PASSIVE HOUSES: ACHIEVABLE CONCEPTS FOR LOW CO_2 HOUSING

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ABSTRACT

Within the European Union, in particular Germany and Austria have implemented very low energy building concepts. In Germany, the Passiv Haus Institut took the traditional concept of passive solar building as a starting point and developed concepts for very low energy buildings. The principles of passive solar building are combined with a very well insulated and air tight building envelope. More than 4000 passive houses have been built in Germany already and more than 1000 in Austria, and more and more non-residential buildings are built following the passive house technologies.

Also in other European countries initiatives have been taken to promote the passive house concept, though only a few have actually been built yet. Building passive houses in other countries is not a matter of straight forward copying the German concepts. For the building tradition, architecture, building technologies and climate differ from country to country.

In an EU-supported project, nine western and northern European countries are co-operating to promote passive house concepts by using the German/Austrian experience and lessons learned in developing passive houses. The project, called Promotion or European Passive houses (PEP), has started in January 2005. The first results are expected in the early summer, and will be presented on the conference. This paper goes into the questions the project deals with.

1. INTRODUCTION

In the Western world the built environment takes about 40% of all energy consumptions. Therefore, reduction of energy use in buildings is an important issue in the policy of European countries. Within the European Union, in particular Germany and Austria have implemented very low energy building concepts. In Germany, the Passiv Haus Institut of Darmstadt took the traditional concept of passive solar building as a starting point and developed concepts for very low energy buildings. The principles of passive solar building are combined with a very well insulated and air tight building envelope. Thanks to the high thermal quality of the building, and superb air-tightness the house does not need an additional heating system. Heating for very cold days is provided by raising the temperature of the ventilation air (which is much less complicated than conventional air heating). By definition, passive houses do not exceed 15 kWh per square meter floor area for heating per year. This is a saving of 90% compared to the amount of heating energy that is needed for the existing housing stock. The total primary energy consumption (so included DHW and consumers electricity) does not exceed 120 kWh/m^2. Apart from the excellent energy performance, the comfort level of these houses is very high and in Germany and Austria the price of the houses is as an average only 8% higher compared to traditionally built buildings. The goal to reduce the extra investments to less than 4% can be achieved within 10 years. In recent years more than 4000 passive houses have been built in Germany already and more than 1000 in Austria, and more and more non-residential buildings are built following the passive house technologies. For the coming years, again many of thousands of passive houses will be built in Germany and Austria.

Also in other European countries initiatives have been taken to promote the passive house concept, though only a few have actually been built yet. Building passive houses in other countries is not a matter of straight forward copying the German concepts. For the building tradition, architecture and building technologies differ from country to country. In Germany, for instance, outer wall plastering is quite common, whilst in Belgium and in the Netherlands brick cavity walls are mostly applied, and Sweden and Finland have broad experience with wooden buildings. These three various construction methods ask for different constructional solutions. E.g. details of a passive house will even be different in Belgium compared to the Netherlands since constructors are familiar with local construction materials and detailed solutions. And even when this has technically been solved (which is the case in fact in this example), the solutions found in one country must be adapted to the specific building codes and standards of the other countries. In theory a construction method could be transferred from one country to the other, the practice will show however that this is not that straight forward. Architects and contractors must be shown the specific solutions for passive houses for the specific building technology, building tradition and climatic conditions of their countries. The climatic differences make that where the 15 kWh is an excellent result in one country it is only a moderate improvement in another country.

2. PEP PROJECT GOALS

In an EU-supported project, nine western and northern European countries are co-operating to promote passive house concepts by using the German/Austrian experience and lessons learned in developing passive houses. The project, called Promotion or European Passive houses (PEP), has started in January 2005.
As will be discussed below, it is debatable if one general definition of Passive Houses should be used for all the countries, regardless the climate. One of the first things to be done in the PEP project is to define the 'Passive House" for the various countries. Furthermore, copying successful examples of passive houses from one country to the other is difficult, if not impossible. Building traditions and building economy play an important role in the process. The adaptation of passive house technologies by the local building contractors, architects and principals will be a theme of investigation in the project. As the project has just started when this paper was written, we cannot go into the answers here. However, at the conference the first outcomes can be presented and discussed. The questions (passive house definition, economy of passive houses, occupants behaviour, passive house design and passive solar contribution) that have to be answered in the project will be explained in this paper, and where necessary illustrated with specific Dutch experience gained by the Energy Research Centre of the Netherlands ECN.

2.1 Definition of Passive Houses

Although the term Passive house seems to be directly derived form the German word 'Passivhaus' the actual origin is from the United States where the term Passive House was used in the seventies. The German/American definition of a 'Passive house' is : "An (ideal) passive house heats and cools itself in a purely passive way" [Adamson 1987, Feist 1988]. For practical use in colder climates, the definition was adapted to "houses that do not use more than 15 kWh/m^2 heated floor area per year."
The graph below illustrates the differences in energy-use for a Passive house in comparison with a standard Dutch newly built dwelling (row house),

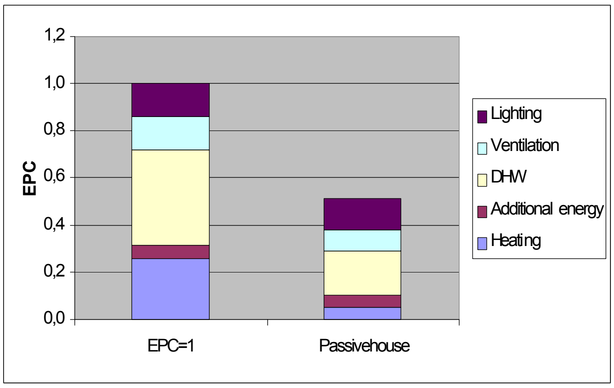

Fig. 1 Passive house versus modern Dutch standard houses

The amount of energy for space heating is approximately one third of the normal use. The use of domestic hot water (DHW) is also lower at the Passive house due to 6 m^2 of solar collector installed. The total energy consumption is about half of the normal energy use. Space heating is about 10 times as low as for an average existing dwelling.

The 15 kWh limitation is chosen from the point of economy at the one hand, and from physical characteristics of pre-heated air at the other hand. The extra costs for insulation and airtight constructions are in Germany mainly compensated by reduction of costs on heating systems. As said before, thanks to the high thermal quality of the building and superb air-tightness the house does not need an additional heating system. Heating for very cold days is provided by raising the temperature of the ventilation air, which is much less complicated and hence much cheaper than conventional air heating systems. On the other hand, the temperature of the air cannot be too high: 50^{o}C is the maximum. From this physical boundary the maximum can be calculated at approximately 15 kWh/m^2. The extra costs for insulation and other measures in turn give a saving for installation costs and therefore an optimum can be found. To illustrate this, the Passive House Institute has developed the following ideogram.

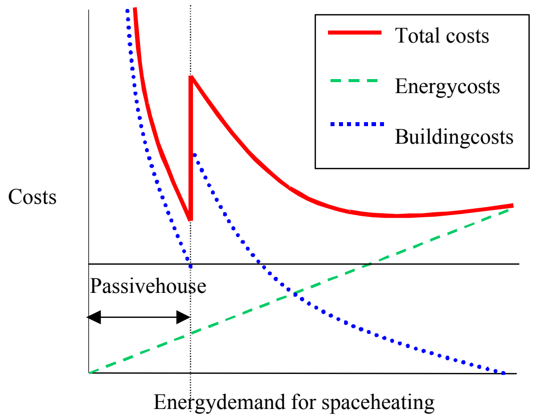

Fig. 2: Ideogram of costs as a function of energy demand for space heating (source: Passivhaus Institut, Darmstadt)

The energy use in an absolute sense does not by definition tell whether the building is good or not. The energy performance should therefore be related to the climate. One can therefore question whether passive houses should always be defined according to the maximum energy use for heating of 15 kWh per square meter per year, or whether various criteria for various countries are more obvious. Should energy for cooling be taken into account as well? And energy for domestic hot water? Those are some of the first questions to be discussed in the PEP-project.

2.2 Economy of Passive Houses

As said above, the costs of extra insulation, air tightness and heat recovery should be compensated by the saved costs of a heating installation. However, the costs of building in Germany (and the quality) are much higher than for instance in the Netherlands (for reasons not to be discussed here). Furthermore, small row houses have much lower energy consumption than large detached houses. The savings compared to the investments in the row house can differ considerable from those in the detached house. What is the optimum? The German/Austrian market for building products offers a wide range of products that fulfil the Passive House criteria, for instance very well insulating windows and doors, high efficiency heat recovery systems on ventilation air, insulation materials. On the market for building products in other countries only a few of these products are available. Is in those countries a market for and production of passive house building components feasible in the near future, or should those components be imported from Germany, with large influence on the costs (due to transport)?

2.3 Behaviour of the Occupants

Although calculations may predict an energy consumption of 15 kWh per square meter per year, the actual consumption may be much more or less. The behaviour of the occupant has a very big influence on the real consumption. This is not only true for groups of occupants in various climatic zones (in countries with a moderate climate for instance it is usual to sleep with windows open, also in the winter (even when the house is provided with a mechanical ventilation system). In cold climates this is much less usual) but also within a complex of houses. Should the occupants be "educated" to live in a potentially low energy house? Should the technology take over the decisions? Should the heating and ventilation system be designed as "fool proof?"

2.4 Contribution of Passive Solar Energy

_In well-insulated, low energy houses the contribution of passive solar energy is limited, as the house is mainly heated by the internal heat gains. There is even a chance of overheating, also in moderate climates. Where and when has solar oriented building really sense in passive house designs? Which principles of solar building should prevail? To what extend should solar cooling be taken into account in moderate climates?

Prior the PEP project, the Energy Research Centre of the Netherlands ECN made a study called ‘The Optimal Passive House’ which deals with passive solar energy and energy conscious design. The report describes how to use passive solar energy at Passive Solar Homes (PSH) in the most optimal way for Dutch climatic conditions.

As can be seen in the graph below the amount of solar energy that contributes to heating energy is relatively small if compared to the contribution of internal heating. However, in winter still a large part is used. The implication of this is that the orientation of the dwelling and the window size do not substantially influence the energy-use.

A well-considered choice of energy conscious design parameters should be made. Modelling of the passive solar home- design showed that it is possible to increase the amount of solar gains while securing a high indoor comfort at an acceptable level of overheating.

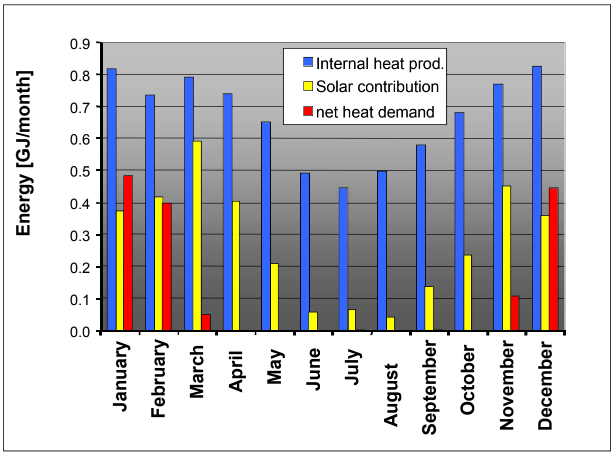

Fig.3: Internal heat production, solar contribution and net heat demand through the year for the ECN passive solar home

By using the building simulation computer program TRNSYS the significance of different design parameters on heating demand and comfort (overheating hours) has been modelled, using the Dutch test reference year. The results of varying the different parameters are given in the table below:

TABLE 1: INFLUENCE OF DESIGN PARAMETERS ON HEATING ENERGY

Influence of parameter on heating energy	**[GJ/house/a**
air tightness, infiltration	1.3 - 42
heat recovery	1.3 - 22
insulation closed parts	1.3 - 6.5
conservatory	1.2 - 5.3
glass type (U and G-value)	1.0 - 3
building shape	1.3 - 2.5
overhang	1.3 - 1.8
orientation	1.3 -1.8
glass percentage	1.3 - 1.4
building mass	1.2 - 1.4
sun shading	1.2 - 1.3

In order of impact on heating demand the most important design aspects are: air tightness, heat recovery from ventilation air, insulation of building envelope, building type and building shape. Less essential, but still of great importance in respect to prevention of overheating, turned out to be: external sun shading, overhang, orientation, glass percentage and building mass. The table below illustrates the amount of ‘overheating’ hours (temperatures higher then 25 ^{o}C).

TABLE 2: INFLUENCE OF DESIGN PARAMETERS ON OVERHEATING

Influence of parameter on overheating	**hours**
sun shading	20 -2000
overhang	400 - 1200
conservatory	150 - 530
glass percentage	25 -75
orientation	35 - 45
building mass	10 - 40

Not much effective is the use of interior instead of exterior shading. Using conservatories is also not advised due to the risk of being wrongly used by adding the space to the living zone instead of using it as a buffer zone.

3. FURTHER ACTIVITIES

The question rises, if the above findings are also true in other climatic zones than the Dutch. It is true, that cooling, and hence passive cooling, has not the first priority in the Dutch situation. But this is different in hotter climates, as in southern Europe. It can be expected, that each country has its own Passive House definition and characteristics, depending on climatic characteristics and building traditions. The PEP project will find out the similarities and differences between the passive houses in the participating countries, and show how the countries can learn from each other. The first findings will be presented and discussed on the conference.

4. REFERENCES

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