White Paper

Leonardo ENERGY

Ultra Low Energy Houses

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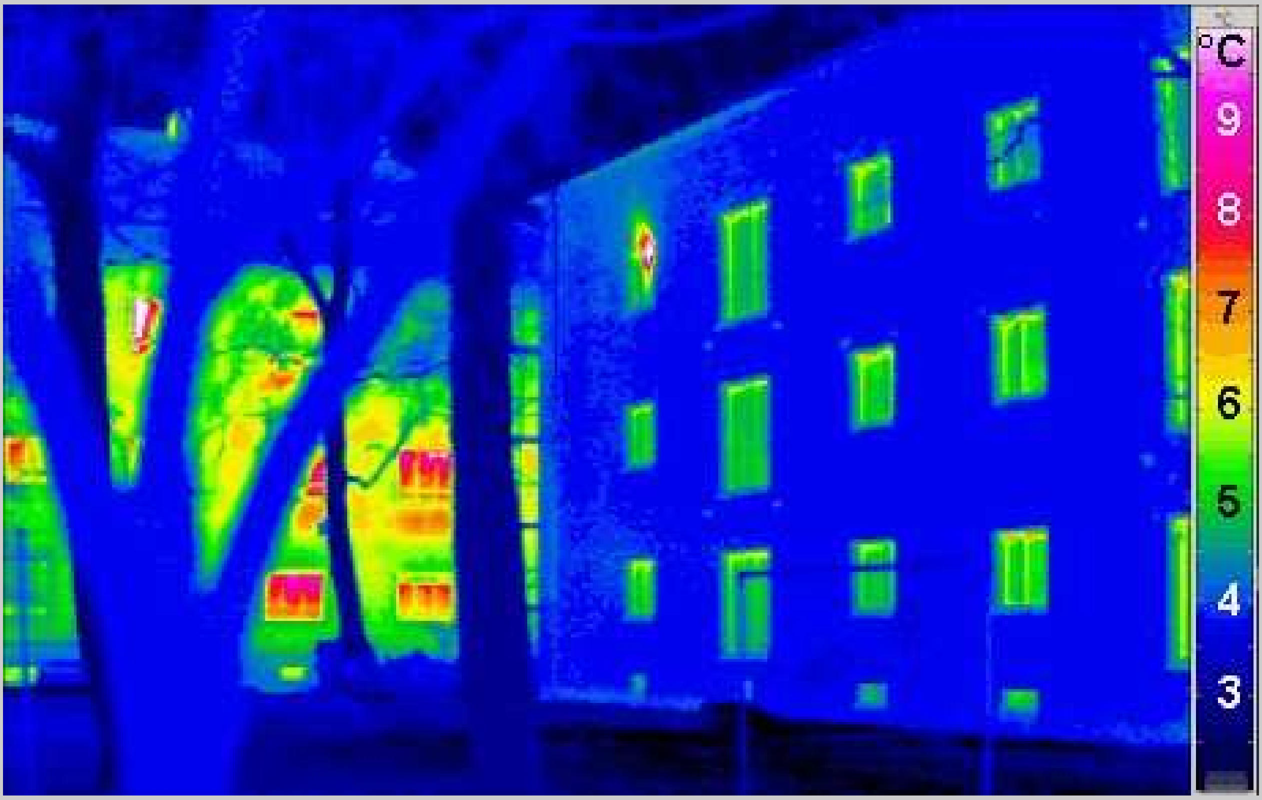

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Energy Efficiency

1. Introduction

The 160 million buildings in the European Union account for over 40% of Europe's primary energy consumption. Hence energy use in buildings represents a major contributor to fossil fuel use and carbon dioxide emission.
According to the Kyoto protocol, Europe is committed to reducing emissions, but the energy consumption share of buildings is increasing. Following uncertainties in energy supply and concern over the risk of global warming, energy efficiency in the building sector is gaining importance. The European Commission Action Plan for Energy Efficiency identifies energy efficiency in the building sector as top priority (Commission of the European Communities, 2006). One example of energy efficient buildings is the Ultra Low Energy House (ULEH). Ultra Low Energy Houses reduce the dependency on fossil fuel and the emission of carbon dioxide significantly.

This paper provides an overview of the issues regarding Ultra Low Energy Houses in Europe. It offers a definition for Ultra Low Energy Houses in chapter 2 and discusses the technologies that can be used in Ultra Low Energy Houses in chapter 3. The regulatory framework for energy efficiency in the European building sector is discussed in chapter 4. The path towards Ultra Low Energy Houses, the main trends, development and barriers and a discussion on how ULEH can become reality is given in chapter 5.

2. The Ultra Low Energy House

2.1 What is it?

The "Ultra Low Energy House" is better known as a "Passive house". In this paper, the term "Ultra Low Energy Houses" or ULEH will be used.

The concept of ULEH has been developed in Germany in 1988 by professors Bo Adamson from Sweden and Wolfgang Feist from Germany.

Fig 1: A Passive House in Italy

A passive house should comply to the following requirements:

- A space heating energy requirement of ≤ 15 kWh/m^2 per year
- A specific heat load of ≤ 10 W/m^2
- Air tightness of n_{50} ≤ 0,6/hour.
- Total primary energy requirement is ≤ 120 kWh/m^2

For comparison, the average energy use of dwellings in the Netherlands in 2006 is given in table 1.

Item	Amount (primary energy)	Primary energy content	Share of total primary energy	Energy per m^2	Energy ULEH requirements per m^2 (max)
Electricity	8365 kWh	30 GJ	39%	67 kWh/m^2	-
Gas for room heating	1155 m^3	36,5 GJ	47%	81.2 kWh/m^2	15 kWh/m^2
Gas for hot water	345 m^3	11 GJ	14%	24,3 kWh/m^2	-
Total	21552 kWh	77,5 GJ	100%	172.5 kWh/m^2	120 kWh/m^2 (primary energy)

Table 1: The average household primary energy consumption in 2006 for the Netherlands (reference: EnergieNed 2007 and KEMA internal information)

In the Netherlands, current requirements for energy use for room heating in new dwellings is approximately 60 kWh/m^2. No requirements are set regarding the use of electricity, this is highly dependent upon the behaviour of the residents.

2.2 What is the impact of Ultra Low Energy Houses on CO_2 emissions?

Due to the reduced energy consumption of Ultra Low Energy Houses, the CO_2 production and fossil fuel consumption are drastically reduced with Passive Houses compared to traditional dwellings. The fossil fuel use in passive houses can be close to zero, leaving the electricity use within the household as the main producer of CO-$_2$ (in power plants). Although investment costs for a passive house are often slightly larger compared to traditional dwellings, energy costs are less and the market value (or purchase costs) of the house is higher. The potential for energy saving is shown in figure 2. This figure shows the primary energy use in kWh/m^2. More is explained in chapter 3.

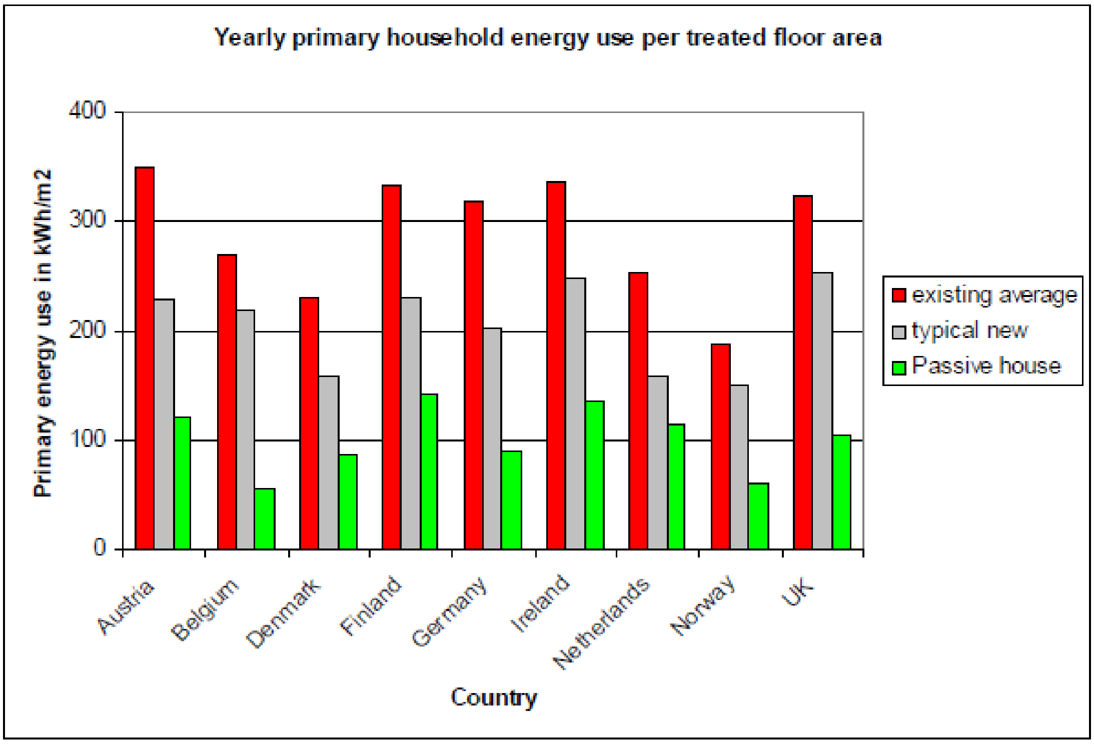

Figure 2: The potential for energy saving of passive houses per country (Source: PEP 2006b)

2.3 How is the market for passive houses developing in Europe?

The amount of new passive houses and dwellings refurbished to passive houses (PH) as expected by the "Promotion of European Passive Houses" workgroup (PEP) differs per country as shown in figure 3. The market for new and refurbished dwellings (both PH and non-PH) is especially large in Germany. In Austria, several of the states are motivating the construction of passive houses (Energiegids 2008). In the Netherlands, a number of passive houses have been constructed and plans exist for large scale construction (i.e. in Almere city).

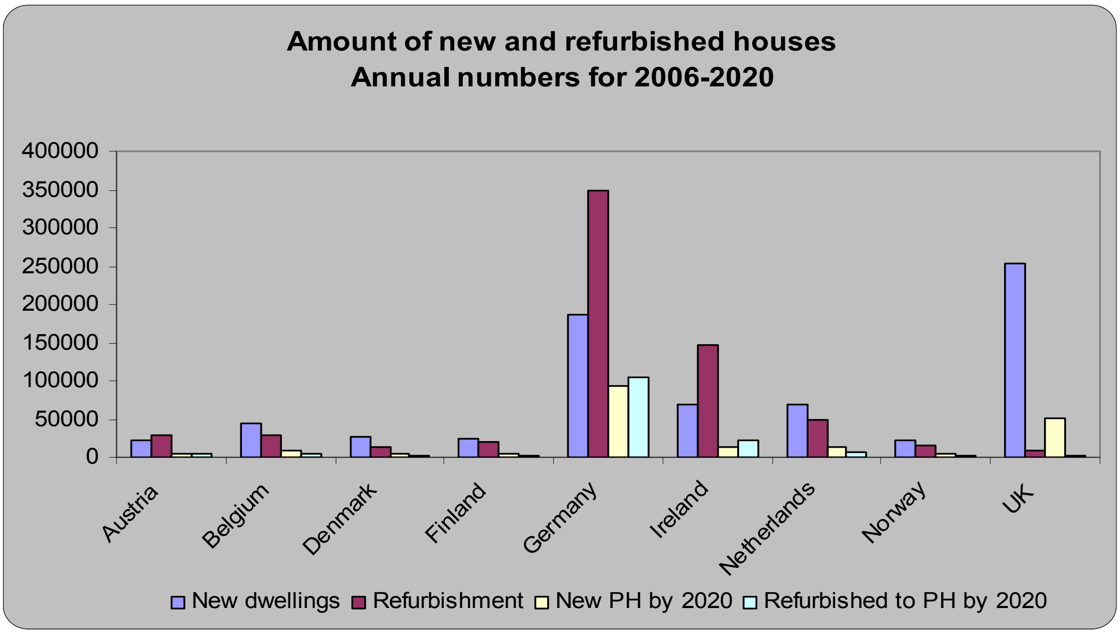

Figure 3 New and refurbished houses in European countries annually for 2006-2020, source of data: PEP 2006b

3. How to reduce the energy consumption in dwellings?

3.1 What are the available technologies for Passive Houses?

Insulation and air tightness

In a passive house, the heat bridges and losses are reduced to a minimum. This is achieved by using an outer building skin with an overall heat transfer of ≤ 0,1 W/m^{2}K. To achieve the reduced heat transfer, the building shell insulation is approximately 30 cm thick (single insulation layer, commonly consisting of expanded polystyrene). The walls, roofs and floors are highly insulated. The windows in passive houses are triple layers.

To reduce the loss of warm air and the inflow of cold air, the building should be constructed as air tight as possible. The requirements are set to n_{50} ≤ 0,6/hour. This implies that when the building is closed, and the building is pressurized to 50 Pa. above atmospheric pressure, the building is not allowed to leak more than 0,6 times the volume of the building per hour.

Building orientation

Orientation of the building and the position of the windows are important factors in achieving the required energy efficiency. A North-South alignment increases solar heat gain. Large windows on the south-side of the building increase solar energy gains. Measures should be taken to avoid overheating during the summer.

Ventilation with heat recovery and solar collectors

Most of the passive houses are equipped with a ventilation system with heat recovery. The ventilation system is required to provide the building with enough fresh air. The heat recovery system is able to warm up the incoming air using waste heat of outgoing air. The heat recovery system consists of:

- A subsoil heat exchanger to heat or cool the ambient air
- A heat recuperator to heat the ingoing air with the outgoing air
- A post heater, powered by solar collectors

A simplified scheme is shown in figure 4.

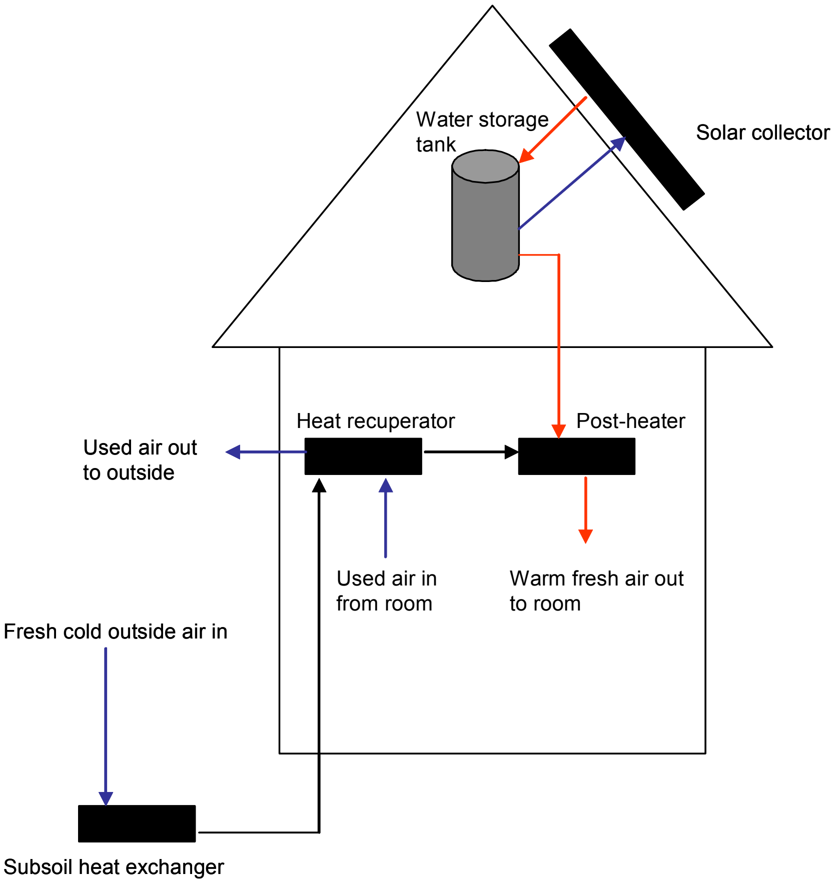

Figure 4: A schematic example of ventilation with heat recovery in a passive house

A heat recuperation system using soil heating to heat the ingoing air, in combination with a post heater, that is powered by solar collectors (through a water storage tank). For backup purposes during cold periods, a wood pellet stove can be applied. A simpler solution is to apply local electrical heating by the use of small heaters.

No radiators are required, which reduces investment costs for heating systems. This also results in a uniform surface temperature and hence, more comfort for residents.

The use and efficiencies of these systems highly depend upon the season and atmospheric conditions. The solar collector has a relatively high heat flux, for a limited period of time (highest between 10.00 and 14.00 hr.). The heat flux for the passive solar heat flux (via windows) is less, but also highest in the noon period.
The heat flux of the ground heat exchanger is more stable during day and night. The heat flux extracted however, is lower compared to the solar collector. Combining these items however provides the possibility to provide passive houses as constructed in Germany, Scandinavia and in limited numbers in Belgium and the Netherlands with a comfortable temperature during the seasons.

Internal heat sources

An important source of energy within the passive houses are the internal heat sources. These consist of the residents and all electrical equipment in the building. Adults have a heat flux of about 90 W. Apparatus in the building also contribute to heating. Cooking stoves, a TV and other apparatus contribute to the heat supply

Efficient electrical apparatus

To reduce the use of electrical energy, residents should be motivated to purchase energy efficient electrical apparatus, i.e. energy saving washing machines, energy saving lighting, etc. The energy performance of most electrical household apparatus is indicated with a European Union energy label.

Software calculation models

Software models to predict the energy consumption of passive houses, used during the design phase are available. One example is Passive House Planning Package (PHPP). This software model incorporates energy calculations, window design specifications, the design of the indoor ventilation system, forecasting for summer comfort, sizing of domestic hot water system, climate data sheets per region. etc to predict energy consumption.

Table 3 provides an overview of the measures taken in a passive house.

Measure	Value in Passive House	Application in Passive
Insulation		
Walls	U ≤ 0,15 W/(m²K)	Basic measure
Roof	U ≤ 0,15 W/(m²K)	Basic measure
Floor	U ≤ 0,15 W/(m²K)	Basic measure
Window casing and doors	U ≤ 0,8 W/(m²K)	Basic measure
Window glazing	U ≤ 0,8 W/(m²K)	Basic measure
Thermal bridges	Linear heat coefficient Ψ ≤ 0,01 W/(m	Basic measure
Air tightness	n_{50} = 0,6 h^{-1}	Basic measure
Heat recovery		
Ventilation heat recovery air to air	HR η ≥ 75%	Basic measure
Ventilation air sub-soil heat ex-		Often applied but optional
Ventilation ducts insulated		Basic measure
DHW heat recovery		Optional
Air quality through ventilation rate		Basic measure
Passive solar gain		
Window glazing	Solar energy transmittance g ≥ 50%	Basic measure
DHW solar heater		Basic measure
Solar orientation		Basic measure
Electrical efficiency		
Energy efficient apparatus		Often applied but optional
Hot fill washing machines		Often applied but optional
Energy efficient lighting		Often applied but optional
On-site renewables		
Small wind turbine		Optional
Photo Voltaics		Optional
Solar thermal energy		Often applied but optional
Biomass system		Optional

Table 3: The measures applied in PH (from PEP 2006)

3.2 An example of passive houses

This section provides a short analysis of a successful project of passive houses.

Figure 5: The passive houses in Hannover (Source: Passiv Haus Institut 2003)

In 1998 in Hannover, Germany, 32 terraced houses (see figures 5 and 6) were built according to the passive house philosophy. The houses were built in three sizes, 79, 97 and 120 m^2 floor area. The main windows were directed south to gain from solar irradiation. For summer periods, a automated shading system reduces solar irradiation.

The houses are equipped with very good insulation, thermal-bridge free construction, airtight building element junctions and triple-glazed windows. The houses are not equipped with radiators, except for a small one in the bathroom. The limited amount of required heat is supplied by a district heat supply system to the houses and by the use of heat exchangers. Possible concerns about the air quality proved unnecessary because the indoor air quality was given the best notes by the residents in a socio-economic questionnaire. The air filters have to be changed regularly.

Figure 6: The heat quantity meter and insulation of the piping (Source: Passiv Haus Institut 2003)

Walls and roofs are made of light weight materials with U-values of U_{wall}= 0,13 W/(m^{2}K) and U_{roof} = 0,10 W/(m^{2}K). The roofs are covered with moss to increase insulation. Modular building allowed cost reductions, lowering the costs to the price level of conventional dwellings. Air tightness tests were performed and values of n_{50} = 0,3 were reached.

Throughout the years the houses were able to maintain an average indoor temperature of 21,1 ^{o}C during the winters. In 2000, with an extremely hot summer, the number of hours during which the average indoor temperature rose above 25 ^{o}C was less than 2,5% based on the total annual hours. Determining the energy performance of the houses was done by the use of meters and thermo-graphical analysis.
To reduce the amount of electricity consumption, the developer offered a financial benefit when the occupants would buy energy efficient apparatus. On average, this resulted in a cost reduction of 583 Euro annually (PEP 2006b, IEA 2003).

3.3 What are some of the local technical variations, barriers and incentives?

The applied materials and construction methods for new houses and new passive houses can differ per region and country (as shown in fig 7). Building tradition, availability of components, regulations and local constraints are deciding factors for the construction of passive houses.

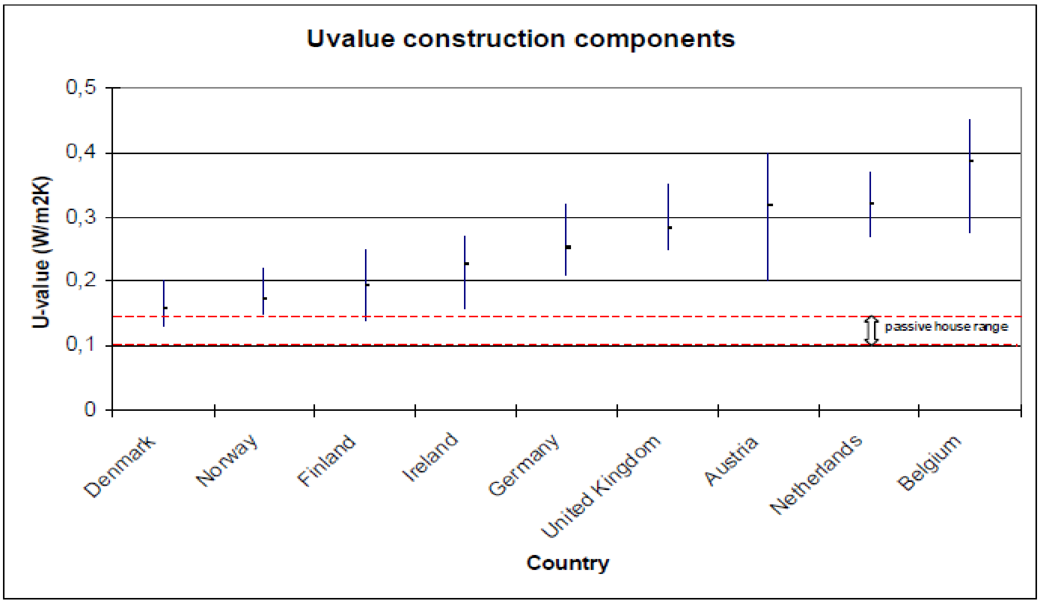

Figure 7: Local variations in average U-values for construction components of new buildings per country (Source: PEP 2006)

Barriers and incentives differ per country:

- Increasing the thickness of insulation is not feasible with the existing components in countries with a brick cavity wall tradition (i.e. the Netherlands, Belgium and the north of Germany),.
- The availability of affordable and suitable construction materials for passive houses differs per country.
- The construction experience for passive houses and knowledge of architect, developers and builders differs per country
- Passive houses have to comply to local building directives
- Local government requirements play a role in the construction of passive houses
- Awareness of the technicalities involved with passive houses at the architects, builders and project developers differs largely per country

3.4 What are the differences in costs?

The workgroup ‘Promotion of European Passive houses’ performed research into the purchase and operational costs of passive houses. The following outcomes were observed:

- Purchase costs: 0 - 5% higher compared to traditional design dwelling
- Operational costs: 10-30% lower compared to a traditional design dwelling
- Market value: 10-30% higher compared to a traditional design dwelling

The Passivhaus Institut in Darmstadt, Germany made the following figure, concerning the costs (see figure 8)

In figure 8, the green line represents the energy costs (in a lifetime), the blue line represents the extra construction costs and the red line represents the extra total costs. The costs for a heating system can be prevented, thus reducing the costs, investment costs for materials are mostly slightly higher for a Passive House. Professional management of the construction project can reduce costs.

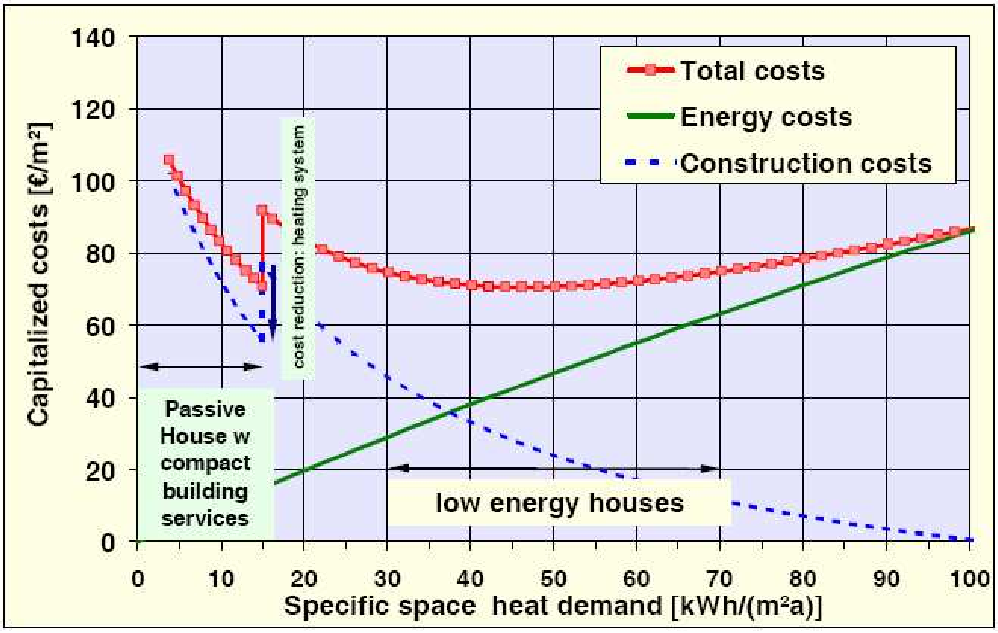

Figure 8: The capitalized costs to the specific space demand for PH and low energy houses compared to normal dwellings (from: PEP 2007)

A small simplified financial calculation to provide some insight is shown in table 4

Table 4 shows that the higher investment costs of passive houses do not have to result in

Cost item	Price (Euro)
Extra investment costs	+ 15.000
Annual costs for extra investments (with tax deduction and 4% interest), Netherlands situation	+ 400 (approximately)
Savings of gas (at 200 m^3 of natural gas for a PH and 1000 m^3 for a normal dwelling at the costs of 0,62 Euro/m^3)	- 496
Extra costs for electricity (300 kWh extra for the ventilation system)	+ 63
Total	400- 496 + 63 = **-33**
Extra benefit	Higher market value of the passive house

higher costs for the inhabitants. When energy prices will rise (which is expected), the benefits for the inhabitants are likely to increase further.

4. What does legislation require?

At present, there is little regulation for Member States at EU level in the field of low energy buildings by the Member States. Most Member States tend to develop policy and legislation at a national level. Many countries have now introduced target values for reducing energy consumption in buildings. Overall, these are aimed at reducing the 1990 energy consumption level by 15-30% in 2020. To achieve this target, international co-operation in which research activities and knowledge can be shared, is seen as an essential activity (IEA, 2008). Hence, the EU legislation in this field are basically programs to facilitate R&D, stimulate awareness and exchange information. To increase energy efficiency in the building sector, the European Union has adopted the Energy Performance of Buildings Directive (EPBD), which came into force in 2006.

The Energy Performance of Buildings Directive aims to promote the improvement of the energy performance of buildings. Based on a common methodology to measure the energy performance of buildings, EU governments have set minimum performance standards on the energy performance of new buildings and existing buildings that are subject to major renovation. The directive requires systems for the energy certification of new and existing buildings and, for public buildings, prominent display of this certification and other relevant information. Furthermore, it prescribes regular inspection of boilers and central air-conditioning systems. The directive concerns the residential sector and tertiary sector (offices, public buildings etc). It does not lay down measures on moveable equipment, like household appliances.

The Energy Performance of Buildings Directive is considered a very important legislative component of energy efficiency activities of the European Union designed to meet Kyoto commitment and respond to issues raised in the Green Paper on energy supply security. According to the European Climate Change Programme, the EPBD could deliver a reduction of up to 45 million tonnes of carbon dioxide by 2010 (European Commission, 2006).

It is the individual responsibility of each EU Member State to choose measures that satisfy the EPBD requirements and correspond best to its particular situation (subsidiary principle). As legal and building control systems, infrastructure and practices differ in the various EU countries, the directive will be implemented in different ways in the different countries. As a result, the national directives for sustainable buildings differ. In general, there is no specific legislation for Ultra Low Energy Houses . In accordance with the

EPBD directive, countries have national building codes prescribing minimum energy performance for new buildings. Most EU legislation in this field came into force very recently. Hence, most national measures are still to be developed and communicated. Therefore, there is no overview of regulations at the national level available at this stage.

5. The path towards Ultra Low Energy Houses

5.1 Trends and developments

Several developments in Europe will stimulate energy efficiency in buildings. The rising energy prices have led to an increasing demand for energy efficient homes and energy-efficient appliances. A growing awareness of climate problems results in high interest for houses which reduce carbon dioxide emissions, such as Ultra Low Energy Houses. Materials for energy efficiency and generation will become more common and less expensive.

The European Union has set directives for an EU energy label for white goods, light bulbs and cars. This provides customers with the ability to determine and compare the energy consumption of apparatus. In some European countries, a similar system is in use for the energy performance of dwellings.

In the future, smart grids will provide a different, more flexible energy infrastructure and enable distributed generation. This allows houses to interact with the grid, buy renewable energy from the grid and sell any surplus energy that is generated by the house.

The European Union can do little about the energy supply to Europe, but it *has* influence on the energy demand of the European citizens. Regulation regarding the energy consumption of buildings are likely to become stricter. When the supply of energy is more problematic, there will be more focus on energy demand. It is therefore likely that the requirements for low energy houses will be stricter in course of time.

5.2 What are the barriers?

In contrast to the trends towards energy efficient houses, there are several barriers that prevent building Ultra Low Energy Houses in Europe on a large scale.
Buildings can have lifetimes of 100 years or more. Most houses that are needed in the future are already built, which makes it more difficult to implement high-efficient

technologies. Therefore, energy efficiency should be included in renovations as well, though these measures will not be able to achieve the energy efficiency levels of new houses.

A very important barrier is that property investors in office and non-residential buildings have little motivation to invest in high energy efficiency buildings. They do not occupy the buildings as these buildings are normally rented out. The rent does not reflect the energy costs associated with the buildings. Renters are normally interested in the lowest rental costs, without taking future energy costs into account. Even when renters are interested, ways need to be found to overcome the split incentive problem.

Third, very few designers or builders have the expertise to build Ultra Low Energy Houses. Expertise may differ from country to country or even from region to region within a country. Furthermore, the Life Cycle Costing is lacking. Low construction cost is still the prime factor in selecting the winning project. Lack of information on ultra low energy technologies prevent the construction of low cost and energy efficient buildings. The building professional industry and architects need to be convinced that there is a market for green builders, whereas investors and residents need to be convinced that it is worth the investment.

5.3 How to make it happen?

To increase the amount of Ultra Low Energy Houses on large scale, technical, economical and political issues have to be solved.

To start changes, investments for production of high-efficient technologies and equipment is needed. Research should be focused on energy efficiency rather than on generation using fossil or nuclear power, which is the core focus at present. More expertise is required in the field of energy efficiency for the built environment.

To attract large investments, there is a need for long term markets and mass markets. Political decisions can create these markets. Progressive targets for energy efficiency in dwellings must be defined at European and national level. Subsidies can be introduced where renewable energy can not
compete with fossil energy sources.

Public and social awareness is vital to create a vivid demand to energy efficient dwellings and energy efficient behaviour. Ultra Low Energy Houses need local involvement, local investment and local decision-making, more than with conventional dwellings.

6. References

Energiegids (2008), Nr. 5. SDU Uitgevers

EnergieNed (2007) *Huishoudelijk Onderzoek Markt en Energie 2006 onderzoek, Arnhem The Netherlands.*

European Commission (2006) *The European Climate Change Programme. EU against Climate Change*. European Commission, January 2006

IEA (2003) *Demonstration houses in Hannover-Kronsberg, Germany*, IEA-SCH Task 28/ ECBCS Annex 38: Sustainable Solar Housing

Passiv Haus Institut et. al. (2003) *Climate neutral Passive Houses estate in Hannover-Kronsberg: Construction and measurement results*, supported by the European Commission

Promotion of European Passive Houses (PEP) (2006) *Passive house solutions*, Working paper supported by the European Commission

PEP (2006b). *Energy saving potential*, Working paper supported by the European Commision

PEP (2007). *Passiefhuis handleiding voor projectontwikkelaars*, Working paper for the European Commision

7. Further reading

Ample information about passive houses can be found, though scattered, on the internet. Some useful internet websites are:

- www.europeanpassivehouses.org
- www.passiv.de
- www.passivhaustagung.de