
- the waste heat of the electrical appliances

plays a vital role (2/3) in compensating for any heat losses.

This leads to a higher thermal living comfort and a much better air quality.

2 Exploiting the potential of the thermal protection building method!

In Saxony, buildings account for approx. 40 % of the designated end use of energy. The construction of Passive Houses and the refurbishment of existing buildings with Passive House elements is a good way of exploiting the high potential of energy savings available. This can also make a noticeable contribution towards minimising greenhouse gas emissions.

Figure 1 Passive House Kindergarten in Döbeln

The downside is that available public funding is limited. The additional costs of the Passive House construction method can however be subsidised in the so-called Passive House Innovation and Cooperative Study Programme for projects which suit this purpose. In addition, the promotion of Passive House technology is also being subsidised.

With regard to newly constructed buildings, the remaining energy requirements for heating purposes for a dwelling unit in East Germany equals

$$[(15\ kWh/m^2*a) * 75\ m^2] / \eta = \text{approx. } 1400\ kWh/a,$$

whereby the average rate of the effective use of the energy contained in a fuel is estimated at $\eta = 0.8$. With a gas price of about 11 Ct/kWh applying for consumers who use less energy (e.g. rates charged for private consumption in Dresden), costs equalling approx. 170 € a year will accrue for the resident of an average-sized flat in a Passive House. This equals about 14 € a month or a rent surcharge of 0.18 €/m² which can be incorporated into the basic net rent without the service charges. The flats can be let with the heating costs set at zero (rent including heating). This means that the tenants will also save the costs of having to rent the counter and settling the heating costs.

3 The main criteria of the Passive House standard

The Passive House standard reduces the amount of energy needed to heat a new building for a year to the low level of

15 kWh per m² living area
= 1.5 l heating oil /m²
or
1.5 m³ natural gas /m².

What is more important, however, is that expressed in the fuel energy of wood fuels (pellets, wood chip, firewood, etc.) this would equal approx. 300 kg of wood (approx. 1 Rm of dry firewood) a year for a 75 m² flat!

This is approximately **1:7** of the energy requirement compared to the current German thermal protection standard for newly constructed buildings, whereby the aim is to achieve a **quotient of 10**. The reference area (the actual living area) being the habitable floor space within a thermal shell. The term “thermal shell” will be explained later.

Passive Houses are therefore not zero energy houses. It is easier to conserve the low amount of energy required for the winter months by stockpiling (bio) fuel for the winter than to conserve the solar energy in the summer in large seasonal tanks (10-20 m³ for each flat or house) for later use during winter peaks.

Passive Houses are simple. In order to obtain a net energetic benefit from an investment, they don’t require any additional technology to reduce the amount of energy needed to heat a place. They can also be converted into zero energy houses and even into small power stations (using all kinds of energy) providing a net yield more easily than other buildings if, for example, a photovoltaic system for generating additional power is added. Decisive is always the respective aim of the individual owner.

The energy balance of Passive Houses depicted on the right hand side of the following figure shows how this advantageous effect can be achieved through insulating and sealing measures as outlined in section 1:

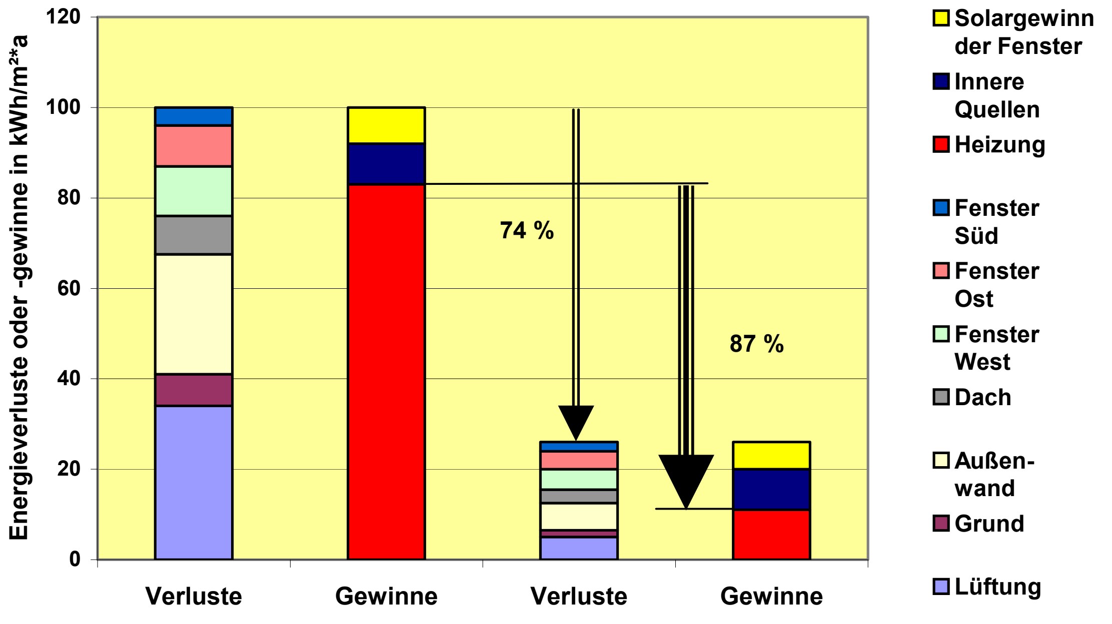

Figure 2: ***The energy balance over one year for a building conforming to the current German thermal protection regulations EnEV (on the left) and for a Passive House (on the right).***
The reinforcing effect through the constant accumulation of energy (solar energy derived from the windows and inside sources) in the area of low losses has the following effect:
a 74% reduction of the energy losses with heating energy savings of 87%.

The energy balance shows: Passive Houses are so-called “Anyway Houses.” After reducing the losses, they are able to use the energy which builds up in a house **anyway** more effectively:

- the heat which is otherwise lost through the use of energy inside an occupied house and
- the solar energy which enters through the windows.

Waste heat is produced for example when meals are cooked, when refrigerators are used, when washing is done with or without washing machines, and when hot water is either being prepared, distributed or used. It is also produced when computers and electrical appliances are being used. Even our body heat is an exploitable source of thermal energy.

Passive Houses use less heating energy depending on the insulating effect of the windows and on how well the amount of solar energy entering the building through the windows is adjusted to the energy requirements in the winter and the summer (of course in the summer it shouldn’t be too high an amount!).
The Passive House Planning Package allows the heating energy requirements of a Passive House to be easily calculated using a spread sheet analysis without requiring a dynamic computer simulation. The spread sheet software uses parameters obtained from a dynamic simulation of the yearly energy balance.

Another criteria affecting the effectiveness of Passive Houses which cannot be gone into further here is the fact that the **primary energy required** to live in a dwelling unit with all the different energy uses in a flat or a house may not exceed **120 kWh/m²** in a year. With a solar energy system for preparing hot water and with low energy household appliances, this criteria can be easily fulfilled when the main criteria are satisfied.

4 Individual components of Passive House construction

4.1 The thermal envelope

The thermal envelope refers to the uninterrupted insulation of all the enveloping surfaces of a building. This insulation must be applied without gaps and preferably without creating any thermal bridges. It should fit like a snug overall!

The respective thermal insulation value is indicated in chart 1.

A surface is considered to be free of thermal bridges when existing heat leaks lead to an additional heat loss of less than 0.01 W/K (= 0.35 W with Delta t = 35 K) for thermal bridges' points and less than 0.01 W/K per metre length of a linear thermal bridge.

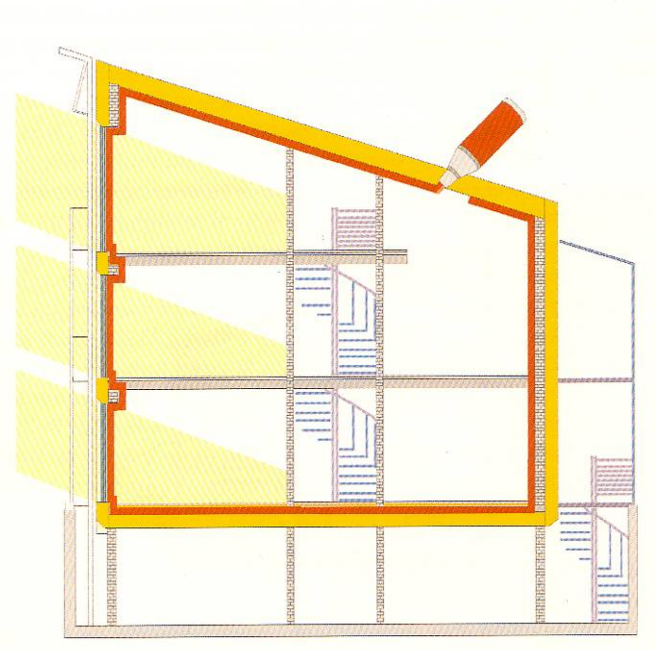

Figure 2: The two envelopes of a Passive House: The thermal envelope (yellow) and the convection proof envelope (red)

Bild 3: Insulating using 30 cm thick mineral rock wool

4.2 Convection proof envelopes

Passive Houses should be as convection proof as possible while being open to diffusion! Professionally built Passive Houses will not contain an excessive amount of moisture.

If kept within an admissible range (50%), even in the worst case (behind a closet in the cold corner of an external wall), mould will not develop because of the strong insulation protection. The corner will remain warm (this requires temperatures of approx. 16°C; t >12.6°C!).

A building's air tightness can be tested using a "Blow Door" pressure test. The building as a completed shell construction is exposed to excess pressure and negative pressure of 50 Pa. The air volume flow required to maintain the respective pressure is then measured in m³/h.

Sealing work may not be discontinued before the air exchange rate "n" (the correlation between the air volume flow and the space volume of the building) remains below 0.6. Otherwise the leaks through the convection proof envelope will be too great and the ventilation system with the installed heat exchanger for recovering heat will not function efficiently.

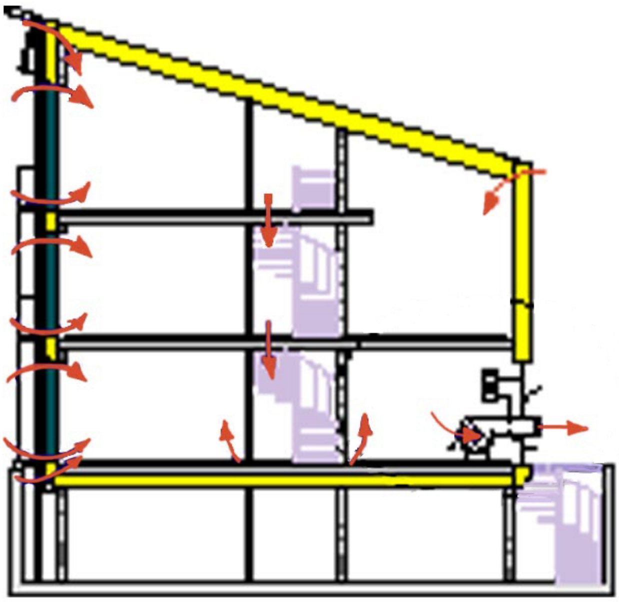

Figure 4. The leak flows in the building during the Blow Door tests

Figure 5. The “Blower” in the door during the tests

The convection proof envelope of the dry lining consists of conglutinated foil or building paper which is open to diffusion. With the external walls of newly constructed buildings made of masonry, this is the interior plaster with the air-tight enclosures for socket outlets, switches, branch boxes or other enclosures which have been sealed air-tight. All other leads going through this envelope (piping and conduits, cables, etc.) must also be individually sealed.

All transition points must be taped with special adhesive tape and adhesives, e.g. between the internal plaster and the gypsum plasterboard. This also includes the areas where the window frames reach the walls, etc. Here special attention is of utmost importance.

4.3 Passive House windows

The “high tech” part of Passive House buildings is represented by their windows and the heat recovery ventilation system. Both systems must be suitable for use with Passive House buildings and certified. This is to ensure that the parameters used for calculation purposes are met.

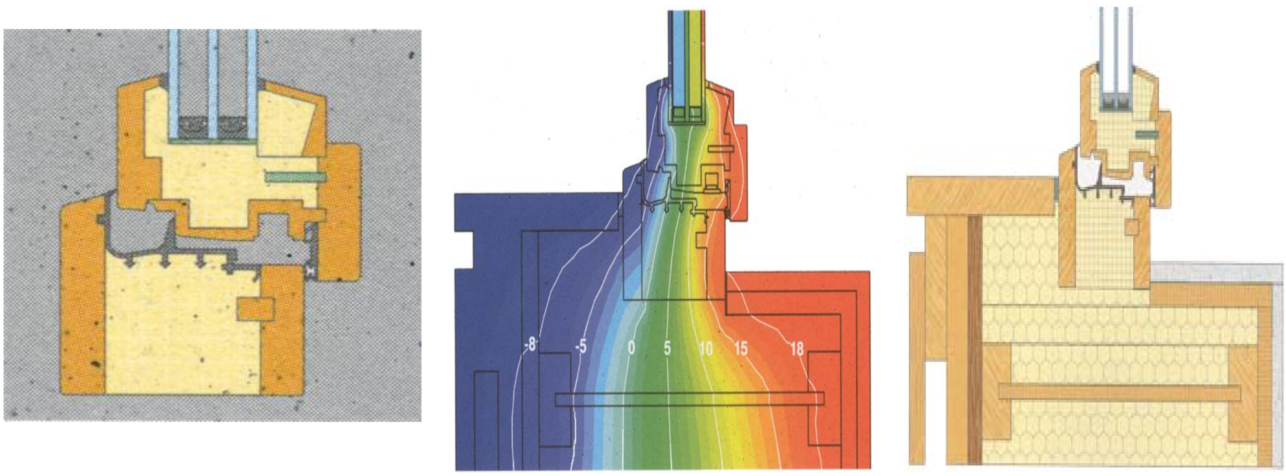

Figure 4: ***A section view of a Passive House window with the points with the same mean temperature. The correct installation in an insulated wooden wall.***

Three main elements of the windows are important: the glazing, the frames and the gaskets.

Details are contained in chart 1. With the best window frames, the maximum value of 0.8 W/m²*K for U_W can only be met with a glass value of U_g </= 0.7 W/m²*K. The design of this triple glazed window with mirror coating and an inert gas filling was required so that the first Passive Houses could be built. The building trade now offers a wide range of glass types and complete Passive House windows. The windows are also available with wooden frames. In my opinion, the best windows available today are the box-type windows shown in the following two figures.

Figure 5: "Leipzig" box-type Passive House window system featuring U_w =0,68 W/ m²*K

Figure 6: This window does not require any additional thermal protection in the summer.

Passive House windows feature a positive energy balance throughout the year when built facing south to west or east. They must have a sufficiently large surface area in these directions to allow enough energy to enter the building in the winter and feature a small enough surface area to prevent an overheating effect in the summer (while allowing for any required summer heat protection measures). This optimisation effect can easily be calculated with the help of the Passive House Planning Package. The windows facing north to east or north to west should not be larger than required.

4.4 Heat recovery from exhaust air

The column on the left of figure 2 shows that unless the ventilation losses are reduced – at least to the same degree as the transmission losses – the Passive House standard cannot be met. That can only be done by recovering the heat contained in the exhaust air. This is used to heat the ingoing air. The easiest way of doing this is by placing a recuperating device (heat exchanger) between the ingoing air and the exhaust air.

Passive Houses require a ventilation system for the winter in order to recover the heat. When used together with a geothermal heat exchanger during the summer, this provides an additional cooling effect.

The ventilation system for ingoing air takes the fresh heated air into the living area. The exhaust air ventilation system draws the same amount of air from the kitchen, the bathroom, the WC, etc. A control system combines both ventilators to form a central ventilation unit.

People who are not knowledgeable will often think that a separate ventilation system for the winter is unnecessary. It actually has numerous benefits with only a few disadvantages (e.g. the additional costs). This means that it has to be optimally adjusted to the actual heating requirements.

In his presentation, Mr Paul will go into further details including the geothermal exchanger. Here I only want to touch upon those aspects which are of special interest for the Passive House system:

1 In the winter, the air flow (ingoing air = exhaust air) should be limited to 30 m³/h for each person in the living unit. Otherwise the air will become too dry.

The air flow is adjusted at the central ventilation unit. It must be easily adjustable to the number of people who are living in the dwelling unit over an extended period of time. This is usually done by a manual 3-step switch featuring the settings minimal ventilation, basic ventilation and inrush airing. Especially the minimal step must be set low enough. When a dwelling unit is only occupied by two people, 60 m³/h are sufficient.

This means that it may become difficult to adjust the air flows in the individual rooms. With a low occupancy rate an interval switch could therefore be desirable.

2 Until now there has not been much experience regarding the use of air quality sensors (CO_2 content, humidity, motion detectors, etc.) to control the air flow in Passive Houses. However, I believe that this is an option which is worth looking into.

3 In multiple dwellings each residential unit would have its own central ventilation unit, however only in exceptional cases its own heating boiler.

4 The electricity required for the central ventilation unit should not exceed 0.45 W/(m³/h). With such a device for a maximum of 200 m³/h, this would equal a peak demand of 90 W.

5 Most of the central ventilation units still make so much noise that they have to be kept in a closed installations room.

6 The ingoing air leads for each room and the exhaust air leads from the bathroom, the kitchen, etc. must be equipped with sound absorbers to prevent them from transmitting sound between the rooms.

7 Some experts prefer that the remaining required heat be supplied by subsequently heating the supply air with the help of an additional heat exchanger (supplementary heating register) in the central ventilation unit. Because the air flow depends on the number of people and because of the supply air temperature's upper limit of 50 °C, I would recommend that the thermal heat be distributed in the individual rooms using decentralised heaters. This would call for a reduced heating effort through the low remaining requirement for thermal heat.

8 No ventilation system without a measuring log to adjust the air flows for the supply air and the exhaust air in the living rooms and from the kitchen, bathroom, etc. as well as to adjust the supply air and the exhaust air in the central ventilation unit.

9 The airflow from the living rooms to the exhaust air side in the kitchen and the bathroom, etc. requires acoustically insulated overflow openings in the interior doors.

5 Overview of the components and parameters of Passive House construction

Chart 1: Overview of the components

1	An enclosed thermal envelope with reinforced thermal insulation of the enclosing surfaces External walls of new buildings: (depending on the climatic conditions)	U_{total} </= 0.15 W/m²*K approx. 30 cm thick with λ= 0.04 W/m*K

	exterior walls with the modernisation of existing buildings:	approx. 25 cm
2	Heat recovery ventilation system Volume flow (input = output): Heat recovery rate:	30 m³/h per person > 85%
3	Heat exchanger in the ground to preheat the supply air to a temperature close to the ground temperature	Min. of +4°C
4	Envelope at/in the enclosure surfaces which is impervious to the development of convection (but open to diffusion!) air exchange at 50 Pascal pressure difference:	$n_{50} < 0.6\ h^{-1}$
5	External doors and windows with the best possible thermal protection, Glass: triple glazed windows with mirror coating and inert gas, tightly insulated frames	$U_{w(glass+frame)} < 0.8$ W/m²*K
6	Glass with the highest possible transmission rate for solar radiation, rate of energy transmission:	g> 0.5
7	Construction eliminating thermal bridges as far as possible, thermal bridge coefficient:	Ψ< 0.01 W/m*K
8	Big window surfaces preferably facing east-south-west No window surfaces facing east-north	
9	Minimum degree of shade through surrounding buildings or mountains, preferably only foliage trees	
10	Solar thermal collectors for heating water and perhaps for ensuring remaining required heating, solar coverage rate:	> 50%

What makes Passive Houses so different are the parameters of the last column, i.e. the intensity in which the measures are applied: the strong heat insulation, the restriction of the volume flow of the ventilation system to 30 m³ per hour and person, the high degree of air tightness in the building envelope, etc., the quality of the planning measures and the optimal mixture of the components in carrying out the work.

6 Quality assurance

• During the planning and preparation stages

You should definitely not attempt to plan a Passive House by yourself if you lack previous experience or training! You should moreover appoint either an architect or a consultant experienced in Passive Houses to carry out or accompany the planning and the construction work.

They will perform the calculation work using the Passive House Planning Package and carry out a Passive House audit and have the work certified for you.

• Implementation stage

The same also applies here: A special training or instruction of the construction workers is required if these people lack previous experience in the construction of Passive Houses.
A special inspection of the components being used in the Passive House is also required if the other building supervisors lack the comprehensive knowledge required for making Passive Houses.

The bottom line is: No fiddling around! Only those building components and construction technologies should be used which are suitable and permissible for being used for Passive Houses and which have preferably been certified by the Passive House Institute. The Passive House Institute publishes a regularly updated list of these requirements (see www.passiv.de).

No building contract should be signed before copies of the certificates of the Passive House elements are at hand. The company performing the work with the thermal insulation compound system must be licensed by the system agent.

7 Results and experience

- **Experience**

Passive Houses have passed the test of time. The elements of the Passive House construction are fully developed, they have been proven time and again, and they are available on the European market. Several thousands of such houses have been previously built with success in Germany, Austria, Switzerland and other countries.

Passive Houses always provide air with a good quality and an equal degree of warmth everywhere. People simply feel comfortable in them! If no serious mistakes are made. But that applies to construction engineering in general.

If parts of the house or dwelling unit, e.g. the bedroom, are to remain cold, then they must be thermally decoupled. This means a greater investment with additional costs. Here one could however also open the window. This results in higher energy losses which means further costs. Calculations show that these will however remain within narrow limits (an additional approx. 3 kWh/m² a).

The windows of Passive Houses are so warm on the inside that cold air does not flow in front of them. As a result, radiators do not have to be installed in front of the windows. The small radiators can thus be located in a more central position. This results in shorter connection lines.

A pleasant indoor climate is created in the summer if the ventilation system is occasionally turned on. This will bypass the heat exchanger in the central ventilation unit and allow air which has been cooled by the geothermal exchanger to reach the building directly. Otherwise the building can also be kept cool by opening the windows at night and by keeping the windows closed during the day. Better than in any other house.

- **Documented results**

The EU (DG 17, Thermie Programme) supported this development with its CEPHEUS project from 1998 to 2001. Various types of Passive Houses were built in the three countries mentioned above as well as in Sweden and France. Along with a thorough assessment, a comparison was made with the same buildings using the national thermal protection standards. All 250 residential units in 14 buildings complied with the strict criteria of the Passive House standard (Lit. 2-3).

Surprisingly, in five European countries the investment required for the CEPHEUS project only averaged 8 % more than for the other 14 buildings!

In Germany, additional investment costs of approx. 10 compared with the currently valid legal standard for thermal protection (EnEV 2002) have been estimated.

8 Final remarks: Passive Houses are not only easy to build, but they also achieve their purpose

The Passive House idea has a clear purpose: to enable the residents to save a maximum amount of energy while applying only as little additional effort in the actual building of the house as possible.

Compared to everything which solar construction has to offer, Passive Houses are simply simpler. That’s why more and more solar architects are becoming interested in the Passive House building method.

Even a good solar construction can only save 15 kWh/m²*a of the required heating energy which is already a low amount. This will be difficult for it to achieve. Solar houses will usually use more energy. But even more important, they are also more expensive.

Passive Houses do not require any additional air conditioning to protect against overheating in the summer. Protection from heat in the summer can be provided by simple means partly even without any additional devices such as awnings, Venetian blinds or projections on the external walls, etc.

There is no such thing as “the” Passive House. There are only Passive Houses. Almost any kind of building can be designed as a Passive House if the amount and size of thermal bridges (corners of the external walls, intersections, shoulders, etc.) are kept within limits.

Almost any kind of building can be made as a Passive House. Schools, office buildings, factories, residential buildings, kindergartens, etc. already exist. Usually this is associated with an increase in the value of the building even if this does require some simplifying modifications.

Passive Houses are also simple because contrary to the “multistage therapy”, they provide thermal protection up to the limit stop (close to zero) **in one step**. The necessary measures must be planned and implemented as a total package.

With regard to energy savings, the Passive House concept is **achievement-oriented**. That is the reason for the strict limit to the yearly consumption of heating energy at 15 kWh/m². It is not directed at increasing the profit of the designing offices and construction companies, but rather committed to conserving energy. Passive Houses **also aim at an increase in efficiency** in the interest of the landlord **and** the direct user.

Local trade and commerce also stand to benefit from the construction of Passive Houses and from refurbishment work using Passive House elements. This creates jobs and real net output in the region similar to the development of local renewable energy sources.

Literature

[1] Feist W., “*Gestaltungsgrundlagen Passivhäuser*”,
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[2] Krapmeier H. and Drössler E., “*CEPHEUS Wohnkomfort ohne Heizung*”
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This book is the final official document of the Austrian CEPHEUS project (**C**ost **E**fficient **P**assive **H**ouses as an **Eu**ropean **S**tandard) 1998-2001,
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[3] Final report of the EU Germany CEPHEUS project in German, published by the German Passive House Institute.

Definitions and symbols

	Unit	Definition
U	W/m²*K	Thermal transition coefficient: The heat flow in W which flows through 1m² of a wall surface when the temperature difference between inside and outside equals 1K
λ	W/m*K	Thermal conductivity of a building material: The heat flow in W which flows through the cross-sectional area of 1m² of a test piece with the thickness of 1m when the temperature difference between the two sides equals 1K
n	-	Ventilation value: The air volume flow in m³/h in relation to the inner volume in m³ of a building
Ψ	W/m*K	Thermal bridge coefficient of a linear thermal bridge: The heat flow in W which flows through a thermal bridge with a length of 1m when the temperature difference equals 1K.

Ψ	W/K	Thermal bridge coefficient of a punctiform thermal bridge: The heat flow in W which flows through a thermal bridge when the temperature difference equals 1K.
		Primary energy is the energy in the raw materials of the fuels. With electric current it refers to the coal required to generate electric current.