



PROMOTION OF EUROPEAN PASSIVE HOUSES

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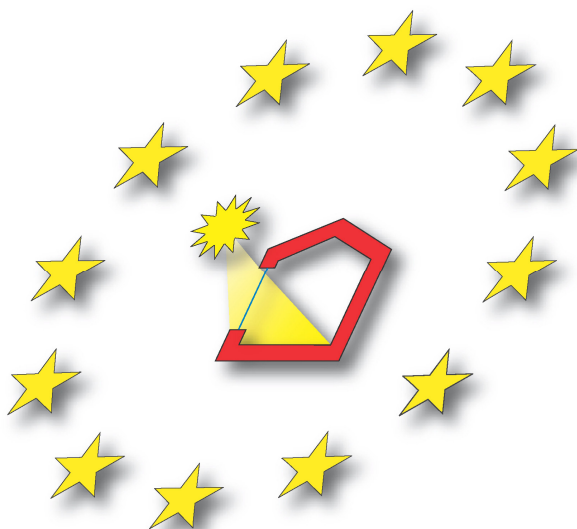
Energy Saving Potential



May 2006

Intelligent Energy  Europe

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PEP

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UK: SAP 2005

Acronyms and Abbreviations

PH	Passive house
CO ₂	Carbon dioxide

Executive summary

In this working paper an overview is given of the calculated energy savings by Passive House construction in all partner countries.

As part of PEP Work Package 1, a method for determining the energy saving potential on national level has been developed (appendix). In this report the calculation method is described and the energy saving potential on both national and European level are given. Based on these potential energy savings, avoided CO₂ emissions are calculated as well. These figures are consequently compared to the 'business as usual'.

Through implementation of the Passive House concept a considerable energy saving compared to the business as usual can be obtained, which goes together with significant CO₂ reductions. It must be noted that these results are very much dependent on energy sources used, and applied conversion factors for primary energy uses and CO₂ emissions. Also, the total CO₂ reduction for each country is very much dependent on the projected number of Passive Houses to be built in each country.

Consolidating the results of all countries, an average reduction of 50% to 65% can be obtained per Passive House compared to the business as usual.

In the new-build housing market, Passive Houses are projected to realize an average annual reduction of 0,46% with respect to business as usual within two years of Passive House developments, thereby satisfying the Kyoto goal for that sector. Moreover an annual reduction of 14% in new-build housing is projected by 2020, far exceeding the Kyoto target of 0,4% annually.

1 Introduction

In this age of increased energy prices and emission excesses, efficient energy use is becoming more and more important. This is no longer solely an environmental consideration, but increasingly also a financial one. Some 40% of our annual energy consumption is used in buildings. The Passive House concept primarily focuses on residential buildings, though these principles are applicable in other building types as well. As the numbers show, energy-wise, there is much to be gained in buildings. For this reason, more and more building professionals have recognized the Passive House approach as the sensible way forward.

As part of PEP (Promotion of European Passive Houses), a method for determining the energy saving potential on national level has been developed. In this report the calculation method will be described and energy saving potential on both national and European level are given. These figures will be compared to the 'business as usual' and related to Kyoto targets.

2 Calculation method

In this case study the total energy savings and CO₂ reductions of Passive Houses for the participating countries will be estimated.

The energy saving and avoided emissions of a Passive House will be compared to:

- Business as usual (new-build and refurbishment).
- Kyoto targets.

Business as usual for new construction

Regarding new construction, the energy use of a Passive House will be compared to the business as usual, which means a Passive House will be constructed instead of a typical new-build dwelling.

Business as usual for refurbishment

Regarding refurbishment, a refurbished passive House is assumed have the same energy performance as a new Passive House, which implies an energy demand of 15 kWh/m² treated floor area. The energy use of a Passive House will be compared to an average existing dwelling, which means a Passive House dwelling will replace an existing dwelling or an existing dwelling will be refurbished to Passive House standards. In both cases energy performance data will be the same.

2.1 *Collected data*

Per participating country data has been collected for:

- Building stock;
- Scenarios (expected numbers of new passive houses over the next 10 years);
- Energy uses;

2.1.1 Building stock

First, data of the building stock of each country is collected. This means:

- Average TFA (treated floor area) per dwelling;
- Number of existing dwellings in the country;
- Yearly number of new to build dwellings;
- Yearly number of refurbished dwellings.

2.1.2 Scenarios

Data of yearly expected numbers of, new as well as refurbished passive houses, are collected. These estimated numbers are expressed in three scenarios:

- Scenario low (most pessimistic)
- Scenario medium (neutral)
- Scenario high (most optimistic)

2.1.3 Energy uses

Regarding the energy uses with respect to business as usual and refurbishments, data is collected of a:

- Passive House in that country
- New to build dwelling
- Existing average dwelling

Data of energy demand and use of each category are collected and split into energy use for:

- Space heating
- Space cooling (if applicable)
- Domestic hot water

- Household appliances
- Cooking
- Other (e.g. pumps & fans)

For each energy use the applied energy sources are collected as well.

2.1.4 Energy conversion factors

In order to determine national primary energy uses and CO₂ emission, applied energy sources, conversion factors from metered energy uses into primary energy and CO₂ emission have been collected.

2.2 Calculation of energy saving potential

1. Energy uses per applied energy source

The energy saving potential per country is calculated by comparing energy uses per applied energy source for new to build dwellings and refurbishment dwellings with those of the Passive House.

$$\Delta Q_i = \sum(Q_{\text{NEW}} - Q_{\text{PH}})_i$$

$$\Delta Q_i = \sum(Q_{\text{REFURBISHED}} - Q_{\text{PH}})_i$$

2. Primary energy uses and CO₂ emissions

The energy uses per applied energy source are multiplied by the conversion factors to primary energy use, expressed in kWh and by conversion factors to CO₂ emissions, expressed in kilograms. Reliable primary energy and CO₂ emission factors for all countries combined were not available; therefore national factors have been used in this report.

Primary energy reduction: $\sum(\Delta Q_i * f_{\text{primary energy use},i})_i$

CO₂ reduction: $\sum(\Delta Q_i * f_{\text{conversion CO}_2,i})_i$

3. Energy savings per Passive House

The energy saving is calculated by subtracting energy use of a Passive House from the energy use of a typical new dwelling and from the energy use of an average existing dwelling.

4. Energy saving potential

The energy saving potential is calculated by multiplying energy savings by the expected

numbers of Passive Houses and Passive House refurbishments. Energy saving potentials and avoided emissions are expressed in primary energy uses and CO₂ emissions.

5. Energy saving potential compared to total CO₂ emissions

This energy saving potential is compared to total household energy uses and CO₂ emissions per country and in total for all participating countries.

3 Results

3.1 Energy sources

Before discussing the gathered information for energy uses, the applied energy sources are listed below. In Table 1 energy sources applied per country in the examples reviewed are given for space heating only.

Table 1: Considered energy sources for space heating in the examples reviewed here

Energy sources Space heating	Austria	Belgium	Denmark	Finland	Germany	Ireland	Netherlands	Norway	UK
Electricity	x		x		x	x		x	
Gas		x	x		x	x	x		x
Oil	x		x		x	x		x	
Wood pellets	x							x	
District heating	x		x	x	x			x	
Biomass					(x)				
Renewables			x						
Coal					x	x			

3.1.1 Conversion factors

The applied conversion factors for the different applied energy sources are given in the figure below. The conversion factors are given in kg CO₂ per kWh energy.

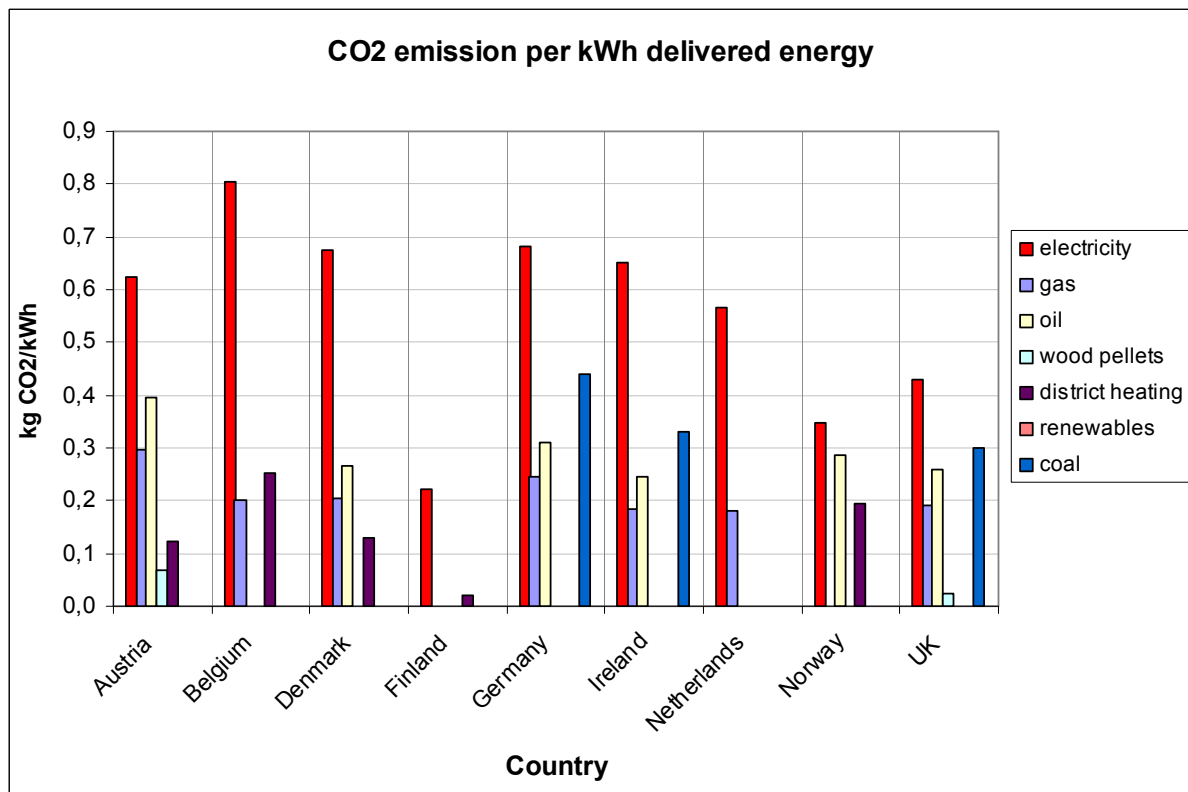


Figure 1: CO₂ emissions related to energy (kg CO₂/kWh) for the considered energy sources

A lot of diversity can be seen in CO₂ emission per kWh. Electricity use goes together with highest CO₂ emissions, gas, district heating and wood pellets show lowest emissions. As this section illustrates the actual energy source used for space heating has a significant impact on primary energy use and CO₂ emissions.

3.2 Energy uses

The estimated yearly primary energy use of a passive house, in relation to an existing dwelling and a typical new to build dwelling are given for space heating (Figure 2) and total household energy use (Figure 3).

Please note that the Passive House requirement of 15 kWh/m² TFA is for design energy-demand, not actual energy use, as this is strongly influenced by occupant behaviour and can therefore not be adequately controlled nor predicted.

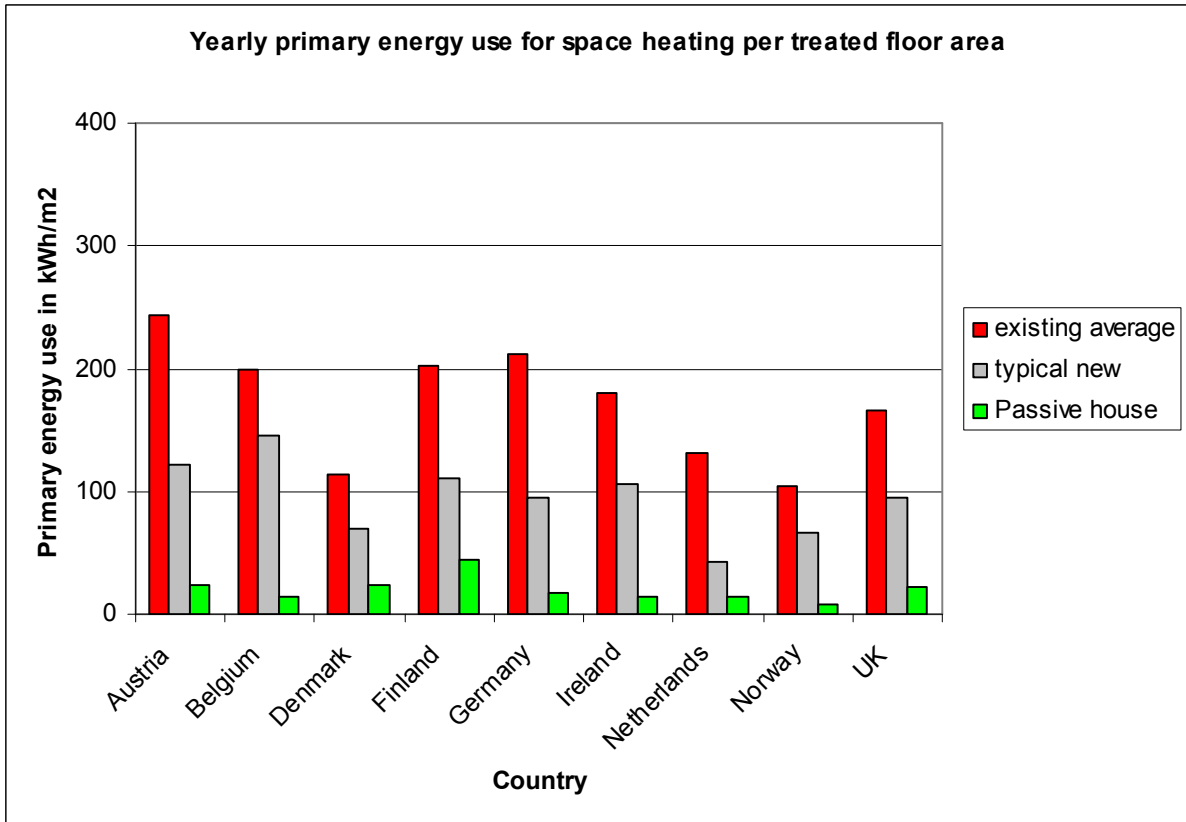


Figure 2: yearly primary space heating energy uses per dwelling, per existing, typical new and passive house

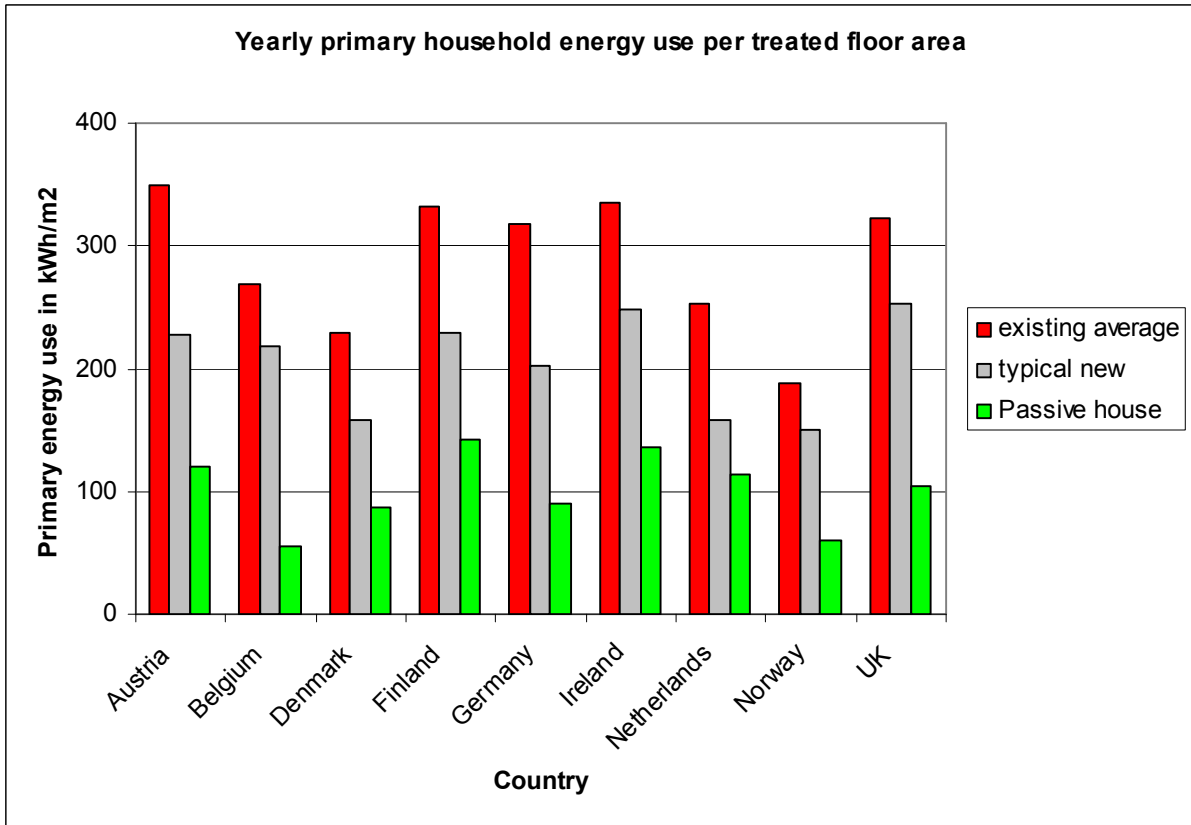


Figure 3: total household primary energy use per dwelling, per existing, new and passive house

3.3 Energy savings

The energy saving of a Passive House compared to an average existing dwelling (refurbished PH) and compared to a typical new-build dwelling (new PH) is given below.

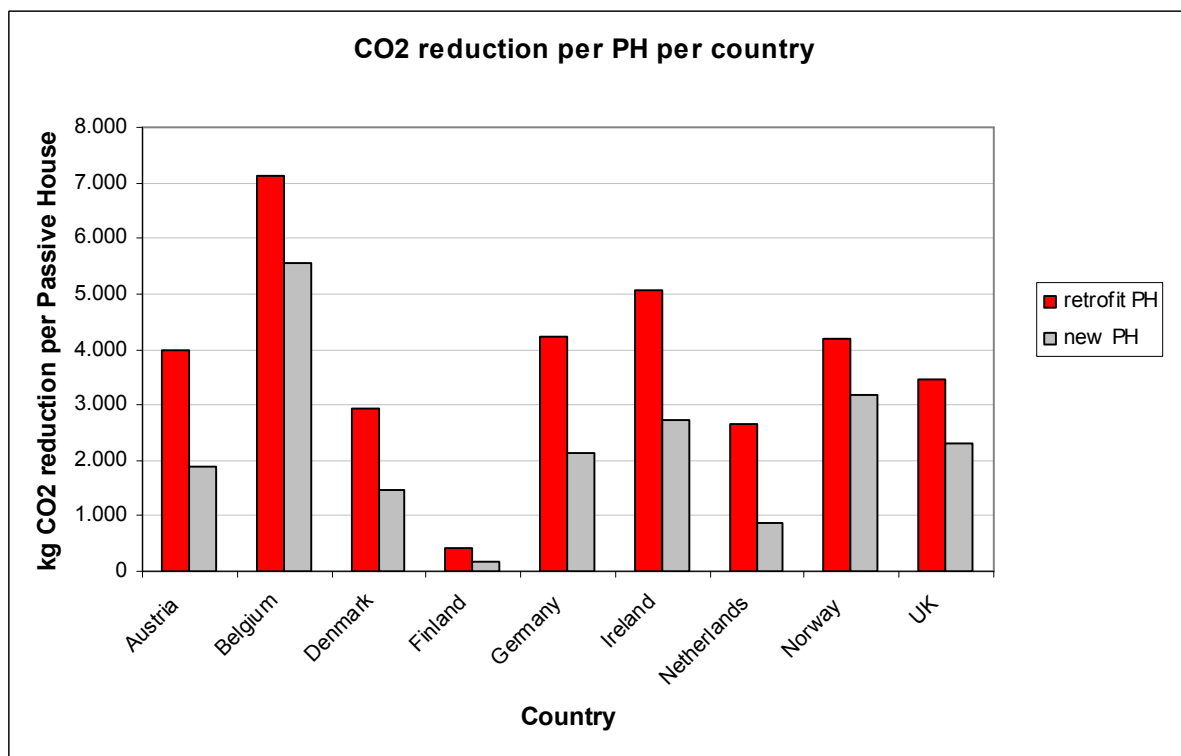


Figure 4: CO₂ reduction per Passive House compared to business as usual (new PH) and existing dwellings (refurbished PH).

Lots of diversity can be seen in the participating countries. Due to different levels of energy use, different types of applied energy sources and different conversion factors for each country, CO₂ reductions vary a great deal, explaining already a part of the differences in CO₂ reduction per Passive House between the countries. In the following paragraph these differences will be discussed.

3.4 Analysis

Final avoided CO₂ emission results per country are influenced by a host of factors. As discussed above, current energy use levels, Passive House energy use levels, energy sources, and conversion factors all play a significant role. Regarding conversion from fuel (energy type) used to Kg CO₂, the following must be noted:

Energy source → primary energy → CO₂ emission: As mentioned before, the conversion factors for primary energy and for CO₂ emissions differ per country. Overall, however, it can be noted that electricity has the highest factor (meaning highest CO₂ emission per amount of

energy), while district heating and gas, for example, have much lower conversion factors (see also Figure 1). This means that savings in electricity use will result in much greater avoided emissions than savings in district heating. As this example illustrates, the energy sources used in a Passive House (which differs per country) can have a large impact on the resulting emissions.

3.4.1 Austria

The current primary energy use of the typical new dwelling and the average existing household is relatively high in Austria. A Passive House uses around a factor 10 less for space heating than existing dwellings, resulting in a high energy saving potential for the Passive House, mostly in gas, oil and electricity. The CO₂ reduction of a Passive House is 1879 kg compared to a new, and 3987 kg compared to an existing dwelling.

3.4.2 Belgium

The current energy use of the typical new dwelling and the average existing household is relatively high in Belgium. A Passive House uses around a factor 10 less for space heating than existing dwellings, resulting in a high energy saving potential for the Passive House. The CO₂ reduction of a Passive House is 5556 kg compared to a new, and 7130 kg compared to an existing dwelling.

3.4.3 Denmark

Denmark shows an average CO₂ reduction per dwelling of 1475 kg per new Passive House and 2931 kg per refurbished Passive House. Compared to typical new dwellings savings are mostly in electricity due to reduction in space heating and household appliances. Compared to existing dwellings savings are spread over more energy sources: electricity, district heating, gas and oil.

3.4.4 Finland

Due to climate restrictions, the Passive house in Finland, has an annual space heating energy demand of 40 kWh/m² instead of 15 kWh/m².

Finland shows a CO₂ reduction of 182 and 406 kg for new and refurbished Passive Houses respectively. The absolute CO₂ reduction for Finland is relatively low, due to relatively high energy uses for the Passive House (owing to climate). The Passive House in Finland however still saves about 55% of the energy use for an existing dwelling.

The fact that most reduction is achieved for district heating, which has a low CO₂ conversion factor (while electricity has a more significant impact on the amount of CO₂ emissions), causes the avoided CO₂ emissions through Passive Houses in Finland to be lower. Moreover, even electricity in Finland shows relatively low CO₂ emissions compared to other countries, as shown in Figure 1, which also results in fewer avoided CO₂ emissions.

3.4.5 Germany

The primary energy use of a Passive House in Germany is only about 28% of that of an existing dwelling.

The CO₂ reduction per Passive House in Germany is high, 2140 and 4226 kg for new and refurbished Passive Houses respectively. For a new Passive House most CO₂ reduction is due to large electricity savings for household appliances (-50%) and space heating (-80%). Compared to existing dwellings, Passive House savings are mostly in gas, oil (space heating -90%) and electricity savings (household appliances -50%).

3.4.6 Ireland

The Irish existing dwellings show high energy uses. By realizing Passive Houses much energy savings can be reached. The CO₂ reduction per dwelling for Ireland is about 2742 kg CO₂ compared to a typical new dwelling, and 5070 kg CO₂ for each refurbished Passive House. Most reduction is due to gas and heating oil savings.

3.4.7 Netherlands

The primary energy use of a Passive House in the Netherlands is 45% of that of an existing dwelling and 72% of the primary energy use of a typical new dwelling. For the Netherlands the CO₂ reduction per dwelling is average compared to other countries: 885 and 2260 kg CO₂ for new and refurbished Passive Houses respectively. Savings are mainly for space heating with reductions in gas use of 90% with respect to existing and 65% with respect to new dwellings.

3.4.8 Norway

The total primary energy use of a Passive House in Norway is 32% of that of an existing dwelling, and the energy use for space heating is 7% of that of an existing dwelling. Compared to a typical new dwelling, a Passive House shows a total primary energy use of 41% and a energy use for space heating of 10%.

Norway has low CO₂ emission factors for electricity. Nevertheless, due to high reductions in energy use for space heating (electricity), CO₂ reductions are relatively high for both new and refurbished Passive Houses.

3.4.9 United Kingdom

The total primary energy use of a Passive House is 32% of that of an existing dwelling. Compared to a typical new dwelling, a Passive House in the UK shows a total primary energy use of 41% and an energy use for space heating of 23%. In both cases a reduction of energy use for domestic hot water of 50% is expected.

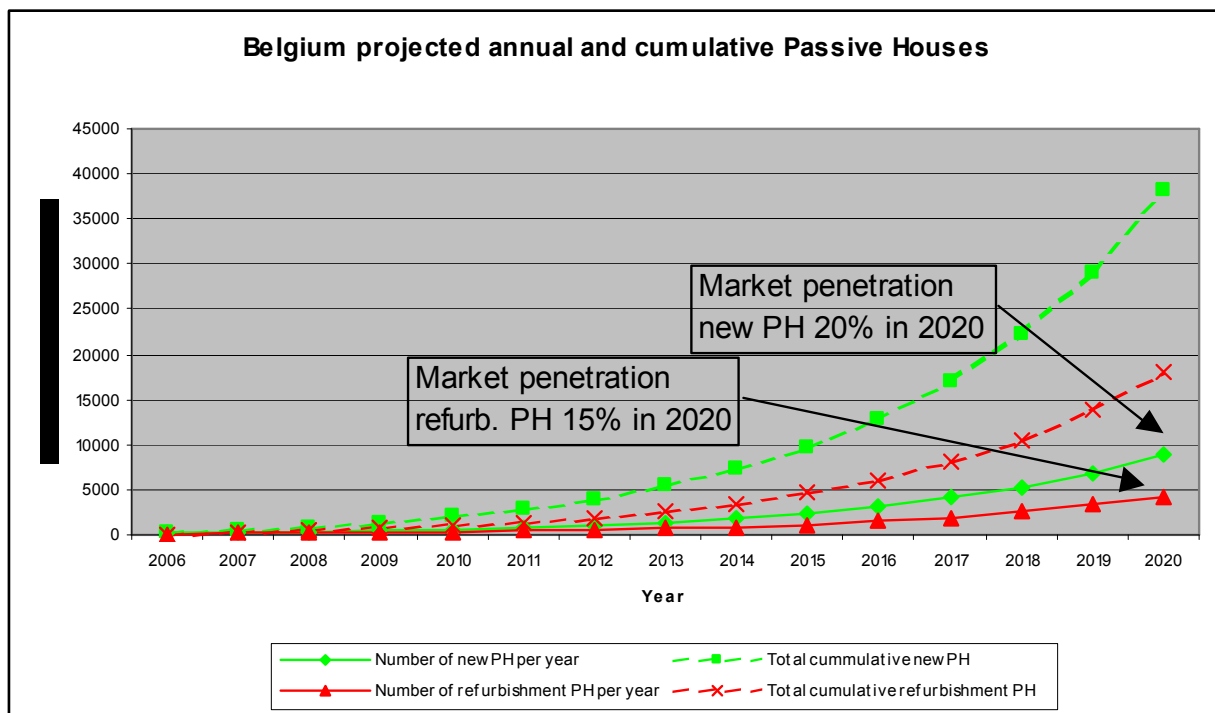
The CO₂ reduction per dwelling for the United Kingdom is average to high. Savings are mainly in electricity (household appliances) and gas use (space heating and domestic hot water).

3.5 Overall results

Consolidating the results of all countries, an average existing household is responsible for CO₂ emissions of 6.000 kg, due to energy use for space heating, domestic hot water and household appliances. One household in a typical new dwelling is responsible for 4.400 kg of emissions. The same households in a Passive House have CO₂ emissions of only 2100 kg. This results in reductions of 3800 and 2300 kg for new and refurbished Passive Houses respectively, which means reductions of **about 50% and 65%**.

The energy saving potential and consequent avoided CO₂ emission is dependent on the expected number of Passive Houses developed per year. Based on national trends in the housing market, the partners have established the expected market penetration for Passive Houses in the new-build and refurbishment housing market in their country by the year 2020. The expected penetration by 2020 in the new-build housing market is 50% for Germany, and 20% for Austria, Belgium, Denmark, Finland, Ireland, the Netherlands, Norway and the UK. Next, the expected penetration of Passive House refurbishments in the housing refurbishment market is 30% of all annual refurbishments for Germany, and 15% for the other partner countries. The higher expected market penetration for Passive Houses in Germany is due to the fact that Germany is currently farther ahead in the field of Passive House development. The expected annual growth has been established at 30% for both new and refurbishment Passive Houses. The annual and cumulative growth of Passive Houses in partner countries through the year 2020 is illustrated in *Figure 5* for Belgium:

Figure 5 Expected number of Passive Houses in Belgium



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In the table below the expected numbers of annual new-builds and refurbishments are given per country, both conventional and projected Passive House developments.

Table 2: Expected numbers of annual new to build and refurbished dwellings for 2006 and 2020

EXPECTED ANNUAL NUMBER OF NEW TO BUILD DWELLINGS AND REFRUBISHMENTS										
Business as usual										
	Austria	Belgium	Denmark	Finland	Germany	Ireland	Netherlands	Norway	UK	Total
new dwellings	23000	44869	27000	25000	187047	70000	70000	22000	254000	722.916
refurbishments	30000	28311	13500	20500	350000	145600	50000	15000	10000	662.911
New Passive Houses										
First year (2006), with 30% annual growth and expected market penetration of 20% (50% for Germany) by 2020.	117	228	137	127	2.375	356	356	112	1.290	5.098
Year 2020 (20% market penetration, Germany: 50%)	4.607	8.977	5.394	5.000	93.513	14.017	14.017	4.410	50.792	200.727
Refurbished Passive Houses										
First year (2006), with 30% annual growth and expected market penetration of 15% (30% for Germany) by 2020.	114	108	51	78	2.667	555	190	57	38	3.858
Year 2020 (15% market penetration, Germany: 30%)	4.489	4.252	2.008	3.071	105.010	21.852	7.481	2.244	1.496	151.904

To establish the avoided CO₂ emissions per year through Passive House development in each country, first the avoided emissions per individual new and refurbished Passive House have been established. These amounts are listed below per country as well as an overall average.

Table 3: Avoided CO₂ emissions per dwelling

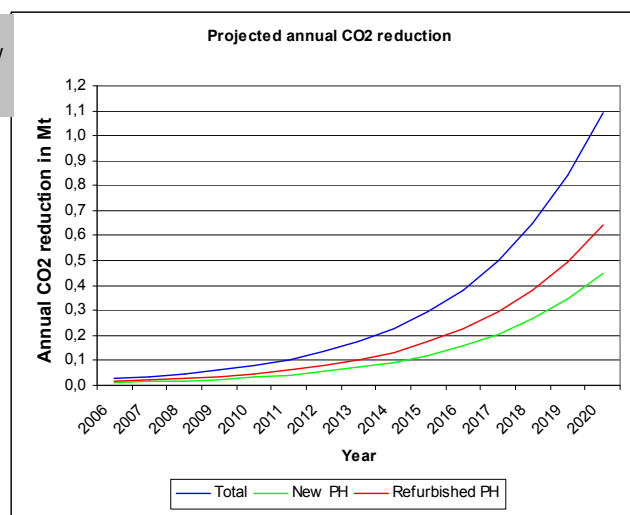
AVOIDED CO ₂ EMISSION										
ΔCO ₂ emission (kg) per Passive House										
New Passive Houses										
	Austria	Belgium	Denmark	Finland	Germany	Ireland	Netherlands	Norway	UK	Average
per dwelling	1.879	5.556	1.475	182	2.140	2.742	885	3.182	2.304	2.261
Refurbished Passive Houses										
per dwelling	3.987	7.130	2.931	406	4.226	5.070	2.660	4.184	3.467	3.785

Next, by multiplying these emissions per Passive House with the numbers of expected Passive House constructions for each year, the following CO₂ emissions have been obtained.

Table 4 Projected annual avoided CO₂ emissions for all partner countries

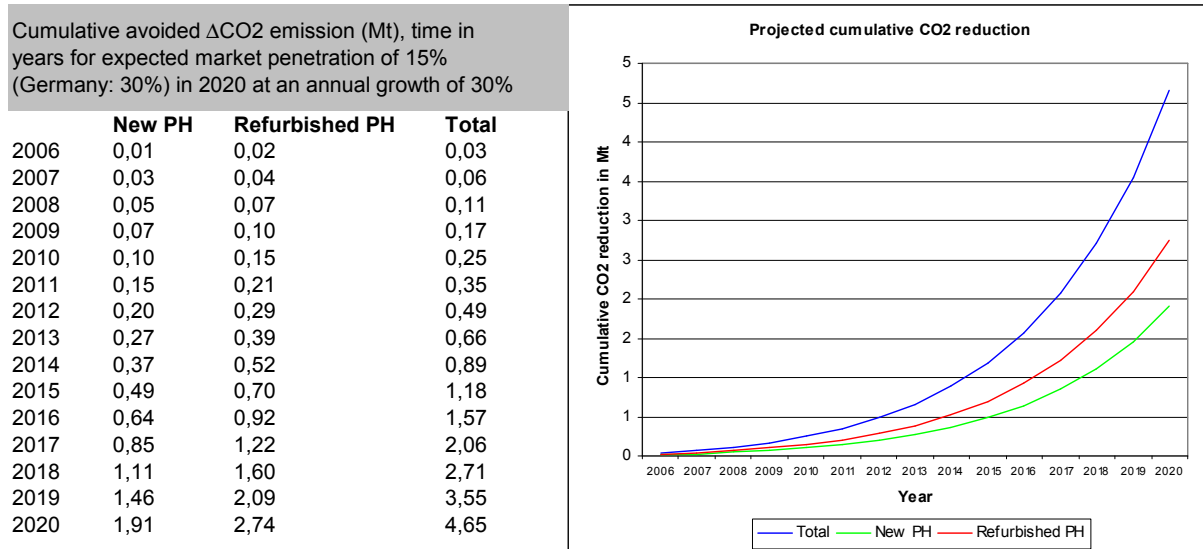
Annual avoided ΔCO₂ emission (Mt), time in years for expected market penetration of 20% (Germany: 50%) for new PH and 15% (Germany: 30%) for refurbished PH in 2020 at an annual growth of 30%

	New PH	Refurbished PH	Total
2006	0,01	0,02	0,03
2007	0,01	0,02	0,04
2008	0,02	0,03	0,05
2009	0,03	0,04	0,06
2010	0,03	0,05	0,08
2011	0,04	0,06	0,10
2012	0,06	0,08	0,13
2013	0,07	0,10	0,17
2014	0,09	0,13	0,23
2015	0,12	0,17	0,29
2016	0,16	0,23	0,38
2017	0,20	0,29	0,50
2018	0,27	0,38	0,65
2019	0,35	0,50	0,84
2020	0,45	0,64	1,09



The cumulative CO₂ reduction of all partner countries combined over the next fifteen years is expressed in Table 5.

Table 5 Projected cumulative avoided CO₂ emissions for all partner countries



Annual reductions after fifteen years will be much greater than the initial numbers, due to both the growth in annual Passive House developments and an increased number of existing Passive Houses.

The total avoided CO₂ emissions by 2020 are projected at 4,65 Mt for new and refurbished dwellings in all partner countries combined. The annually avoided emissions in that year are projected to be over one Mt of CO₂. It should be noted that projected data from Germany accounts for more than half of the total energy saving potential for Europe, due in part to the fact that Germany expects higher market penetration by the year 2020. Another reason is that Germany has a large population with a large residential building market in absolute numbers.

Another effect of Passive House development that has not been taken into account in these projections is the penetration of energy efficient Passive House components in conventional construction and refurbishments. As these components become more readily available, they will be applied in non-Passive House construction and thereby cause more emissions reduction with respect to current standard practice.

3.5.1 Kyoto targets

The Kyoto target for the European Union is a reduction of Greenhouse Gas Emissions of 8% CO₂ equivalent in 2010 compared to emissions in the year 1990. (Note that this is based on absolute emissions, not cumulative.) The Kyoto protocol is set for the timeframe 1990 to 2010. Since Passive House developments do not follow the same timeframe, an annual target is deduced here from the Kyoto goals for comparison purposes. A reduction of 8% over 20 years implies a reduction of 0,4% (of the level in 1990) per year, though it must be

noted that actual reductions in emissions do not show a perfectly straight line. In this review is it assumed that the relative reduction in each sector (industry, household energy use, schools, transport etc.) will be equal (= 8%).

The existing residential building stock, which has lower average energy efficiency than the current typical new-build residence, shows the largest energy consumption in the residential housing sector (around 540 Mt CO₂ emission in 2006). Due to the large amount of existing, low efficiency residences in the building stock, it takes a long time to decrease relative emissions in this sector through incidental renovations. However, if we consider just the new-build residential market, annual emission reduction compared to business as usual will within two years reach 0,46%, complying with the Kyoto goal for that sector (= 0,4% annually). By 2020, the projected avoided annual CO₂ emissions will have grown to 0,45 Mt CO₂, which is a reduction of 14% compared to business as usual.

However, Passive House development alone will not suffice to reach the Kyoto targets. Obviously, these targets will be reached by many measures in all sectors, not merely residential or even merely construction. Considering the early stage at which Passive House development currently is in most countries, it forms a promising method to contribute to emission reduction in the future, if successfully implemented in national markets.

4 Conclusions

Through the Passive House concept a considerable energy saving compared to the business as usual can be obtained. This energy saving potential for a single residence goes together with CO₂ emission reductions of about 50% to 65%.

The energy saving per country is very much dependent on energy sources used, and applied conversion factors for primary energy uses and CO₂ emissions.

The total CO₂ reduction for each country is dependent on the number of Passive Houses expected to be built for each country. Germany expects to realize greatest market penetration and most Passive Houses within the next fifteen years.

The current annual reduction required by the Kyoto protocol is 0,4% in each sector. In the new-build housing market, Passive Houses are projected to realize an average annual reduction of 0,46% with respect to business as usual within two years of Passive House developments, thereby satisfying the Kyoto goal for that sector. Moreover an annual reduction of 14% in new-build housing is projected by 2020, far exceeding the Kyoto target of 0,4% annually.

Passive Houses alone will not suffice to reach the entire Kyoto target. Obviously, these goals will be reached by many measures in all energy consuming sectors, not merely the residential or even merely the construction sector. However, considering the early stage at which Passive House development currently is in most countries, it forms a very promising method to contribute to significant emission reduction in the future, if successfully implemented in national markets.

Appendix (separate document)

[Energy saving potential method & calculation](#)