Passive Buildings – high isolation technology

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1 Introduction

The term “passive building” is related to a wide range of buildings in which the usage of natural elements is optimized, such as:

- internal heat
- external temperatures
- solar heat
- thermal mass
- pressure differences between inside and outside

In order to prevent active heating, cooling and ventilation systems, smart technologies can help to reduce this in the future. At least the number of active components with high electricity consumption can be reduced significantly.
The focus of this module is on building techniques that reduce the space heat demand by high isolation levels to a very low minimum. The technology is initially developed for houses and schools, but can be applied for other functions as well.

2 Technical starting points

2.1 Starting points regarding to building physics and building services

An important definition of a passive building is the energy consumption per year. A building is called a passive building when the (primary) energy consumption for space heating is lower than 15 kWh/(m^2a) ≈ 1,5 m^3 natural gas per m^2. In order to make this low heat demand possible the internal and external heat sources are, mainly due to the high isolation level of the building, enough to heat the building.

Making it possible to certificate a passive building in Germany, other criteria are important as well:

- Maximum heating load (alternative option for heating)	10 W/m^2
- Maximum specific space cooling demand	15 kWh/m^2a
- Total specific primary energy demand	120 kWh/m^2a[1]
- A very low leakage level, n_{50}[2]	≤ 0.6 h^{-1}

[1] At the moment it is not yet clear in what kind of situations these values can be higher in case buildings have a high internal heat load

[2] This is 42 dm^3/s at 50 Pa or 19 dm^3/s at 10 Pa pressure difference for a house of 250 m^3.This is much lower than the standard of maximum 50 dm^3/s at 10 Pa for airtight houses in the Netherlands. This high degree of airtight requires attention for the health of the occupants in case of failure or malfunction of the ventilation system.

2.2 Building physics

The thermal characteristics of the building envelope are:

- R_c > 8.4 - 10 m^2K/W → U < ≈ 0.10 W/m^2K
- U_{glass} < 0.60 W/m^2K
- g_{glass} > 0.50[3]
- $U_{window\ frame}$ < 0.80 W/m^2K
- $\Psi_{cold\ bridge}$ < 0.01 W/mK[4]

In order to obtain the low U-values for the windows triple or vacuum glass is necessary and the window frame should be isolated as well.

Thick isolation layers are normally integrated in a timber frame construction. The option of accumulation of heat/cold and absorption/desorption of moisture in the construction generally improves the quality of the internal comfort. Some passive house concepts have large windows on the south with a floor that can accumulate solar radiation. A rule of thumb is that 40% of the heat loss of the building should be compensated by solar radiation.

Much attention is required to prevent high temperatures, so the percentage and the g-value of the glass, the window orientation and shading devices are all important parameters to control the temperature. Moreover, the ventilation system should have enough cooling capacity, during the day and during the night. Active cooling, if necessary, should be prevented to a minimum.

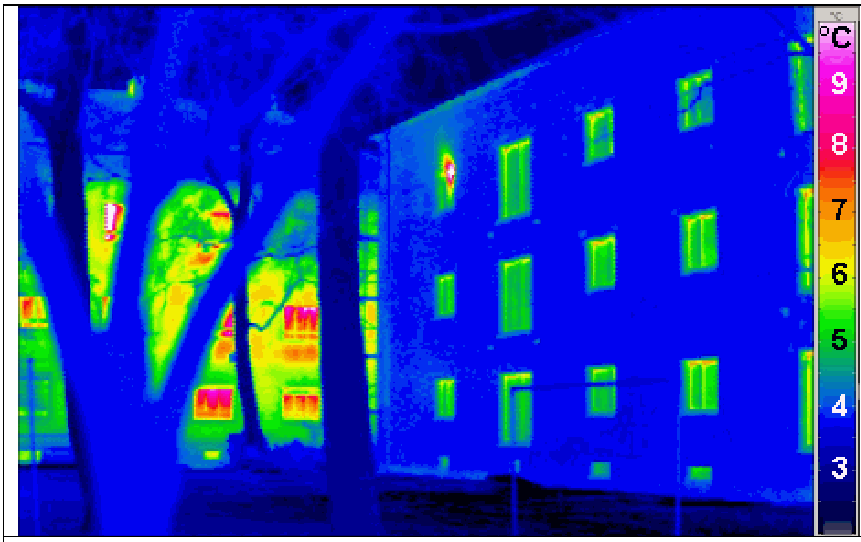

figure 1. the dark colors on this thermogram of a passive house (right) show how little heat escapes compared to a traditional building (left).

[3] The use of solar heat is an important element of the energy balance.

[4] It is very difficult to reach such a low energy loss. Information from handbooks or from manufacturers on internet will give more information about the prevention of cold bridges.

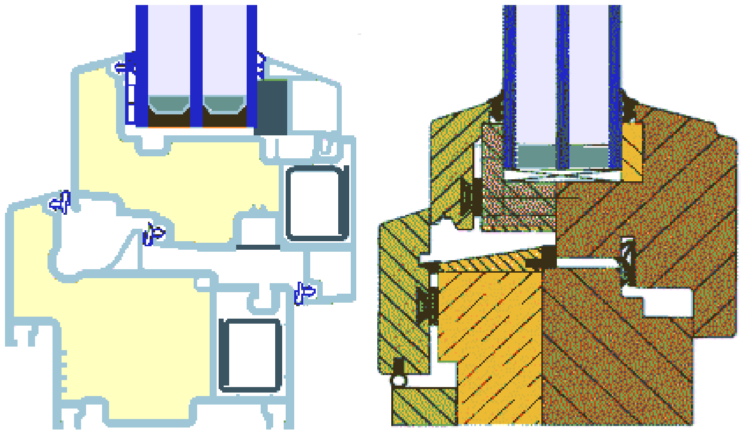

figure 2. example of a well isolated window-frame for passive buildings, the total U-value is below 0.8 W/m^{2}K

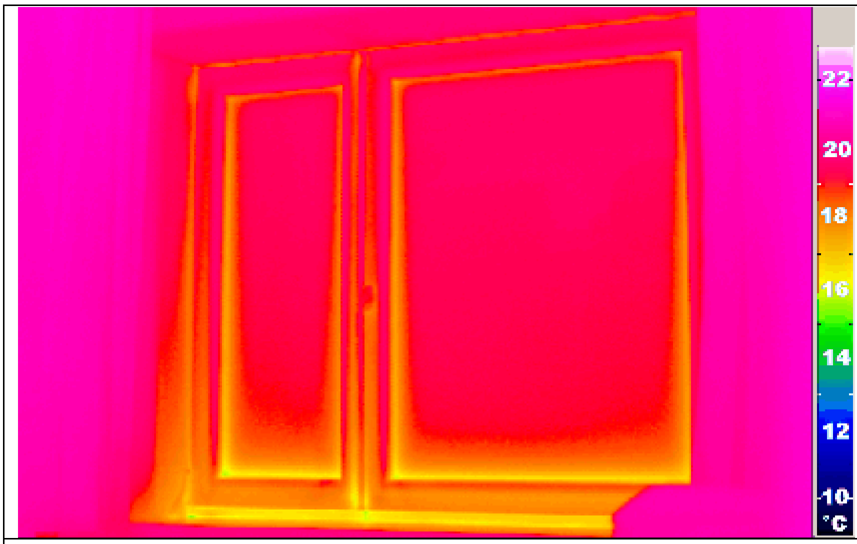

figure 3. example of the thermal effect of a well isolated window-frame for passive buildings with an U-value below 0.8 W/m^{2}K

When a thermographic picture is made of a well isolated window the surface-temperature is 18-19^{o}C at an outside temperature of 2.5^{o}C and a room temperature of 22^{o}C.

Due to the relatively high façade temperatures additional heating near the façade is not necessary.

The required thickness of the isolation layer depends on the λ-value of the isolation material. Some examples are presented in the following table:

Table 1: Different types of isolation material and thickness for a Rc = 10 m^2K/W		
	λ	Thickness layer
cellulose	0.037	37.0 cm
rockwool	0.033 <	33.0 cm
XPS	0.028 <	28.0 cm
high efficiency isolation (PUR)	0.023	23.0 cm
Bluedeck (with aerogel grains)	0.0135	13.5 cm
vacuum panels	0.006	6.0 cm

2.3 Installations

- In order to reduce the energy loss by ventilation to a minimum, in general a heat recovery system for ventilation has to be applied.
- Due to the low space heat demand it is possible to create an all electric heating system with heat pumps. A combination of heat recovery and a heat pump is a development that matches very well with the passive building technology.[5]
- The low space heat demand makes it economic to choose for air heating system.
- Due to the very low heat demand the investment for the heating system can be relatively small.
- Due to the high degree of air tightness and the application of three double glass, the outdoor noise level is very low. Because of this low noise-level, indoor noise of installations is can be noticed easily. Low sound levels below 30 dB(A) are recommended. During the night even lower, below 25 dB(A).

[5] This may be a disadvantage for people who prefer natural air supply.

2.4 Architectural integration

The high insulation level generally leads to massive facades. This can be a part of the architectural expression. However, with little space available or wishing to have another architectural outlook, other and generally more expensive materials could be applied at the outside of the building.

An interesting discussion is where the isolation should be located, at the outside, inside or in the middle of the façade. In Germany, facades with timber constructions are quite common. In the Netherlands, facades with concrete or brick are frequently applied, which might lead to façades with a "massive" expression (next figure).

figure 4. example of the application of 30 cm isolation for the renovation of existing houses; the R_c-value of the façade is 10,0 m^2K/W.

2.5 Economics

Due to technical developments in the passive building technology the extra costs for the high insulation level are becoming lower and in many cases it is possible to have a short or reasonable pay back time.

3. Calculation methods

In order to be able to assess the energy consumption of passive houses a German calculation program is available: PHPP 2007. Passive House Planning Package. The focus of this program is on the reduction of the heat demand, but the necessity of cooling can be evaluated as well, as long as it used for homogenously used residential buildings.

More detailed information, for instance to check overheating problems, can be obtained with building simulation programs. However, at the moment it is not clear if these programs are validated sufficient enough for very low U-values.

4. Examples

Offices	Houses
 Passive office building, Wagner & Co in Cölbe (architect Christian Stamm), 1998. Heat demand 12 kWh/m^2, maximum heat load 10 W/m^2.	 Passive houses in Wiesbaden (architect Rasch & Partner).
	 Passive house in Bretten (architect Oehler), 1998. Heat demand 12.3 kWh/m^2
figure 5. some examples of passive buildings in Germany. Due to well integration of the isolation in the façade-elements the facades do not look “massive”.	

5. Literature

Important internet-links:

1. www.passiefhuis.nl
2. www.passiv.de
3. http://en.wikipedia.org/wiki/Passive_house

Documents:

4. Stichting PassiefHuis Holland. Passiefhuistechnologie. 2008.
5. Software: PHPP.
6. Informationsdienst Holz. Das passiv haus, energie effizientes bouwen. Oktober 2002.
7. EnergieGids. December 2009.
8. Schnieders J. Cepheus – measurement results from more than 100 dwelling units in passive houses. ECEEE 2003 summer study.
9. Feist W. Passivhaus vorprojektierung 2002. Energiebilanzverfahren für die Vorentwurfsplanung von Passivhäusern. May 2002.
10. Feist. W. Certification as "Quality approved passive house". Criteria for non-residential passive house buildings. 11 August 2009.
11. Nieminen J. Life-cycle optimized housing. Nordic Symposium of Building Physics. Copenhagen. 2008.
12. Passivhaus. Details für anwender. Gemeinschaft Dämstoff Industrie. September 2004.