# Promotion of the Very low-energy house Concept to the North European Building Market

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# 1 EXECUTIVE SUMMARY

The overall comparison of existing national building regulations and the existing low energy building definitions of the participating countries showed that while the minimum criteria according to existing building regulations in the Northern European countries are of different types and levels, the existing very low energy definitions and criteria are less different, aiming at a low energy demand. The comparison also emphasized the decisive differences between boundary conditions in terms of reference area, internal heat gain and weighting of electricity and different heat sources. These different requirements constitute an unnecessary technical barrier to trade and can be seen as a challenge for a market driven penetration of very low energy houses across the borders in the Northern European countries.

The general principles of the very low energy design can be summarized to 1) minimize losses and consumption, 2) maximize gains and 3) substitute the remaining energy need with renewable and environmental friendly energies. The special challenges of designing a very low energy house in the Northern European emphasized following additional design rules:

1. U-values of opaque constructions 0.06 – 0.12 W/m$^2$K, depending on the climate
2. Windows orientation to the South is preferable, very low U-values, external shading
3. Best possible ventilation heat recovery rate and a system for avoiding freezing of the heat exchanger e.g. ground-coupled heat exchanger

The Life Cycle Assessment results for conventional and very low-energy buildings demonstrate that although variations in building techniques, materials used, energy supply and heating system very low-energy buildings in general have a lower environmental impact compared to conventional buildings. In order to reduce the impact to global warming and the use of primary energy it is also important to choose an energy source with low greenhouse gas emissions and a low primary energy factor. The Life Cycle Cost (LCC) calculation and the simplified Cost Benefit Analysis (CBA) showed that if the energy price is considered to rise fast in the coming years, a very low-energy building is a good investment. NorthPassTool, a demonstration tool based on Excel spread-sheet, was developed within the NorthPass project. The tool can be used to give an overview of the different parameters affecting the economic and environmental impacts of the building.

Main non-technological barriers to implementation of very low-energy buildings exist mainly within the following areas: market, requirements/regulations, knowledge, costs, instruments of control, responsibility, policy, society and incentives. The potential internal strengths of low energy residential buildings, valid for several participating countries, are good indoor environment, low running costs, high energy efficiency, low LCC and a growing market. Common potential internal weaknesses were inadequately spread competence to build, lacking robustness and quality, indoor environment problems, operation and use problems, bad experience of low energy houses and planning and designing mistakes. Some of these weaknesses e.g. lacking robustness and quality, indoor environment problems, operation and use problems can occur in traditional buildings as well. Several suggestions were made to overcome the potential internal weaknesses and potential external threats of low energy dwellings regarding methods, knowledge, market and incentives.

A study was carried out to determine the state-of-the-art and need for further development of components for very low-energy residential buildings in the participating countries. According to the study most components needed for very low-energy residential buildings are available on the markets. To promote the availability of very low-energy house components, a database with links to web sites of suppliers/manufacturers was created within the NorthPass project. The database includes the major components needed for very low-energy houses.

Regardless of the country-specific market situation, there exists a considerably strong interest in very low-energy construction among individual builders in most of the participating countries. The builders would be willing to pay an extra investment cost for very low-energy buildings but in many cases the amount was not remarkably high and it might not reach the actual extra investment costs estimated by the experts. In most countries the individual builders had experienced that information, products and services regarding low-energy construction do exist but that they might be difficult to find. More demonstration projects are wanted and they would need to be impartially and reliably performance monitored, documented and evaluated. There is a strong belief in the increase of very low-energy construction among the experts, and most of the respondents also foresaw that very low-energy buildings will be more valuable in the future. In most countries the experts strongly favoured measures by the authorities although the respondents also believed that the development towards enhanced energy efficiency in construction would take place also without obligations by law. Despite the differences across the countries, some similar measures are needed everywhere: providing a suitable social environment with raising the awareness of people, coordinating knowledge and facilitating cooperation across different actors for establishing a functioning economic environment for the very low-energy housing market and introducing legal requirements about energy efficiency and defining legal concepts for low-energy construction for creating a suitable political environment. A decent technical environment should be obtained by bringing necessary products and expertise to the market to a sufficient extent

Three different scenarios of reaching the EU 2020 target were examined: Business as Usual scenario (failing in the EU 2020 target), Fast Change scenario (reaching the EU 2020 target) and Change in Market Modes of Operation scenario (reaching the target already by 2016). The Fast Change scenario seems to be plausible for all eight countries. Some measures are needed in all countries and in order to reach both Fast Change and Change in Market Modes of Operation scenario. Improving the availability of information and taking up energy-efficiency issues in the education are main measures which would increase the interest of actors from both demand and supply side. Financial aid (e.g. tax reliefs) offered by the state would be highly beneficial in all countries.

Very low energy houses must be designed according to local climate and conditions. The energy and power demand can be considerably higher in regions with cold climate compared to the milder ones. But with the expected technological development, it will be possible to build very low energy houses also in cold regions. It will therefore make sense to revise the criteria for buildings in cold climate, in accordance with the technological development.

The minimum requirement regarding renewable energy should be gradually sharpened. The share of renewable energy should be considered independent of the concepts of low energy house and passive house, because these concepts are connected to net energy use. It should be possible to regulate requirements on renewable energy share and other energy related requirements separately, without the one influencing the other. In the near future, 5–10 years, it seems reasonable to require very low energy buildings in the regulations. In the longer run, 10–20, it seems possible to require zero-energy / zero-emission buildings for new constructions.

# 2 INTRODUCTION

This report is based on the results of the IEE NorthPass project 26.5.2009-25.5.2012. The coordinator of the NorthPass project was VTT (FI) and the other project participants were Tampere University of Technology (FI), Lund University (SE), Aalborg University (DK), University of Tartu (EE), Riga Technical University (LV), Vilnius Gediminas Technical University (LT), IVL Swedish Environmental Research Institute (SE), SINTEF Building and Infrastructure (NO), Passivhus.dk Aps (DK), CENERGIA (DK) and National Energy Conservation Agency (PL).

NorthPass project aimed at overcoming barriers on the very low-energy house markets in cold climate, such as the lack of well-defined concepts adapted to the severe climate conditions, awareness of very low-energy houses, lack of products on the market and customer attitudes.

The objectives of NorthPass were

1) to define very-low energy house criteria and concept adapted to the North European countries,
2) to find solutions to remove market barriers for wide market acceptance of those concepts and products,
3) to remove the gap between the demonstration of very low-energy house concept and their broad market penetration and
4) to support the implementation of the EU Commission's strategy and recommendations regarding very low-energy buildings.

The project increased the awareness and market acceptance of very low-energy house in the North European construction market, accelerated the identification of suitable solutions adapted to the cold climate environment and supported the implementation of the EU Commission's recommendations regarding very low-energy buildings.

The project was focused on new-erected residential buildings. The target groups of the project were

- customers
  - principals, early adapters, very low-energy house building owners, housing developing companies, social housing authorities, public audience
- designers
  - architects, structural engineers and HVAC designers
- building industry
  - building contractors and building workers
  - building product industry
- building authorities
  - housing ministries, local and national politicians, municipal officials in town planning and supervision of building
- European Commission

Table 1 presents the NorthPass report sources of different chapters.

*Table 1. NorthPass report sources for different chapters of the result-oriented final report*

| **Chapter** | **NorthPass report(s)** | **Leading contributor** |
|---|---|---|
| 3. Special conditions in the Northern Europe | Principles of low-energy houses applicable in North European countries and their applicability throughout the EU | Passivhus.dk |
| 4. Comparison of existing very low-energy house criteria and standard for the Northern climates | Application of the local criteria/standards and their differences for very low-energy and low energy houses in the participating countries. | Passivhus.dk |
| 5. Principles of a very low energy house in North-European climates | Principles of low-energy houses applicable in North European countries and their applicability throughout the EU | Passivhus.dk |
| 6. Impact and saving potential of North European very low-energy houses | A general description of the calculation tools for Cost Benefit Analysis and Life Cycle Assessment of very low-energy houses<br>Identification of tools for cost-benefit and LCC analysis and success factors for very low-energy housing<br>Economic and environmental impact assessment of very low-energy house concepts in the North European countries<br>NorthPassTool- a demonstration tool to promote very low-energy houses | IVL |
| 7. Overcoming barriers to implementation of very low-energy houses | Barriers to implementation of very low energy residential buildings and how to overcome them<br>Availability of components for very low energy residential buildings on the North European Building Market | Lund university |
| 8.1 Very low-energy house markets | Report on low-energy building market situation, trends, and influencing factors<br>Country-specific market analysis, success factors, marketing approach, and market situation<br>Scenarios, business models and examples for very low-energy housing markets | VTT |
| 8.2 National roadmaps | National Roadmaps for promotion of very low-energy house concepts | Sintef |
| 8.3 Suggestions for the reachable minimum performance requirement to be utilized in the update process of the Energy Performance of Buildings Directive | Suggestions for the reachable minimum performance requirement to be utilized in the update process of the Energy Performance of Buildings Directive | Sintef |

# 3 SPECIAL CONDITIONS IN THE NORTHERN EUROPE

## 3.1 Climatic conditions

The building heat losses and solar gains are a direct function of the local climate, mainly outdoor air temperature and solar radiation. Figure 1 presents ten North European locations, whose monthly average outdoor temperatures are shown in Figure 2. The diagrams show that the winter temperatures in all selected Northern European locations are lower than the average Central European climate (Standard PHPP).


*Figure 1. Locations of the weather stations used for comparison.*
*(Source of map: http://www.online-reisefuehrer.com/basebilder/landkarte-europa.jpg)*

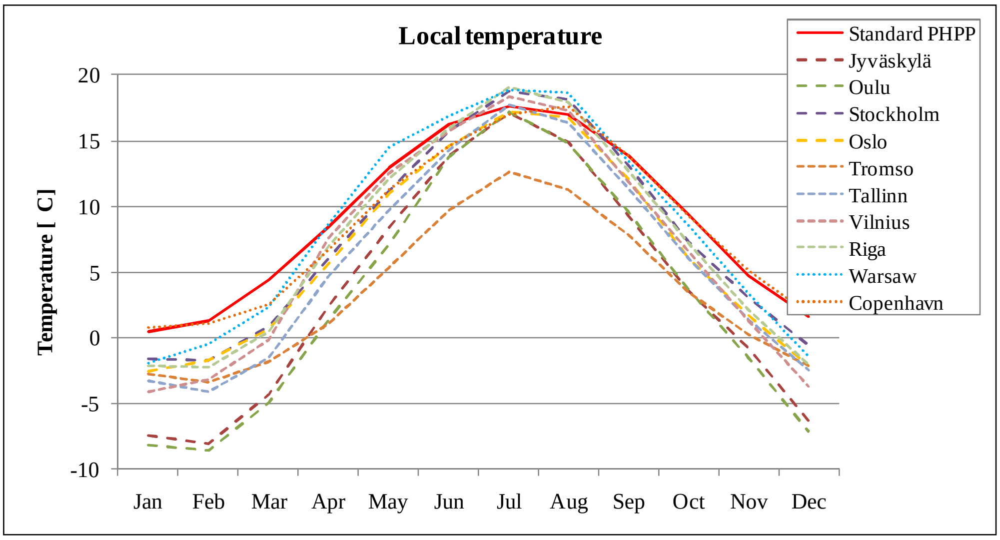


*Figure 2. Monthly average temperatures.*

The yearly global solar irradiation on an optimally south oriented façade throughout the Northern Europe is illustrated in Figure 3. The amount of solar radiation varies clearly and it is not a direct function of the latitude: There are equal amounts of yearly solar radiation e.g. in South-Western Sweden and the Eastern Finland.

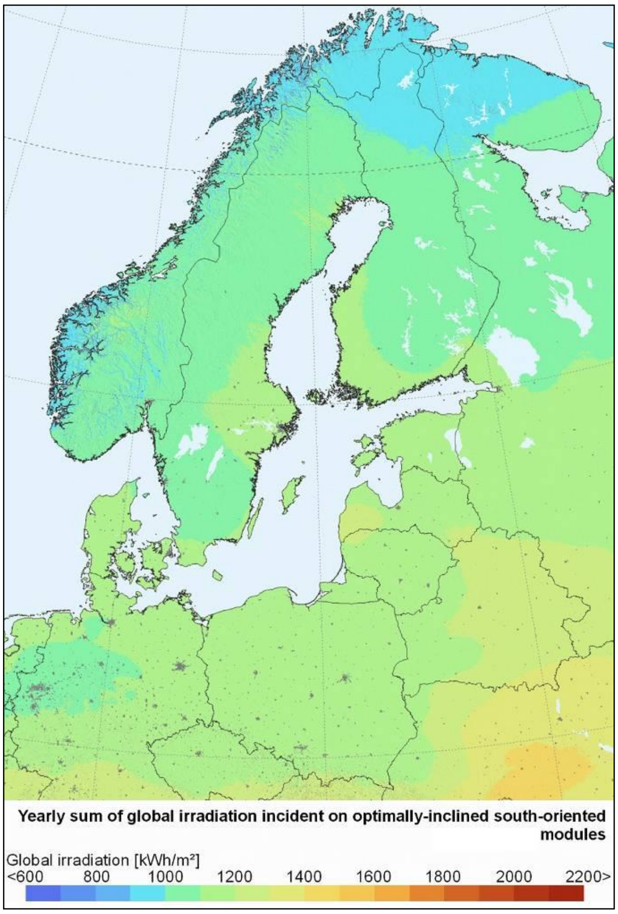


*Figure 3. Yearly radiation to the participating countries on optimal oriented modules; Map source http://re.jrc.ec.europa.eu/pvgis/*

The monthly solar radiation to a south oriented façade is given in Figure 4. An overview of the distribution of the solar radiation on the facades oriented in the main compass directions is given in Figure 5. The figures show how the amount of solar radiation is relatively high in the Northern Europe compared to the Central European conditions, due to two main characteristics:

- Especially outside the heating season the solar radiation is higher in all Northern European locations compared to Standard German conditions. In the wintertime, there is much less solar radiation in the Northern part of the North European region.
- The amount of radiation is high, because the sun path is lower in the North and therefore shines quite straight into the south oriented building façade.

The lower incident angles, when on northern latitudes, and the longer hours of solar radiation during the summer half of the year, result in more solar radiation on a vertical, south oriented facade than in Central Europe. If the window area to south is large, effective solar shading must be used in order to avoid overheating, especially in spring and autumn.

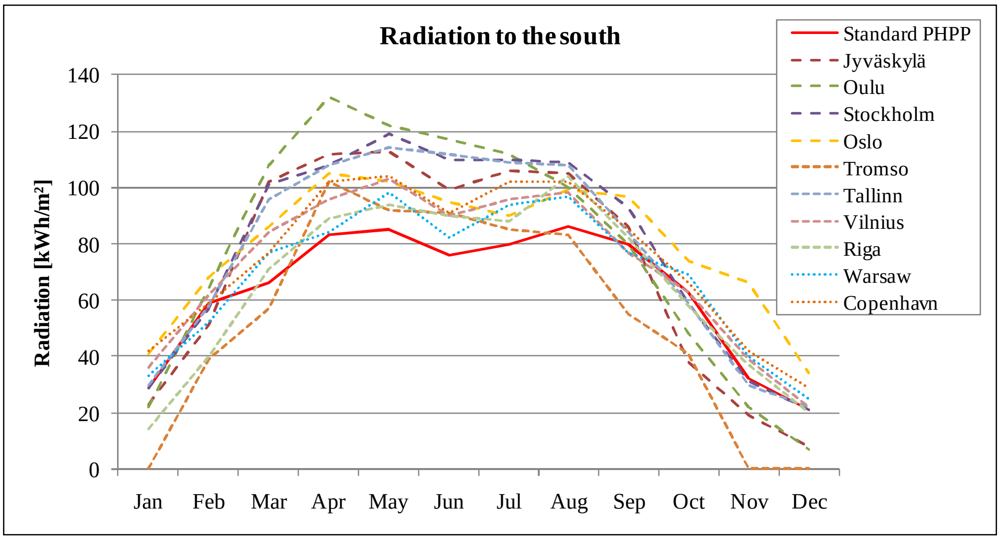


*Figure 4. Monthly radiation (kWh/m$^2$) to a south oriented façade for the selected weather stations*

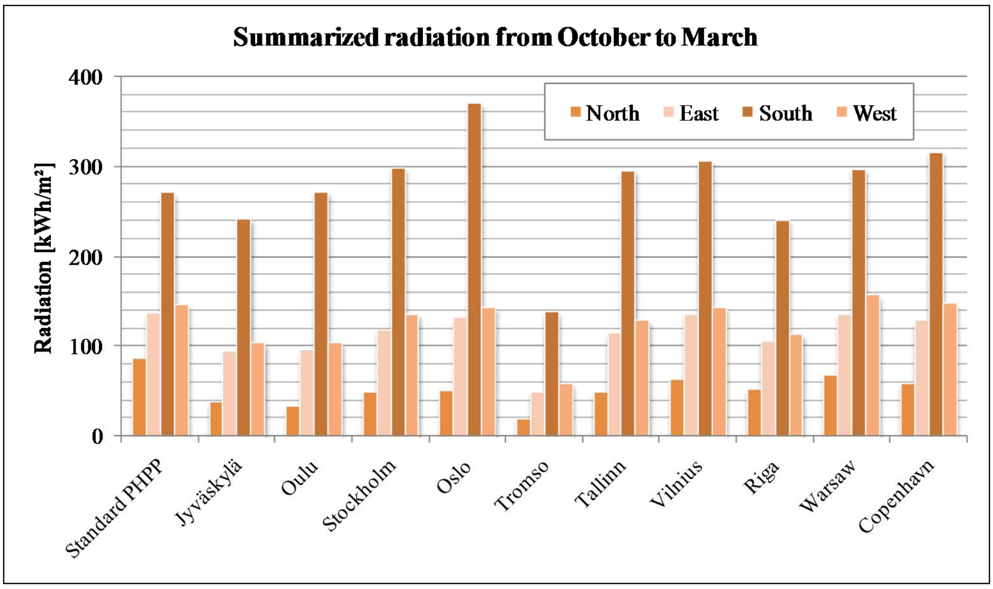


*Figure 5. Summarized solar radiation to a facade oriented in all four main directions from October to March for the selected North European weather stations.*

The low temperature of the ground and especially the freezing ground has in two ways an impact on the very low-energy house:

- A frozen underground can damage a building by melting and changing its density and
- earth-air ground source heat exchanger (earth tubes) cannot work properly in frozen ground.

The area of continuing permafrost is not dominating the Northern Europe and hardly anyone is living in this area. The seasonal influence of frozen ground is quite strong, however, in parts of Finland, Norway and Sweden and has to be taken into account in the planning process. A well-insulated low energy building will have very low heat loss to ground and therefore the ground around the building is not heated in the same way as it is the case for traditional buildings.

## 3.2 Strength of economy

The strength of economy of the different parts of Europe is very different, and in the North European countries, too. Figure 6 illustrates the European purchasing power in 2008/2009. The situation today, 2012, is worse at least for the South European countries. Any extra construction costs related to realization of the very low energy buildings may play a central role in some economies while the role is non-existing in the strong economies. In order to reduce these barriers for implementation of the energy efficient buildings, it is an advantage to keep the very low energy house on a low technical and therefore also on a low cost level. The HVAC-system has to be as simple as possible, and also easy to maintain. The same goes for the envelope to make it reasonably priced and robust.

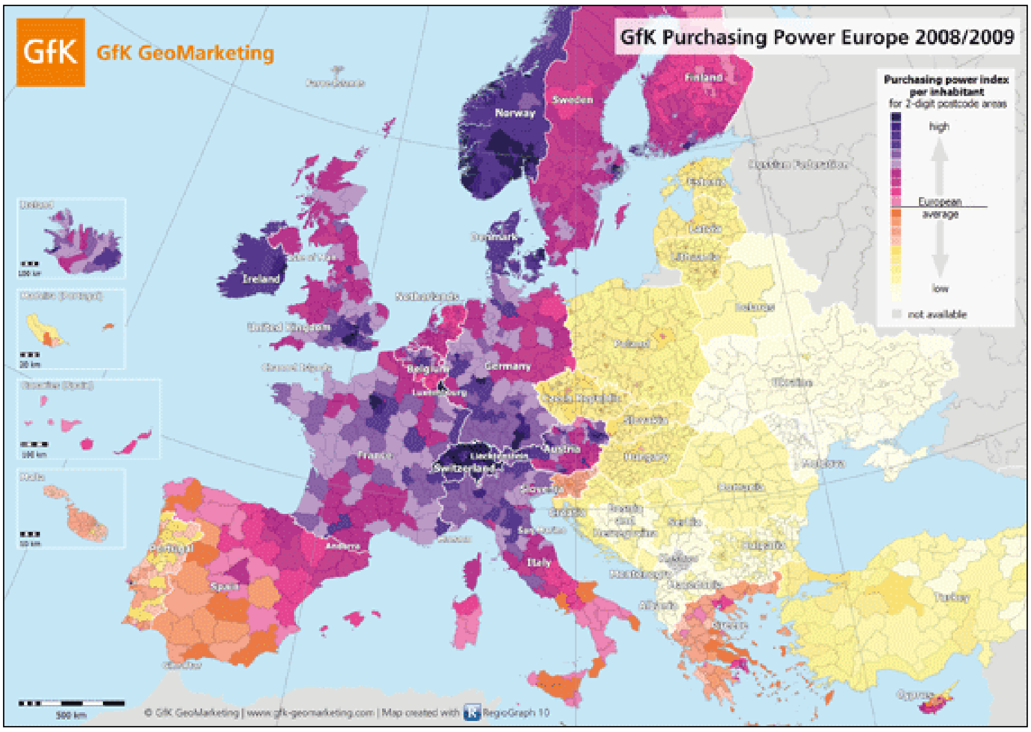


*Figure 6. Discretionary purchasing power over Europe in 2008/2009*[1].

[1]http://www.gfkgeomarketing.com/fileadmin/gfkgeomarketing/en/img/press/purchasing_power_europe_2008_2009.gif

Some example conclusions on economical U-values are showed in Table 2. These values are conclusions of a report “U-values for better energy performance of buildings” established by ECOFYS (Boermans, T. et.al 2007). The report shows economical U-values for 100 European cities. It deals with the most economical U-values for roof, wall and floor including energy prices and material prices (still fulfilling the European Kyoto Agreements).

*Table 2. Resulting optimum U-values based on cost-efficiency sorted by country of the ECOFYS report VII (Boermans, T. et.al 2007)*

| U-values [W/m$^2$K] | | **WEO reference** | | | **Peak price scenario** | | |
|---|---|---|---|---|---|---|---|
| **City** | **Country** | **wall** | **roof** | **floor** | **wall** | **roof** | **floor** |
| Copenhagen | Denmark | 0.19 | 0.16 | 0.24 | 0.16 | 0.13 | 0.21 |
| Aalborg | Denmark | 0.18 | 0.15 | 0.23 | 0.16 | 0.13 | 0.21 |
| Tallinn | Estonia | 0.19 | 0.17 | 0.23 | 0.17 | 0.14 | 0.21 |
| Helsinki | Finland | 0.18 | 0.15 | 0.22 | 0.17 | 0.13 | 0.20 |
| Oulu | Finland | 0.17 | 0.14 | 0.21 | 0.15 | 0.12 | 0.18 |
| Ivalo | Finland | 0.15 | 0.12 | 0.19 | 0.14 | 0.11 | 0.17 |
| Riga | Latvia | 0.20 | 0.18 | 0.25 | 0.17 | 0.15 | 0.22 |
| Klapeida | Lithuania | 0.21 | 0.18 | 0.26 | 0.18 | 0.16 | 0.23 |
| Vilnius | Lithuania | 0.20 | 0.18 | 0.25 | 0.17 | 0.16 | 0.22 |
| Bergen | Norway | 0.21 | 0.17 | 0.25 | 0.18 | 0.15 | 0.22 |
| Oslo | Norway | 0.19 | 0.15 | 0.22 | 0.17 | 0.13 | 0.20 |
| Trondheim | Norway | 0.18 | 0.14 | 0.22 | 0.16 | 0.13 | 0.19 |
| Tromsö | Norway | 0.17 | 0.14 | 0.21 | 0.15 | 0.12 | 0.19 |
| Hammersfest | Norway | 0.17 | 0.13 | 0.20 | 0.15 | 0.12 | 0.18 |
| Swinonjscie | Poland | 0.21 | 0.19 | 0.28 | 0.19 | 0.17 | 0.23 |
| Poznan | Poland | 0.21 | 0.19 | 0.26 | 0.19 | 0.17 | 0.23 |
| Warsaw | Poland | 0.21 | 0.19 | 0.26 | 0.19 | 0.17 | 0.23 |
| Gdansk | Poland | 0.21 | 0.18 | 0.26 | 0.18 | 0.16 | 0.23 |
| Goteborg | Sweden | 0.20 | 0.17 | 0.25 | 0.18 | 0.15 | 0.22 |
| Stockholm | Sweden | 0.20 | 0.16 | 0.24 | 0.18 | 0.14 | 0.22 |
| Umea | Sweden | 0.17 | 0.14 | 0.21 | 0.15 | 0.12 | 0.18 |
| Lulea | Sweden | 0.17 | 0.13 | 0.20 | 0.15 | 0.12 | 0.18 |

# 4 COMPARISON OF EXISTING VERY LOW-ENERGY HOUSE CRITERIA AND STANDARDS FOR THE NORTHERN CLIMATES

National definitions for very low-energy buildings exist in Finland, Sweden, Norway and Denmark. In the other countries (Estonia, Latvia, Lithuania and Poland), there are no national low energy definitions, but especially passive house concept by PHI is applied in the Baltic countries. The international approach of passive houses by PHI is practically the only definition applied across the borders. In Finland, Sweden and Denmark there are also low energy definitions, typically representing around 50% of the space heating demand/total energy consumption according to the building regulations.

The very low energy concepts generally do not have own requirements for maximum U-values (except Passive Energy Building by RIL, Finland). For windows, there is a recommendation for maximum U-value of 0.8 W/m²/K (for Passive House by PHI) and requirement of maximum U-value of 0.9 W/m²/K (for Passive house by FEBY). Air tightness (determined by the blower door test, n50 value) is a common criterion or in individual cases references to floor area or building envelope.

*Table 3. Definitions for space heat demand or heat load (PEB = Passive Energy Building; LEB = Low Energy Building, PH = Passive House)*

| | Country | Space heat demand [kWh/m²] | Heat load [W/m²] |
|---|---|---|---|
| PEB by VTT, Finland | Finland | Southern Finland 20<br>Middle Finland 25<br>Lapland 30 | no requirements |
| PEB by RIL, Finland | Finland | Single family house:<br>10-20 ordinary winter use,<br>25 by use of design situation peak load<br>Apartment building:<br>10-15 ordinary winter use,<br>20 by use of design situation peak load | no requirements |
| PH by FEBY, Sweden | Sweden | no requirements. The energy use demand includes the energy for heating, comfort cooling, domestic hot water, fans and pumps. The Feby PH of 2012 states 50 – 58 including 20-25 for domestic hot water and electricity for fans and pumps. | Southern Sweden 10<br>Central Sweden 11<br>Northern Sweden 12<br>For dwellings less than 200 m²:<br>Southern Sweden 12<br>Central Sweden 13<br>Northern Sweden 14. |
| PH by Norwegian Standard | Norway | 15 and increment for smaller houses (< 250 m²) and for colder locations than Oslo (annual mean temperature: 6,3 °C) | no requirements |
| LEB Class 1 in Denmark | Denmark | no requirements | no requirements |
| PH by PHI | All | 15 (space heat demand and heat load are alternative criteria) | 10 (space heat demand and heat load are alternative criteria) |

The maximum energy demand – given mostly as a space heating demand – varies from 10 to 30 kWh/m²/a depending on the definition. An exception is the FEBY-definition, where the main criteria is the heat load and the corresponding total energy demand is given to be 50 – 58 kWh/m²/a (space and domestic hot water heating, electricity for pumps and fans).. Another exception is the Danish Low energy class 1 definition, where the 35 kWh/m²/a includes the total primary energy use in a building, which makes this definition one of the most challenging (Table 4). A comparison between all of these criteria has to be made with calculations. So just the boundary conditions are really different (internal heat gains, floor area) and the criteria too. In all countries the building regulations have to be met anyway.

*Table 4. Definitions for total or primary energy demand including weighting factors (PEB = Passive Energy Building; LEB = Low Energy Building, PH = Passive House)*

| | Total (or primary) energy demand [kWh/m²] |
|---|---|
| PEB by VTT, Finland | South Finland 130<br>Middle Finland 135<br>Lapland 140 |
| PEB by RIL, Finland | Single family house:<br>140<br>Apartment building:<br>135 |
| PH by FEBY, Sweden | Just a recommendation:<br>The weight of electricity is currently two:<br>Southern Sweden 60<br>Central Sweden 64<br>Northern Sweden 68<br>Without a weighting factor:<br>Southern Sweden 50<br>Central Sweden 54<br>Northern Sweden 58<br>With direct electrical heating as the main source of heating:<br>Southern Sweden 30<br>Central Sweden 32<br>Northern Sweden 34 |
| PH by Norwegian Standard | half of the DHW demand shall be covered by local renewable energy supply |
| LEB Class 1 in Denmark | 50% of the building code (BR08). → Q ≤ (35 + 1100 m² /A) |
| PH by PHI | 120 for heating, domestic hot water, ventilation and electricity (light, household, etc.) with primary energy factors |

*Table 5. Definitions for heat recovery, air tightness and cooling load (PEB = Passive Energy Building; LEB = Low Energy Building, PH = Passive House)*

| | Heat recovery in the mechanical ventilation | Air tightness by 50 Pa | Cooling demand |
|---|---|---|---|
| PEB by VTT, Finland | no requirement | 0,6 $h^{-1}$ | no requirement |
| PEB by RIL, Finland | 75% | 0,6 $h^{-1}$ | included in the primary energy demand too |
| PH by FEBY, Sweden | 70% recommended | 0,3 l/sm² [a] | The indoor temperature during the period April – September should not exceed 26 °C more than 10 % of the time in the most exposed room. |
| PH by Norwegian Standard | 80 % | 0,6 $h^{-1}$ | Cooling is not allowed in residential buildings |
| LEB Class 1 in Denmark | 65% [b] | 1,5 l/sm² [c] | Cooling demand to limit indoor temperature in summer is calculated and included no matter if a cooling system has been established (max. temperature 25 ºC) or not (maximum temperature 26 ºC). This motivates the designer to avoid designs that results in excessive temperatures. |
| PH by PHI | 75 % recommended | 0,6 $h^{-1}$ | There is a mandatory maximum of 15 kWh/m² of cooling demand, if active cooling is applied (rarely). Any cooling demand is included in the primary energy demand, which may not exceed 120 kWh/m². It is recommended that the temperature should not exceed 25 ºC for more than 10% of the time. |

a m² building envelope
b With heat recovery also the requirement for electricity consumption is tighter: For a unit for one dwelling one kitchen and one bathroom with heat recovery the limit for the electricity demand is 368 kWh/a, and without heat recovery as pure exhaust system the limit is 400 kWh.
c m² floor area

*Table 6. Information about calculation values*

| | Indoor temp. | Internal heat gains appliances and persons | Reference area for calculation |
|---|---|---|---|
| PEB by VTT, Finland | 21 °C | not specified | gross floor area |
| PEB by RIL, Finland | 21 °C | not specified | gross floor area |
| PH by FEBY, Sweden | 22 °C | 4 W/m² | overall internal dimensions |
| PH by Norwegian Standard | 20 °C | 4 W/m² | overall internal dimensions |
| LEB Class 1 in Denmark | 20 °C | 5 W/m² | gross floor area |
| PH by PHI | 20 °C | 2,1 W/m² | net floor area |

On the European level a somewhat similar comparison of the national building regulations and the low energy standards "European national strategies to move towards very low energy buildings", SBi 2008:07, was compiled 2007-2008 in EuroACE project.(Engelund et al. 2008)

The definitions and standards used in the participating countries were compared with each other with the focus on the way they are determined and calculated. The short analysis of the differences is as follows:

Calculation methods

- There exists different national and international calculation methods and tools but all are based on European standard EN 13790
- Generally monthly average values are used
- Reference areas are very different: heated internal, overall internal or external dimensions.
  - Example: Typically the reference area in passive houses by PHI amounts to 75-85% of the gross heated floor area as used in the Danish building regulations
- Internal heat gains vary: from 2.1 (passive house by PHI) to 4.0 (FEBY) and 5.0 W/m² (Danish low energy Class 1 – and Danish building regulations in general). A part of the explanation is probably tradition, yet another part is that there is a strong focus on reducing electricity consumption, thus limiting internal heat gains in passive houses by PHI.
  - Example: The combination of differences in internal heat gain and reference area means that Danish low energy building class 1 can take into account roughly three times as much internal heat gain as passive houses by PHI
- Weighting- or primary energy factors for different forms of energy are different, and are defined differently.
  - Example: The Danish building regulations use the factors 1,0 and 2,5 as simple weighting factors. Passive house by PHI assumes 1,1 for e.g. gas, i.e. a "real" primary energy factor, making a difference of 10% when comparing limits for primary or weighted energy demand
- There exist some assumptions for indoor temperature for determination of the energy demand (22 ºC for PEB by FEBY, 21 ºC in Finland otherwise generally 20 ºC)

Performance monitoring

- There are very few requirements for monitoring
- Normally only electricity and heat consumption are monitored (mainly for charging the energy costs for each dwelling)
- Still more common: pressurization test for air tightness

# 5 PRINCIPLES OF A VERY LOW ENERGY HOUSE IN NORTH-EUROPEAN CLIMATES

## 5.1 General design rules

The basic rules for designing buildings with very low energy consumption are:

1. Minimise losses and consumption,
2. Maximize gains and
3. Substitute the remaining energy need with renewable and environmental friendly energies.

There are several possibilities to reach the low energy consumption: using the combination of all three parts – minimise losses, maximize gains and substitute energies – or optimising mainly one of these. However, in the Northern Europe – and of ever increasing importance when the location is on a higher latitude – all these three factors must be optimised in order to reach the design that is equal with the low energy consumption: The final building design is a sum of many different factors, depending on the strategy that has been chosen. . However, effective solar shading of windows may have to be used in order to avoid overheating, especially in spring and autumn. This technical base goes along with the economic opportunities of the builder and should end in a very high comfort for the user and a long-term maintenance of value of the building for the owner.

To know the possibilities for building a very low energy house it is important to know the energy flux around the system house (Figure 7 and Figure 8). The space heat demand for the heat supply is a *sum* of the transmission and ventilation losses *minus* the internal and external gains *multiplied* with the utilisation ratio (how much of the gains can be used) – see Figure 7. To the heat demand must be added the domestic hot water demand. The house has also electrical demand for household appliances, lighting, auxiliary devices and for fans and pumps. The total primary energy use of the building includes also the transportation and transformation losses for the delivered energy and is calculated with using some weighting factors (see Figure 8).

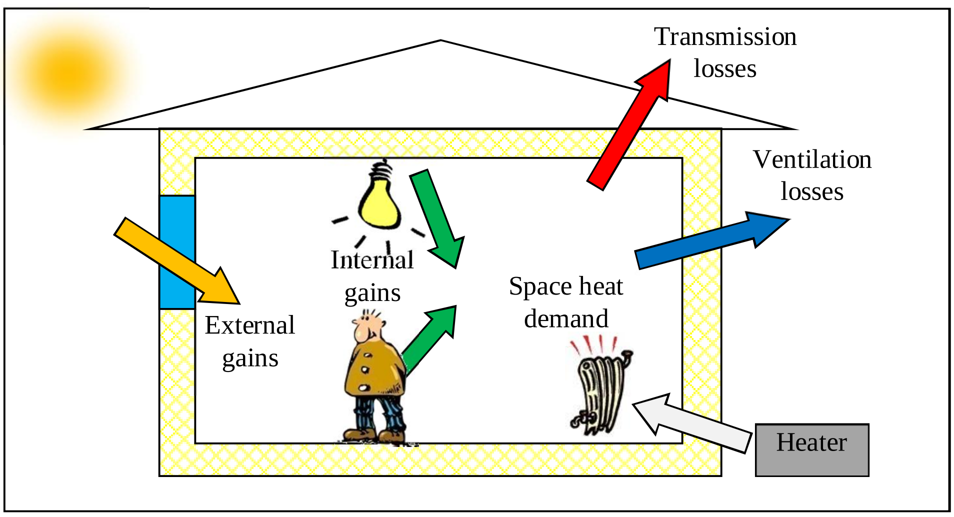


*Figure 7. Space heat demand as result of the energy flux in the building*

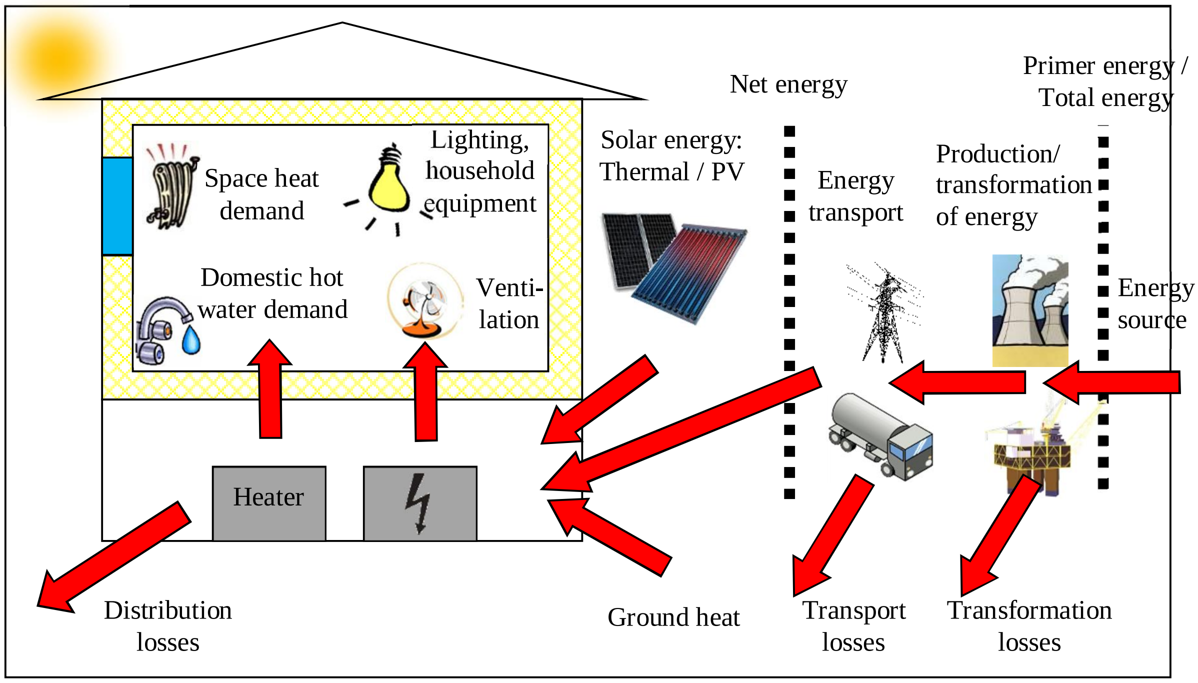


*Figure 8. Energy flux for a building(-system)*

The principles of a very low-energy house can therefore be defined quite simple: One has to try to reduce the heat losses and to cover as much as possible of the remaining losses by the heat gains. All this is realized by optimising the building envelope and/or the building services (Figure 9).

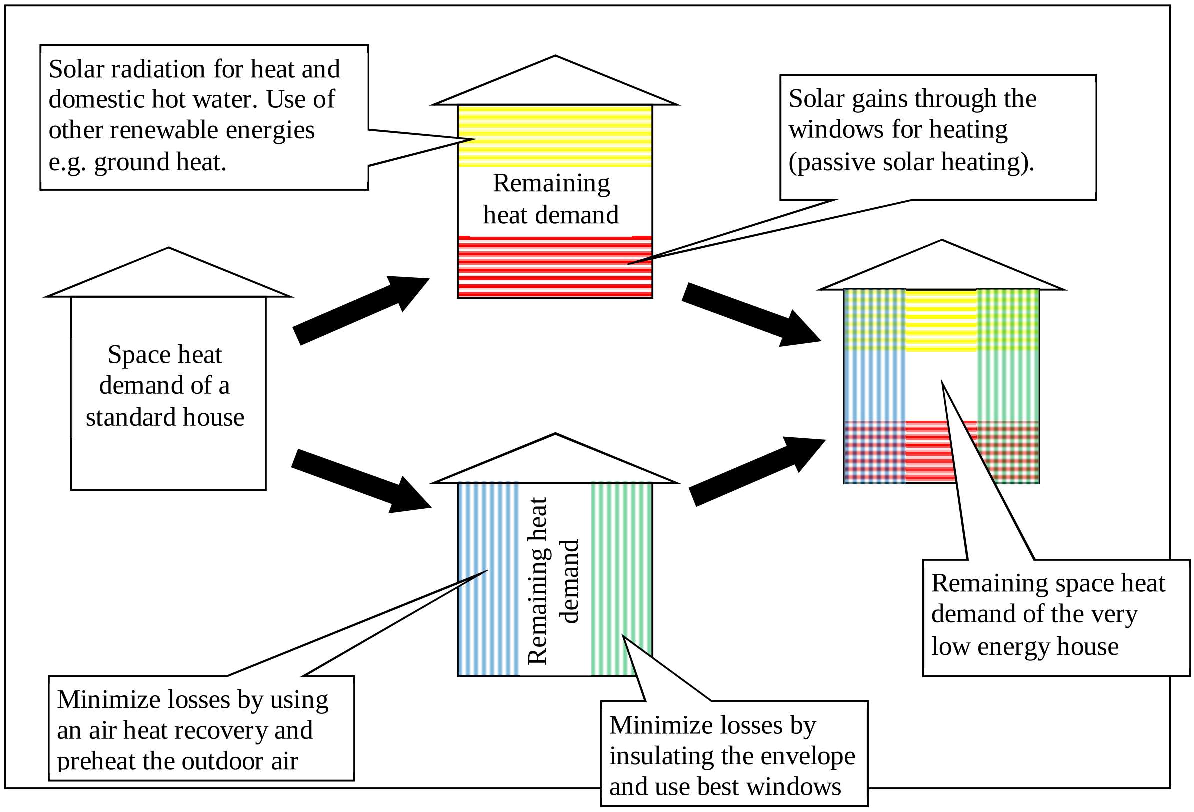


*Figure 9. Interaction of building service and envelope with minimize losses and optimizing gains. (Figure based on a paper of Jenni Energietechnik, Switzerland)*

NorthPass report "*Principles of low-energy houses applicable in North European countries and their applicability throughout the EU*"show the state of the art and some views into the future of these important foundations of the very low-energy building. It is important to see the building as a system to be optimised, not just a sum of components. Therefore, all these aspects must be considered in the very early phase of the design. A short overview of the main principles is presented below.

### 5.1.1 Minimize losses by the building envelope

The central design rules of minimizing losses of a low energy house regarding the building envelope are (Figure 10):

- low U-values of both opaque constructions and windows
- minimal thermal bridges
- good air tightness of the envelope
- low ratio of thermal envelope to building volume (A/V)

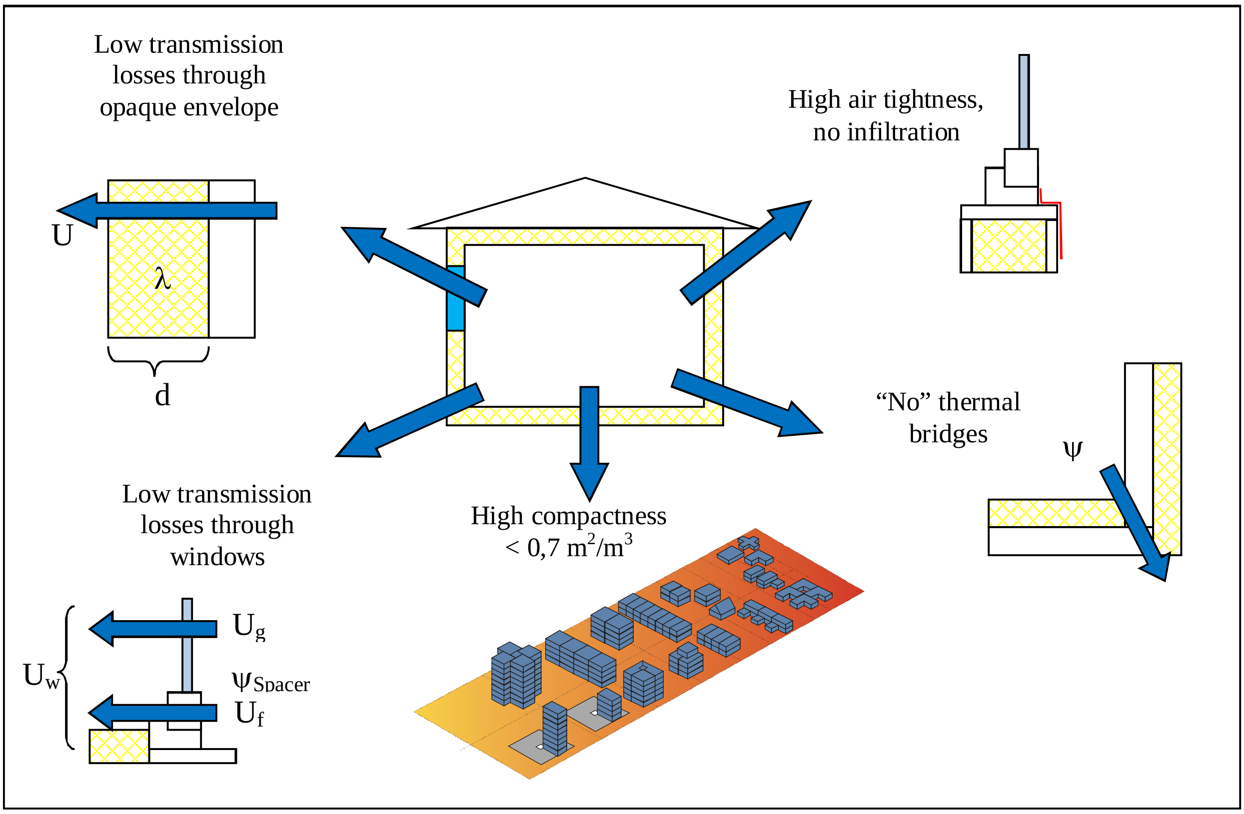


*Figure 10. Important rules for minimizing heat losses*

### 5.1.2 Minimize losses by the building system

The ventilation rate is usually given by the building regulations and should provide a good indoor air quality. As the reduction of the ventilation rate is not generally recommended, the only way to reduce the ventilation heat losses is to introduce heat recovery of the ventilation. Because of the very low in/exfiltration rates of an air tight building, most the ventilation – and the losses, too – can be controlled.

The ventilation heat loss is the heat energy, which is not recovered by the air handling unit. Figure 11 illustrates the magnitude of the heat recovery to the space heating demand of a building. The effect of a good heat recovery is significant because the losses are the difference between the heat recovery effect and 100%. That means, that the losses are doubled by using a 80% heat recovery unit (100% - 80% = 20%) instead of a 90% heat recovery unit (100% - 90% = 10%).

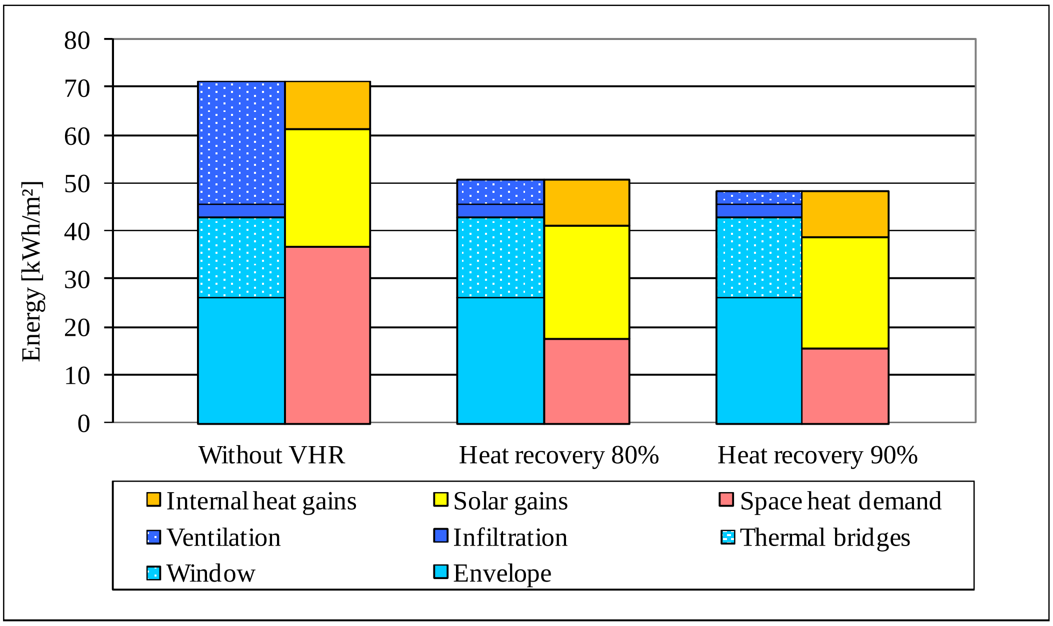


*Figure 11. Energy balance (kWh/m$^2$) without heat recovery (VHR), with 80% and with 90% heat recovery calculated for a single family house.*

Beside the very good thermal insulation of the building's thermal envelope, the attention must also be paid on the reduction of the heat losses from the distribution of heat and domestic hot water. The basic principles of the efficient domestic hot water distribution installations in a very low energy house are:

- Use short distribution distances
- Use well-insulated pipes, pumps and valves
- Use low temperatures.

### 5.1.3 Maximize gains by the building envelope

Utilization of the solar heat is the main way to gain free heat in a residential building. There are two dominating factors:

- Orientation of the building/windows and
- Properties of the window glass.

For a very low energy building, the intensive use of gains of solar radiation is essential. The most effective way to utilize the solar gains is to optimise the building for the winter time and protect the building from too much solar gain through the summer by solar shading.

To reduce the temperature peaks during warm, sunny days, thermal mass of the building should be high enough. In this way, the solar excess energy can be accumulated through the day and emitted through the night. However, usually the thickness above 100 mm of the heavy constructions does not add to the effective thermal mass. When the solar gains are effectively controlled with proper window and shading design, the thermal mass is less important in a very low energy house.

The windows and especially the window frames cause a significant part of a heat losses of the thermal envelope due to the relatively high U-values of windows compared to the opaque parts. On the other hand, the window glass enables the utilization of the passive solar gains. The window glass g-value (solar heat gain coefficient) [-] determines how much of the power of the solar radiation goes through the glass. From the solar gain optimizing point of view, the g-value should be as high as possible. At the same time, the U-value should be as low as possible in order to minimize the heat losses.

Internal heat gains (heat from persons and electrical appliances) are not usually a subject for optimisation as the heat load from electrical appliances should be minimised in order to keep the total energy use of a building low, too. A common misunderstanding is that extreme low energy houses are heated by increasing the use of electrical appliances and letting them be switched-on. Therefore, only the ways to optimise solar gains are relevant.

The central design rules of optimising gains of a low energy house regarding the building envelope are:

- Optimal orientation of the windows
- As little fixed shading as necessary (but with an external flexible shading)
- Glass size and type according to the climate, place and orientation.

The optimal window orientation, size and glass type are a function of the actual building design, location and climate, and must therefore be found for every project. In the future product development, the focus will be e.g. on a glass with a high level of transparency and a low U-value.

### 5.1.4 Maximizing/using environmental gains by the building system

Besides minimizing the energy demand, supplying the rest energy needs in an efficient and environmentally friendly way, are the main principles of a very low energy building. An efficient and intelligent control of the building systems is an essential part of these principles: No heat and no electricity should be used unmotivated!

A simple building control system is to use single room temperature controllers for the heat supply such as floor heating or radiators. That can control heat supply by considering the gains entering each room. It is possible to use a flow controlled temperature control on the heat plant that gives warmer flow by lower outside temperatures.

There are of course more advanced management systems e.g. KNX[2]-devices on the market. They cross-link all control and the energy supply functions. The advantage is that all building techniques, home appliance and light are connected. In present time, these kinds of systems are still expensive, but innovative and flexible.

The energy losses of a building should be covered using as much renewable and environmental friendly energy as possible. By making use of e.g. solar earnings there is a possibility to a fully or partly substitution of conventional energy sources which have to be paid and carried on from distance. It is of course necessary to have enough sun on the building.

There are two established ways to utilize active solar energy on site to produce:

- thermal energy by solar panels
- electricity by photovoltaics (PVs)

The solar panels can have energy efficiencies around 50% but the annual production depends on the heat losses and thus the exterior temperature, and if there is a need for hot water as the same time as there is production. Photovoltaics producing electricity can have energy efficiencies around 5-18%[3]. The system itself has a smaller efficiency because of transport and transformation losses. There also exist products on the market already now that combine these two energy producing technologies in one system as a hybrid solar panel.

In many cases it is possible to gain some energy for free by using a ground source heat pump. The source can also be ground water or waste heat or energy in a distribution network. The advantage of all these sources is the quite high temperature level on the primary side (on the contrary to an air heat pump). This results in a better annual coefficient of performance (COP). The resulting COP depends on the actual temperatures in the system on the site.

## 5.2 Influence of the cold climate on building design

Besides general design rules for very low-energy houses, the NorthPass report "*Principles of low-energy houses applicable in North European countries and their applicability throughout the EU*" also presented the influence of the Northern European climatic challenge on the very low energy building design and the solutions on the building envelope and building services.

### 5.2.1 The building envelope and energy

As a base for the calculation, two already rather optimised low energy buildings were defined: a single family house and a multi-family house. Detailed information of these concept houses and calculation results is presented in NorthPass report "*Energy-demand levels and corresponding residential concept houses and the specific challenges of very low-energy houses in colder climates*". The Northern European exterior climate and its variation were used for an investigation of its influence on the resulting heat load and heat demand and the necessary average U-values.

[2] KNX is a standardised network communications protocol for intelligent buildings. KNX is the successor to, and convergence of, three previous standards: EHS, BatiBUS and EIB. The KNX standard is administered by the KNX Association. KNX separates the control functions and the energy supply from each other. All devices are connected to a bus with each other and can share data. The function of each bus is defined by their programming, which can be readily modified and adapted.

[3] http://www.thema-energie.de/energie-erzeugen/erneuerbare-energien/solarwaerme/auslegung-montage/wirkungsgrad-von-solaranlagen.html

Following two alternative thresholds were used for the calculations for the single family house and multi-family house, which were studied separately:

1. Fixed U-values

   → heat demand and heat load are variable (Figure 12 and Figure 13)

2. Fixed heat demand

   → U-values are variable (Figure 14 and Figure 15)

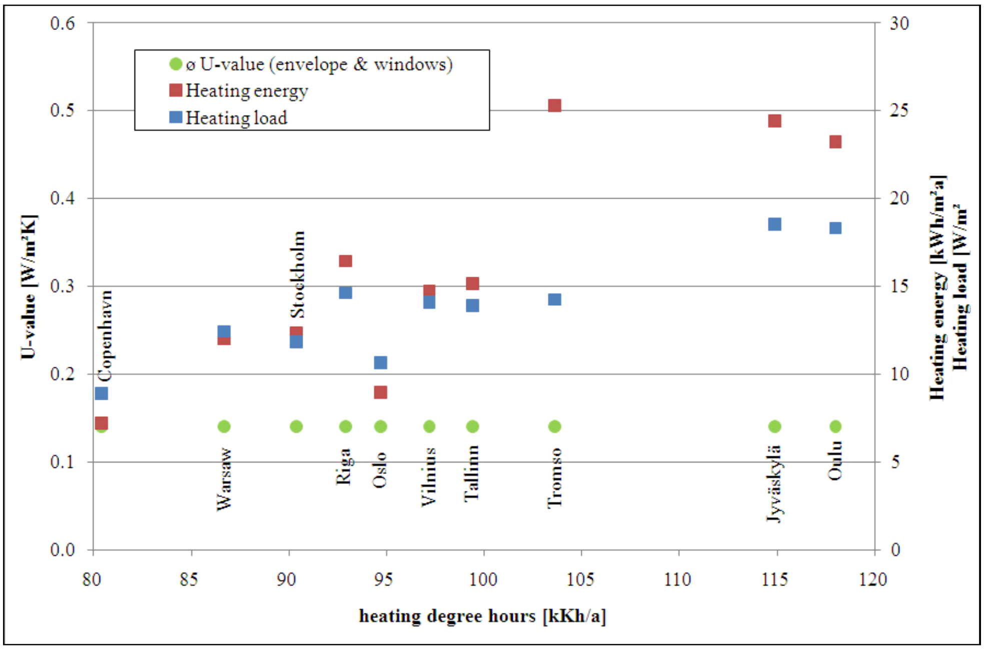


*Figure 12. Comparison of the single family house in the different climates. Envelope U-values are kept constant. U-value is an area weighted mean value of windows and opaque parts.*

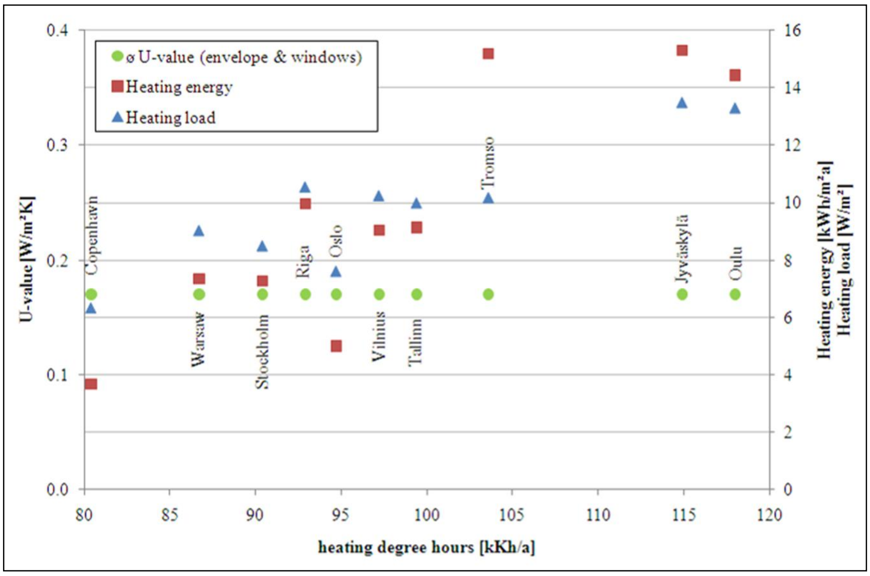


*Figure 13. Comparison of the apartment house in the different climates. Envelope U-values are kept constant. U-value is an area weighted mean value of windows and opaque parts.*

The calculations of the two building types showed that the space heat demand varies from 7 to 25 kWh/m²,a (single family house) and from 4 to 16 kWh/m²,a (multi family house) depending on the climate. To compare these conditions better, the space heat demand was fixed to around 15.4 kWh/m²/y and the U-values of glass, frame and opaque constructions were changed.

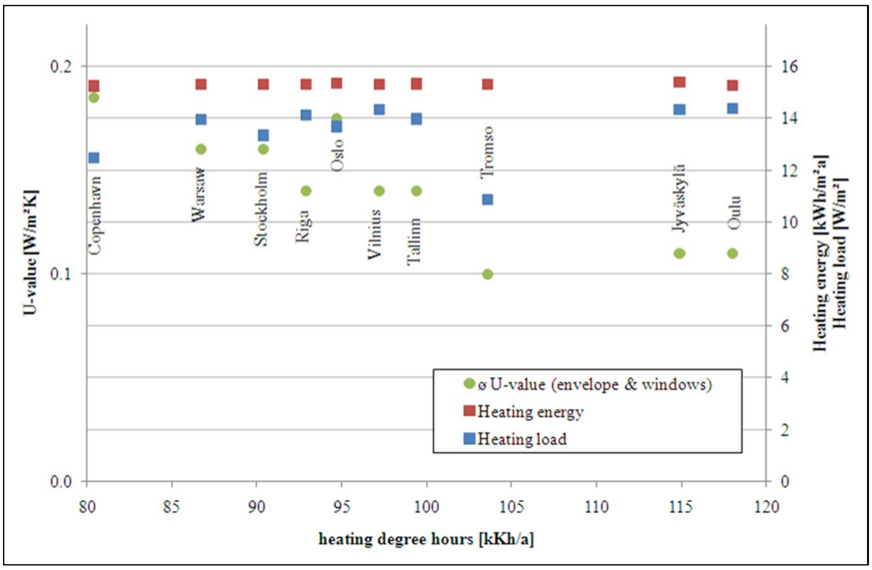


*Figure 14. Comparison of the single family house in the different climates. The heat space demand is kept constant and the envelope U-values are varied. U-value is an area weighted mean value of windows and opaque parts.*

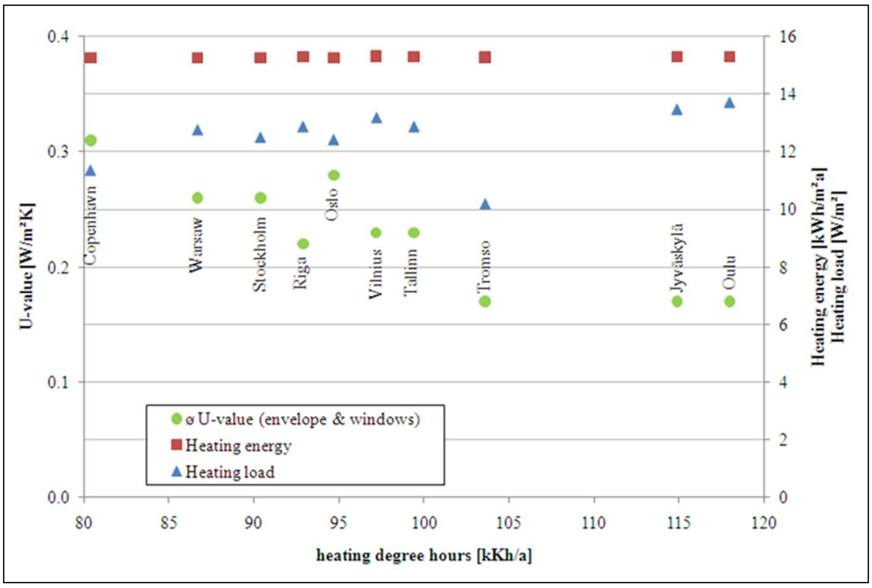


*Figure 15. Comparison of the apartment house in the different climates. The heat space demand is kept constant and the envelope U-values are varied. U-value is an area weighted mean value of windows and opaque parts.*

Keeping the space heat demand (heating energy) constant for all the weather stations, the needed variation in average U-values (including windows) was obvious: For increasing heating degree hours the U-values have to be lower in order to achieve the same heat demand. The variation for a single family house in the studied locations in Northern Europe was 0.1-0.19 W/(m²K)  This means that the weighted U-values needed to be halved in Jyväskylä, Oulu and Tromsø compared to U-values for Copenhagen and Oslo. These values related also quite directly with the solar gains and the outside temperatures.

### 5.2.2 Window as loss and gain-factor

The only envelope component, which can be optimised in two directions – smaller heat transmission or smaller solar transmission – is the window. To get a better view on the influence of the window characteristics on the heat balance an EN 13790 calculation model was used for the studied climates. The results showed that in most of Northern Europe the space heat demand decreases if the glass area to the south gets bigger depending on the quality of glass (Figure 16). There is an upper limit as to the window size, when you don't gain more. The break-through would be in Copenhagen with a glass U-value around 1.3 W/m$^2$K, in Vilnius around 0.8 W/m$^2$K and in Jyväskylä will it start under 0.4 W/m$^2$K. These values are linked with the frame area and installation / spacer thermal bridges.

For the north orientation it is not possible, even with very good windows, to get a better heat balance when using bigger glass area. The west and east orientations are much better than north, but it is still not possible to get a positive energy balance with glass U-values over 0.4 W/m$^2$K (still including additional thermal bridges and frame). However, the losses are rather small. It is extremely important in this context – when optimizing the main window areas to south – carefully to analyse the possible overheating in the summer time. The effect of external blinds, building heat capacity and internal gains has to be calculated and taken into account in the design.

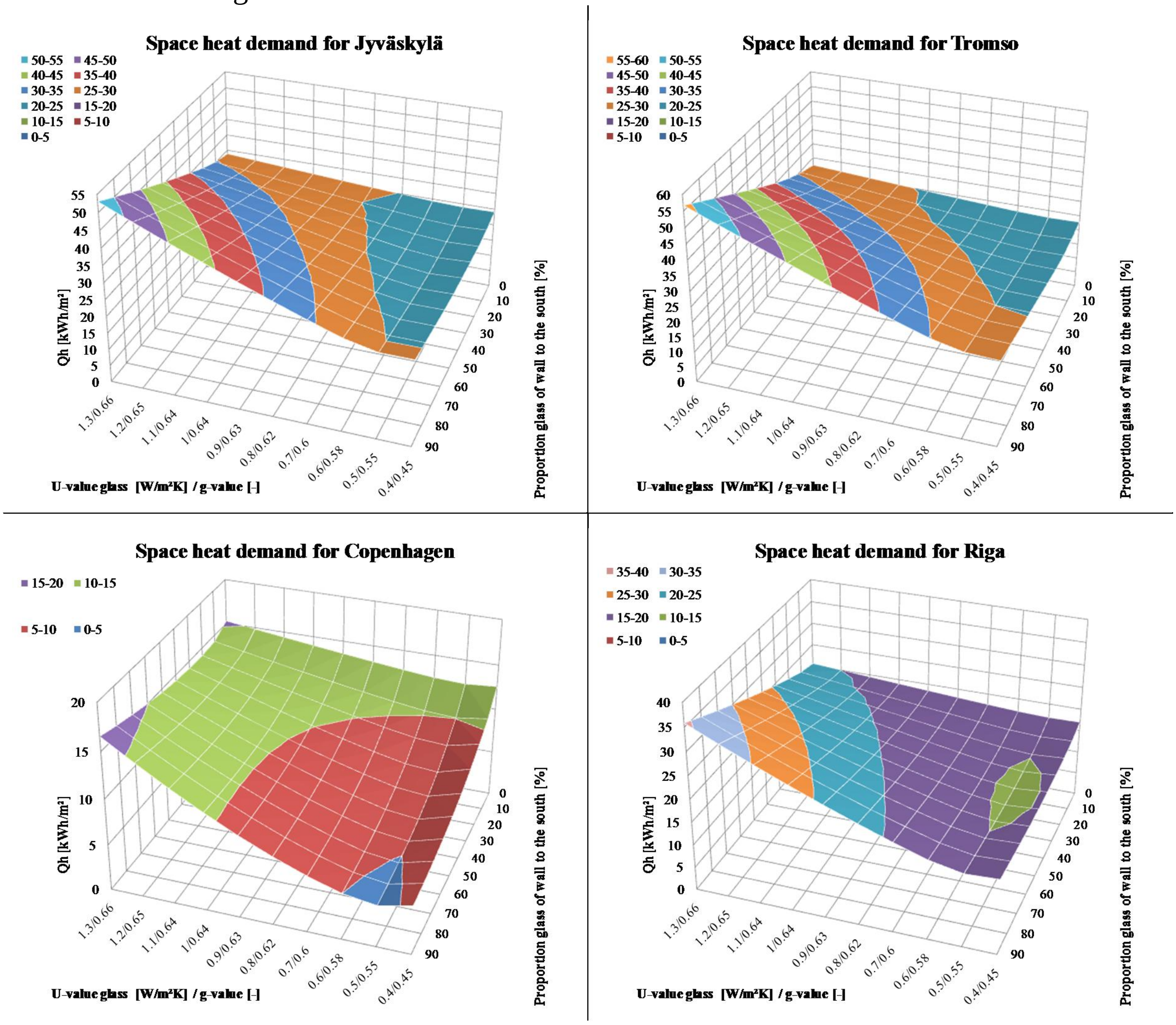


*Figure 16. Space heating demand of the single family house (kWh/m$^2$) as a function window g- and U-values (left horizontal axis) and the ratio of the window area to façade area (right horizontal axis). South oriented windows are studied. Fixed window size to every other orientation: N=1%, E=6% and W=6%.*

### 5.2.3 Interior surface temperatures

Cold interior surfaces can result in draught, growing of mould and worse condensate. Because of the low U-values of the constructions, there are almost no such problems in very low energy buildings. In addition to the well-insulated constructions, these buildings are built as far as possible without any thermal bridges. Regarding windows, draught will normally not be a problem for a 2 m high window when using a 3-layer glass, corresponding to $U_g < 0,8$ $W/m^2K$, and when the outdoor air temperature stays above 0ºC. The colder the climate, the lower must be the acceptable $U_g$, typically under 0.5 $W/m^2K$.

### 5.2.4 Limited potential for heating by supply air

The air has a relatively low heat capacity and sets therefore a physical limit for the heating of the supply air. The corner rooms far from the heating coil have typically

- Bigger heat loss due to the higher envelope ratio to the floor area and
- Heat loss over the supply air duct reduces the local heat load.

Therefore, for every room the balance of needed heat and heat supply by including heat losses over the duct and air volume have to be calculated separately.

### 5.2.5 Freezing of heat recovery

There exist many solutions to keep the heat recovery ice free. In an airtight very low energy house not all of these solutions are useable. Functions, which causes misbalance in the air flow and differences of pressure from outside to inside, must be avoided. To prevent freezing problems in heat recovery units it is recommended to use a ground-coupled heat exchanger to preheat the outdoor air. They have a slightly decreasing effect on the heat recovery rate, but the main advantage is that the energy for defrosting can minimized or left out. There are two common systems: earth-air ground source heat exchanger (earth tubes) or earth-brine ground source heat exchanger. After the ground source heat exchanger a high efficient heat recovery system should be used for recovering heat from outlet air to inlet air. If the temperatures after the liquid-to-air heat exchanger are too low for a plate heat recovery, a thermal wheel which also transfers humidity is the best solution.

Another way to protect the heat recovery against freezing problems is to use a combined humidity and heat exchanger. The excess humidity from the warm extract air is removed and added to the dry supply air before the heat exchange. In this way there is no water that can freeze. The limiting conditions are around -15°C to -20°C – depending on the used ventilation unit. These units are typically rotating systems, which have been working reliable. Also other types of combined heat and moisture exchangers have been developed and introduced.

### 5.2.6 Freezing of ground

As the result of the sub-zero winter temperatures in most parts of the Northern Europe, special attention has to be paid to the foundation system design. The low exterior temperatures combined with the relatively low heat losses to the ground from a very low energy house compared to a traditional building can result in frost damaged buildings if the insulation is not dimensioned correctly. There are different possibilities for solving the problem:

- Locating the building on bedrock or other soil types that have no risk of ice deformation. e.g. gravel or sand.
- Using bearing piles and ending them below the ice rich soil
- Adding sufficient perimeter insulation and design the size and thickness with dynamical simulations.

The existing guidelines for dimensioning the perimeter insulation are generally not updated for very low-energy buildings. Therefore qualified design, e.g. with dynamic 2D-simulations is necessary. The purpose of these simulations is to proof that the ground under the building – i.e. the pressure power field of the building – never freezes under the given design conditions (VTT 2007).

If operating in the area of permafrost, systems like thermosyphon foundations[4] can keep the ground frozen during the life span of the building. Over the last 50 years several types of thermosyphon foundations have been developed and used in Alaska and Canada. These consist of vertical cooling tubes and piles, sloping cooling tubes and flat looped tubes.

### 5.2.7 High summertime indoor temperatures

The focus in designing very low energy houses in the North European climates is naturally on the winter situation. However, to avoid any energy to be used for cooling needs, also the summer situation in a very low energy building must be as carefully designed as the winter situation. If the summer conditions are not taken into account consequently in the design phase, e.g. external blinds are missing; the indoor temperatures can become too high in warm sunny days. The use of external variable solar shading – typically blinds – is very common in Europe but not in Northern Europe. Nevertheless, for a very low energy house with optimised window area and orientation, external blinds are as important as a good ventilation heat recovery rate.

### 5.2.8 Electrical appliance

In a residential building, a big part of the energy is used for home appliances and lighting. The case is similar when relating to heating in standard new buildings and the primary energy demand. In comparison, the electrical use for appliances and lightning in very low energy buildings is usually bigger than the energy use for heating. The European Union introduced the white goods and lighting energy labelling scheme in 1995. Over time the label has been extended to several types – at least in summer 2010 also TVs. In order to reach also the primary energy targets of very low energy buildings categories A, A+ and A++ home appliances must be recommended.

## 5.3 Summary of the principles for very low energy buildings in the Northern Europe

The basis for these recommendations is the general guidelines and the performed parameter variation calculations for a very low energy building described NorthPass report "*Principles of low-energy houses applicable in North European countries and their applicability throughout the EU*". The calculated ranges (e.g. U-values) and other recommendations for the single family house and the apartment building are based on the following basic design rules, other reports and experience.

Opaque envelope: The U-values can theoretically vary a lot, totally depending on the whole building design, the energy targets and the local climate. However, the lower the U-values, the lower the heating energy demand. In Table 7 and Table 8 this range is presented for single family house and for a apartment house. The maximum U-values were taken from the ECOFYS report VII

[4] http://www.pws.gov.nt.ca/pdf/publications/Thermosyphon%20Foundations%20in%20warm%20permafrost%20.pdf

[10], see Table 2. The wall U-value was chosen from [10] because it also represented an average of ground and roof. The lowest U-value was calculated as a minimum for the studied buildings to fulfil the international passive house standard.

Windows: The window is the only part of the house, which has an effect both to the losses and the gains (with U-value / g-value). Even in the coldest and darkest climates investigated, an orientation to the South is preferable. Window orientation to the East and West very generally has a rather neutral influence on the heat demand. North orientation is always a loss when looking at the heat demand. The thermal quality of the window is decisive. Windows with moderate U-values might not reach positive energy balance in the coldest half of the year, even by South orientation. It is important to use external shading to prevent extreme summer situations, and to consider daylight and view in the window design

Heat recovery: The calculations showed that it is important to have the best possible heat recovery. To avoid freezing of the heat exchanger it is recommended in all Northern European climates to use a system to prevent freezing. One of the possibilities is to use a ground-coupled heat exchanger (direct or indirect).

Table 7 shows the summary of the main parts of the design values for a single family house (gross area appr. 172 m², $A_{envelope}/A$ = 2,4 m²/m² , $A_{envelope}/V$ = 0,74 $m^2/m^3$) when planning a very low-energy house in different Northern European climates.

*Table 7. Design rules and values for a single family house*

| | U-value opaque envelope | U-value glass | heat recovery | windows to south | windows to east/west | windows to north |
|---|---|---|---|---|---|---|
| | $W/m^2K$ | $W/m^2K$ | % | % | % | % |
| Jyväskylä | 0.06 – 0.15 | 0.4 – 0.5 | > 85 | 30-50 | < 10 | < 5 |
| Oulu | 0.06 – 0.15 | 0.4 – 0.5 | > 85 | 30-50 | < 10 | < 5 |
| Stockholm | 0.11 – 0.18 | 0.5 – 0.6 | > 85 | 40-60 | < 20 | < 5 |
| Oslo | 0.12 – 0.17 | 0.6 – 0.7 | > 80 | 40-60 | < 20 | < 5 |
| Tromso | 0.06 – 0.15 | 0.4 – 0.5 | > 85 | 30-50 | < 10 | < 5 |
| Tallinn | 0.10 – 0.17 | 0.4 – 0.5 | > 85 | 40-60 | < 20 | < 5 |
| Vilnius | 0.10 – 0.17 | 0.4 – 0.5 | > 85 | 40-60 | < 20 | < 5 |
| Riga | 0.10 – 0.17 | 0.4 – 0.5 | > 85 | 40-60 | < 20 | < 5 |
| Warsaw | 0.11 – 0.19 | 0.5 – 0.6 | > 85 | 40-60 | < 20 | < 5 |
| Copenhagen | 0.12 – 0.16 | 0.6 – 0.7 | > 80 | 40-60 | < 20 | < 5 |

Table 8 shows the summary of the main parts of the design values for an apartment building (gross area appr. 2450 m², $A_{envelope}/A$ = 1,12 m²/m² , $A_{envelope}/V$ = 0,38 $m^2/m^3$) when planning a very low energy house in different Northern European climates. The building has five floors.

*Table 8. Design rules and values for an apartment building.*

| | U-value opaque envelope | U-value glass | heat recovery | windows to south | windows to east/west | windows to north |
|---|---|---|---|---|---|---|
| | $W/m^2K$ | $W/m^2K$ | % | % | % | % |
| Jyväskylä | 0.08 – 0.15 | 0.4 – 0.5 | > 80 | 30-50 | < 10 | < 5 |
| Oulu | 0.09 – 0.15 | 0.4 – 0.5 | > 80 | 30-50 | < 10 | < 5 |
| Stockholm | 0.14 – 0.18 | 0.6 – 0.7 | > 80 | 40-60 | < 20 | < 5 |
| Oslo | 0.16 – 0.17 | 0.6 – 0.7 | > 75 | 40-60 | < 20 | < 5 |
| Tromso | 0.08 – 0.15 | 0.4 – 0.5 | > 80 | 30-50 | < 10 | < 5 |
| Tallinn | 0.11 – 0.17 | 0.6 – 0.7 | > 80 | 40-60 | < 20 | < 5 |
| Vilnius | 0.11 – 0.17 | 0.6 – 0.7 | > 80 | 40-60 | < 20 | < 5 |
| Riga | 0.12 – 0.17 | 0.5 – 0.6 | > 80 | 40-60 | < 20 | < 5 |
| Warsaw | 0.13 – 0.19 | 0.6 – 0.7 | > 80 | 40-60 | < 20 | < 5 |
| Copenhagen | 0.16 – 0.17 | 0.6 – 0.8 | > 75 | 40-60 | < 20 | < 5 |

# 6 IMPACT AND SAVING POTENTIAL OF NORTH EUROPEAN VERY LOW-ENERGY HOUSES IN NORTHERN EUROPE

## 6.1 Calculation methods: LCA, LCC and CBA

NorthPass project used primary energy and carbon dioxide as indicators for the environmental and climatic impact. The environmental assessment used the Life Cycle Assessment (LCA) methodology, suitable for studying global and certain regional environmental impacts by calculation and evaluation of the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle.

Environmental Life Cycle Assessment (LCA) calculates and evaluates the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle (EN-ISO 14044: 2006). Environmental inputs and outputs refer to demand for natural resources and to emissions and solid waste. The life cycle consists of the consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal. LCA is sometimes called a "cradle-to-grave" assessment.

An LCA is divided into four phases. In accordance with the current terminology of the EN-ISO standards, the phases are called goal and scope definition, inventory analysis, impact assessment, and interpretation (Figure 17).

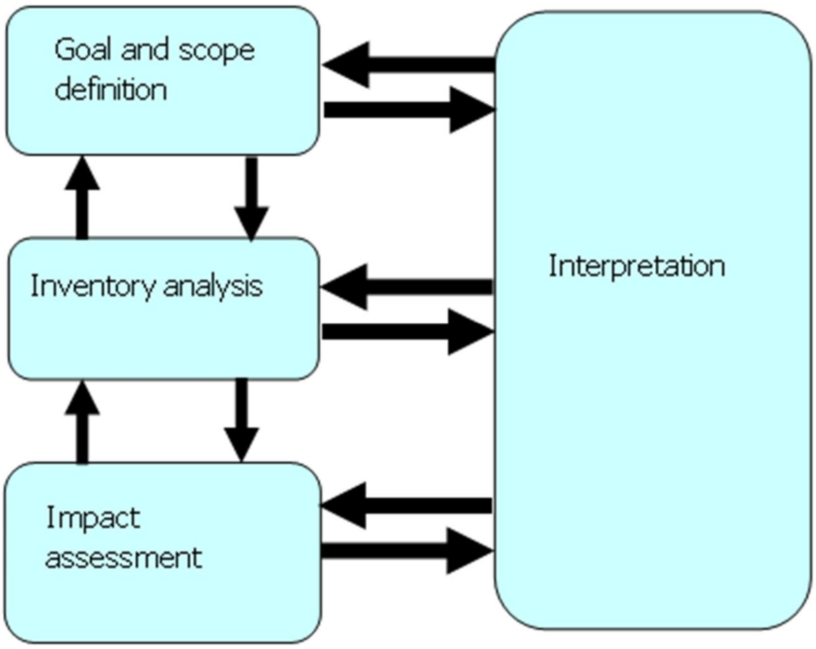


*Figure 17. Phases of LCA*

In the first phase the purpose of the study is described. This description includes the intended application and audience, and the reasons for carrying out the study. Furthermore, the scope of the study is described. This includes a description of the limitations of the study, the functions of the systems investigated, the functional unit, the systems investigated, the system boundaries, the allocation approaches, the data requirements and data quality requirements, the key assumptions, the impact assessment method, the interpretation method, and the type of reporting.

In the inventory analysis, data are collected and interpreted, calculations are made and the inventory results are calculated and presented. Mass flows and environmental inputs and outputs are calculated and presented. In the life cycle impact assessment (LCIA), the production system is examined from an environmental perspective using category indicators. The LCIA also provides information for the interpretation phase. The interpretation is the phase where the results are analysed in relation to the goal and scope definition, where conclusions are reached, the limitations of the results are presented and where recommendations are provided based on the findings of the preceding phases of the LCA.

An LCA is generally an iterative process. The impact assessment helps increasing the knowledge about what environmental inputs and outputs which are important. This knowledge can be used in the collection of better data for those inputs and outputs in order to improve the inventory analysis. The conclusions of the LCA should be compatible to the goals and quality of the study.

Economic modelling and assessment used the Life Cycle Cost analysis (LCC). LCC is an economic assessment that accounts for the total cost of acquisition, operation, maintenance, support and disposal of a product/system/service throughout its useful life. The purpose of life-cycle costing should be to quantify the life-cycle cost for input into a decision-making or evaluation process, and should usually also include parts from other evaluations.

LCC analysis should cover a defined list of costs over the physical, technical, economical or functional life of a constructed asset, over a defined period of analysis. Life cycle costing should also be influenced by non-construction cost and wider occupancy cost, as well as local, national or international policies, allowances, taxes, etc. LCC analysis may include allowances for foreseeable changes, such as future occupancy levels or changing legislative or regulatory parameters. LCC analysis may also form part of a strategic review of procurement routes or objectives (such as enhancing sustainability or improving functionality).

Practice can vary between users as to whether only cost borne by the customer for the analysis (typically the construction client) are taken into account, or whether customer/societal, etc. cost are also included. In NorthPass study, not only the business economic costs are included, but also the societal environmental cost will be included in a cost benefit analysis (see below). However, the business economic costs and the environmental costs were presented separately since the business economic costs and the environmental costs are of different character.

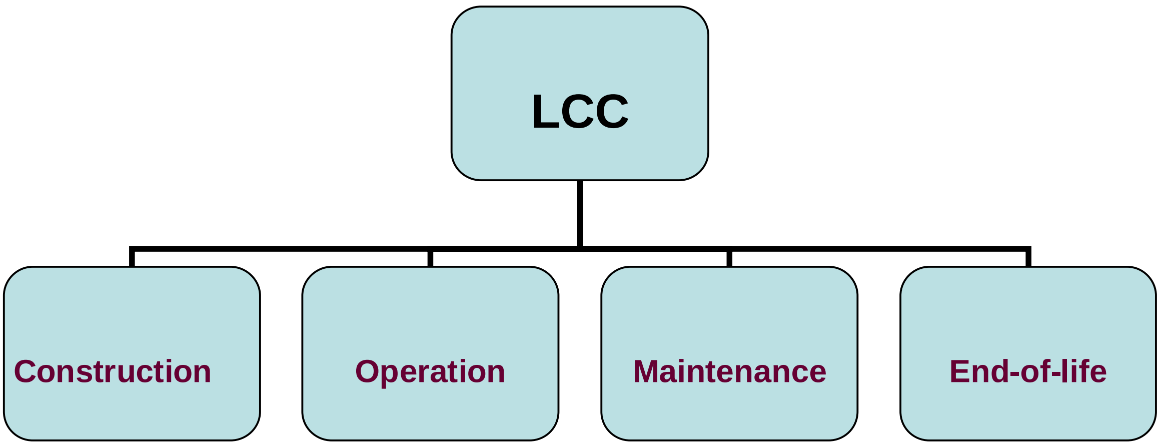


*Figure 18. Costs included in Life Cycle Cost analysis*

Since all costs in the LCC calculation are measured in present value, the costs from construction are the most reliable and certain cost of all. It basically means that the cost from the construction process is added and not calculated further. The cost from the operation is often assumed to have a certain cost every year that increases with consumer price index. The costs may include such things as costs for heating, electricity, hot water distribution and other functions that keep the buildings comfort and functionality on an everyday basis. This may also include costs for cleaning and caretaker services. The yearly cost will then be calculated to the present value, so that it is easily compared and added to the construction costs. The maintenance costs may come from assumptions regarding costs that do not appear on a yearly basis. This means costs for maintenance that is carried out with several years interval n and with different cost every time. This might be façade painting or exchange of tiles in a bathroom. As with the costs of operation the costs is calculated to present value for every year itself and then added to the construction cost. The End-of-life cost is basically the remaining value of the building after a certain amount of years. Depending on how many years, it varies. It is an estimation, and very dependent on factors that do not come from the building itself but from regional and political factors. After a fifty year period, the value of a property is mainly based on the location of the property.

Several tools have been developed to account for multiple dimensions of sustainability. In cost-benefit analysis (CBA), environmental are assessed in monetary terms, making them comparable to economic costs. The objective of a CBA is to evaluate the economic efficiency implications of alternative options for society. The benefits of an option are compared with its associated costs (including the opportunity costs). All costs and benefits should, if possible, be expressed in a common unit, and this is the monetary value, simplified one could say that a CBA puts a pricing on all impacts of the alternative option, so that “apples can be compared with pears”. In the projects studied in the NorthPass project, construction of conventional and very-low energy houses, both the production of materials and the use of energy gave rise to environmental consequences that involved costs for the society, which motivated that a cost benefit analysis was carried out. The private costs included in the study were for example investment and operation costs. To these costs the environmental costs, valuated in monetary terms were added.

It is difficult to measure and compare the environmental effects to those which are directly valued in markets. The main principle when valuing environmental costs or benefits is people’s willingness to pay for avoiding these costs or gaining the benefits. The CBA is affected by the time frame chosen for the analysis. The time frame is crucial for the present values of both costs and benefits and should therefore be carefully chosen so it can account for all the relevant differences in costs and benefits of the scenarios studied (Nordic Guideline for CBA in waste management 2007). As with all theoretical approaches aiming to compare a wide range of entities CBA has limitations and the method is sometimes criticized because of the limitations. One major limitation is the large uncertainty in the economic assessment of environmental and social impacts, and the credibility of the method is sometimes questioned because of this.

The use of a common unit for all effects, facilitating a comparison between costs and benefits is the main advantage of the CBA methodology. This makes CBA a decision-support tool and can be used to assess the effects of new policies or projects. This type of assessment can give information on which alternative that gives the highest benefit to society. However, one should keep in mind that not all information regarding policies or projects can be captured in a CBA. Therefore, a CBA should never be used uncritical and a CBA does not provide one single truth or a final truth.

## 6.2 Economic and environmental impact assessment of very low-energy house concepts in the North European countries

LCC, LCA and CBA assessments were made for 32 conceptual single-family and multi-family buildings – both conventional and very low-energy buildings, in Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Poland and Sweden.

For each of the countries included in the NorthPass project, totally four buildings were assessed; one single-family building and one multi-family building, built with as well very low-energy technology as with conventional building technology (specific for each of the partner countries). Comparisons were made between the single-family buildings and between the multi-family buildings for each of the included countries. No comparisons were made between the different countries.

For the purpose of the NorthPass project, two concept houses were developed, one single-family building and one multi-family building. The concept houses used in the economic and environmental impact assessment were very similar to the concept houses that were developed in previous chapters for studying the influence of the special conditions on the building design.

The building energy demand was assessed for a representative year in each country. This was performed using a computer simulation tool together with input data supplied by participants, generic and estimated data and local climate data. Buildings were modelled with the same internal area dimensions for every single- and multi-family building respectively. Energy simulations were performed in VIP Energy calculation tool. The calculations in VIP Energy are based on the EN-ISO 13790:2006 standard. Climatic data was obtained from METEONORM 6.1.

As an example, the LCC, LCA and CBA assessment results are shown below for the Danish single family house. The detailed input data and results for other concept buildings are presented in NorthPass report "Economic and environmental impact assessment of very low-energy house concepts in the North European countries" (D5).

### 6.2.1 Environmental impact assessment

*Figure 19 - Figure 22* present the LCA calculation results for a Danish single-family house. The potential contribution to global warming was higher for the buildings heated by district heating than for the electricity-heated buildings because the emission factor used for district heating in Denmark, 0.264 kg $CO_2$-equivalents/$m^2$, is higher than the emission factor of the Nordic electricity mix, 0.097 kg $CO_2$-equivalents/$m^2$, used for the electrical heating. However, the primary energy use of the electrically heated buildings was higher than the primary energy use of the buildings heated with district heating, because the primary energy factor for the Nordic electricity mix, 1.74 kWh/kWh, is higher than the primary energy factor 0.98 kWh/kWh of the Danish district heating mix.

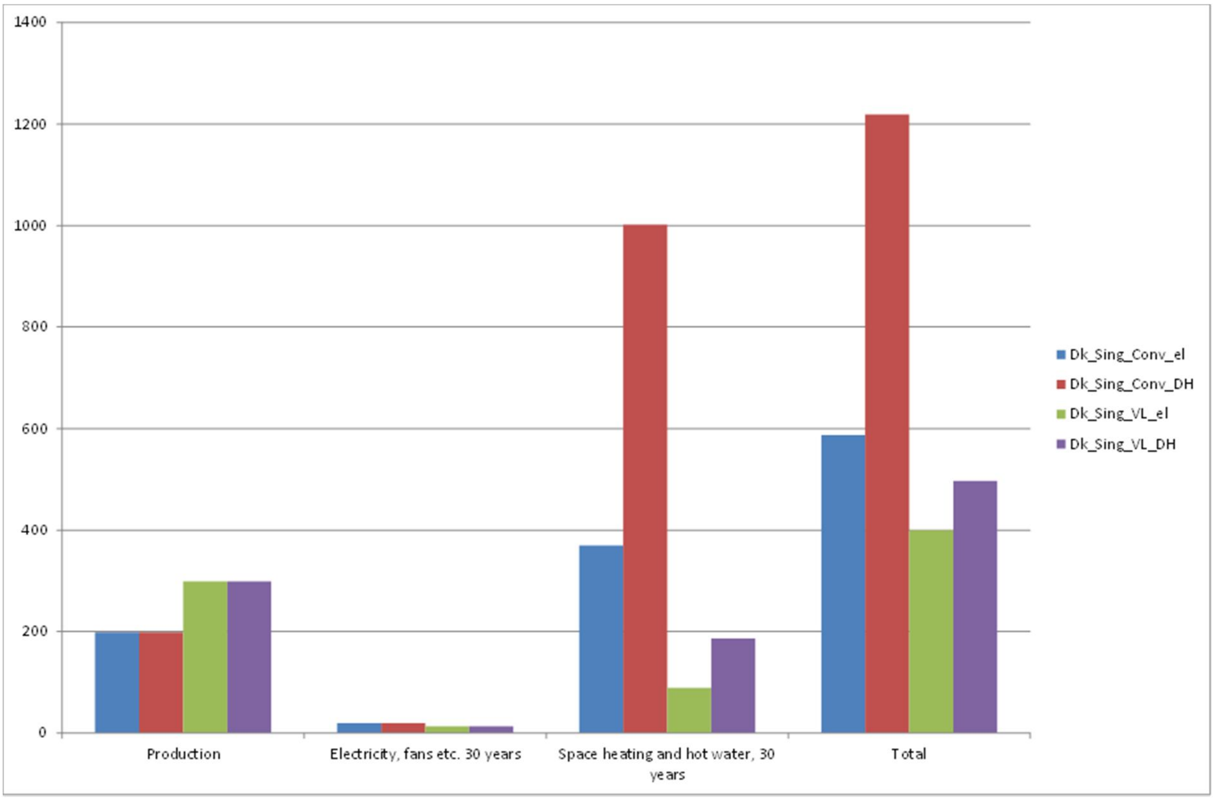


*Figure 19. Potential contribution to global warming for the Danish single-family buildings including 30 years of operation (kg $CO_2$-equivalents/$m^2$). Conv = conventional building, VL = very low-energy building, el = electrically heated, DH = heated through district heating.*

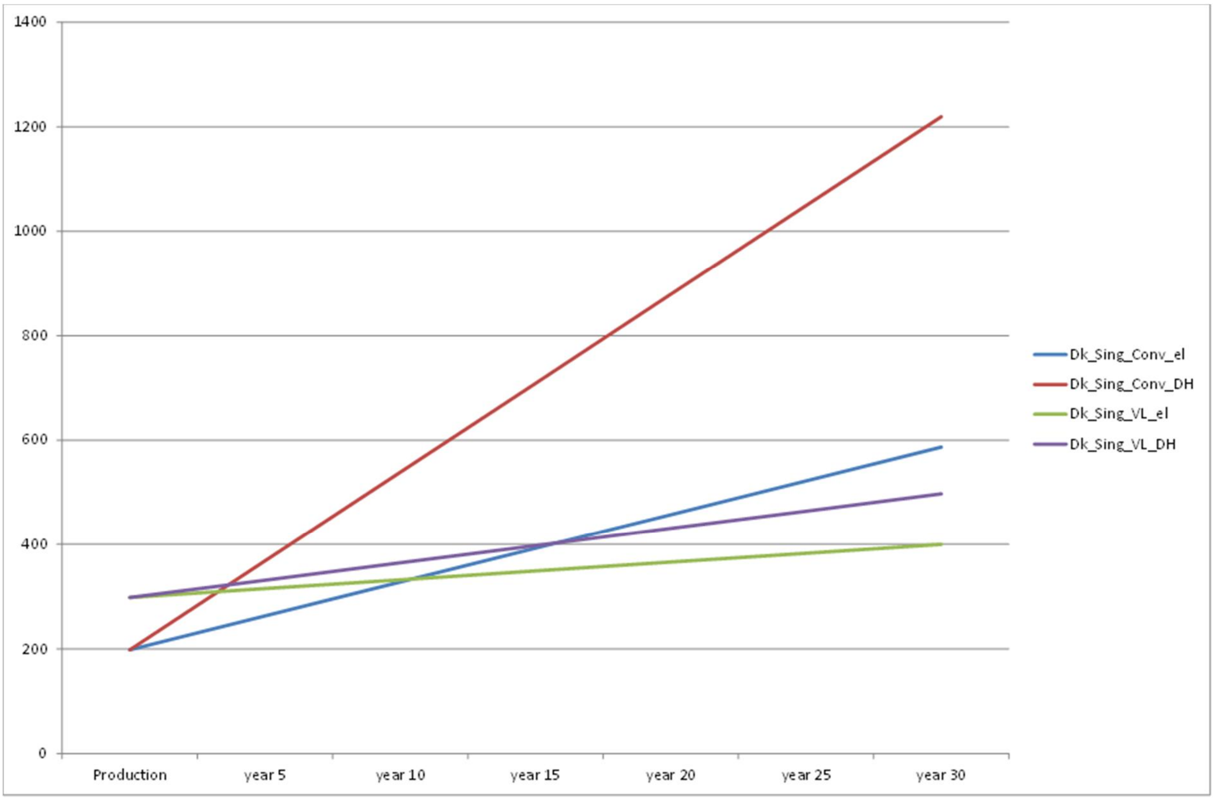


*Figure 20. Potential contribution to global warming for the Danish single-family buildings accumulated over the first 30 years of operation (kg $CO_2$-equivalents/$m^2$). Conv = conventional building, VL = very low-energy building, el = electrically heated, DH = heated through district heating.*

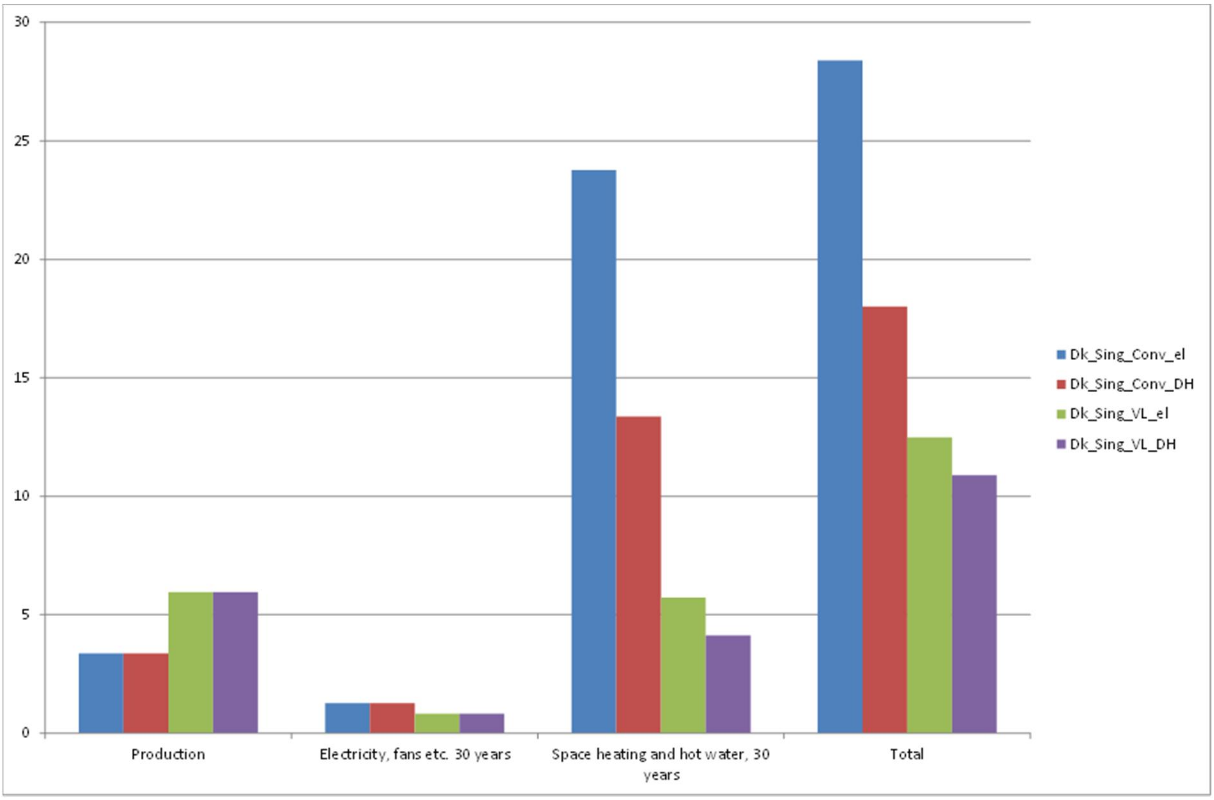


*Figure 21. Use of primary energy for the Danish single-family buildings including 30 years of operation (GJ/m$^2$). Conv = conventional building, VL = very low-energy building, el = electrically heated, DH = heated through district heating.*

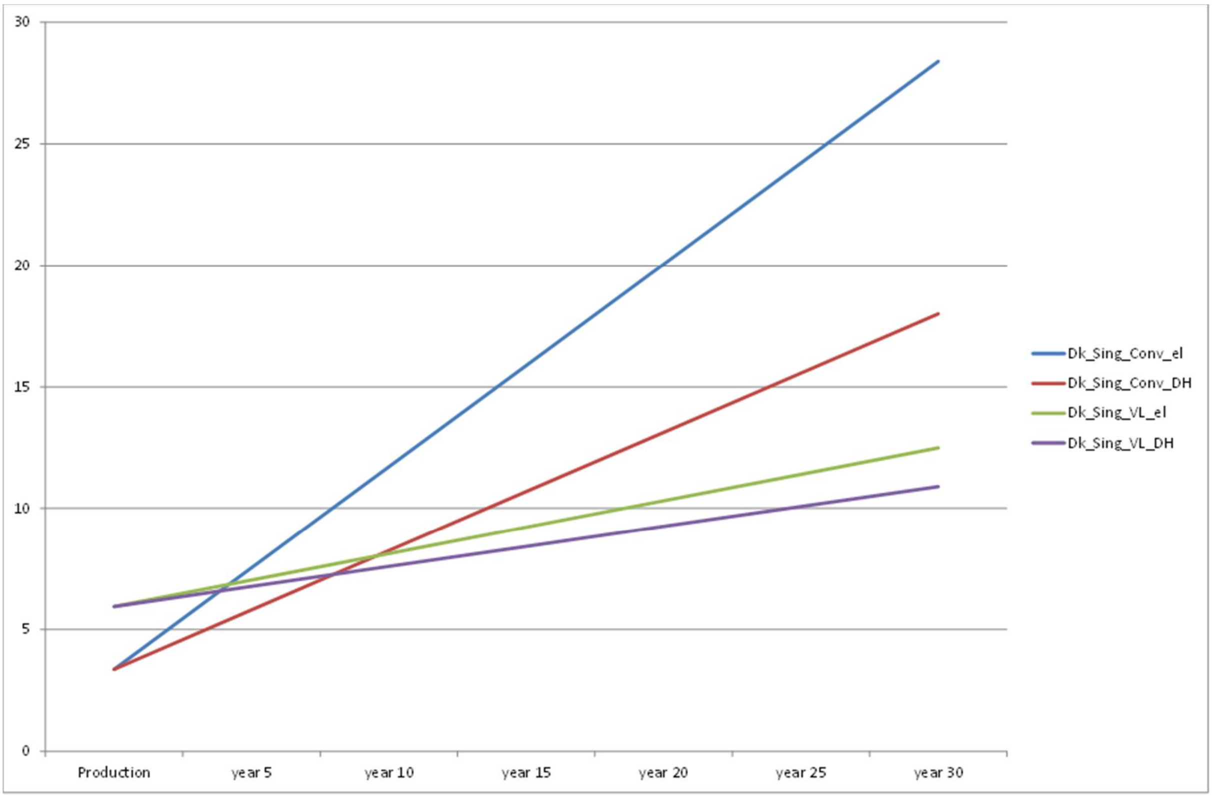


*Figure 22. Use of primary energy for the Danish single-family buildings, accumulated over the first 30 years of operation (GJ/m$^2$). Conv = conventional building, VL = very low-energy building, el = electrically heated, DH = heated through district heating.*

The results of all concept buildings show how the production of the very low-energy building gives a higher potential contribution to global warming and uses more primary energy than the production of a conventional building. The higher contribution from the very low-energy building is primarily caused by the use of more insulation in the foundation, exterior walls and attic joist. However, the potential contribution to global warming and the total use of primary energy is higher for the conventional building than for the very low-energy building due to the higher energy use during the operation.

The heating energy source has a great importance for the results. Thus, in order to reduce the impact to global warming and the use of primary energy, besides reducing the amount of energy required for the operation of the building, it is also important to choose an energy source with low greenhouse gas emissions and a low primary energy factor. The results demonstrate that although variations in building techniques, materials used, energy supply and heating system very low-energy buildings in general have a lower environmental impact compared to conventional buildings.

### 6.2.2 Economic impact assessment

The Life Cycle Cost Analysis was based on a time period of 30 years. The interest and yearly cost adjustment were defined for each country. The initial cost was the cost for constructing the building and it excluded the cost of the land lot and the connection fee to district heating system. Since the time period for the analysis was 30 years, no reinvestments were needed and the costs for reinvestments were excluded in the analysis.

Operation and maintenance cost were assumed to be yearly and the costs increased with the consumer price index for each country. Energy costs consisted of heating energy cost and electricity cost. The energy price development for the analysis period was divided into two different scenarios, one with a high price development and one with a low price development. The development curves for electricity and heating were different for each scenario.

For the Danish single-family buildings the low-energy building has a ground heat pump for energy base load and district heating for peak loads. The initial cost for the low-energy building is 10 % higher than the conventional building, but the energy use is about 70 % lower than the energy use of a conventional building. The life cycle cost for the conventional building exceeds the low-energy building cost after about 16 years in the case with high energy price development (Figure 23). Despite the much lower energy usage, the low-energy building has a higher life cycle cost in the scenario with a low energy price development (Figure 24).

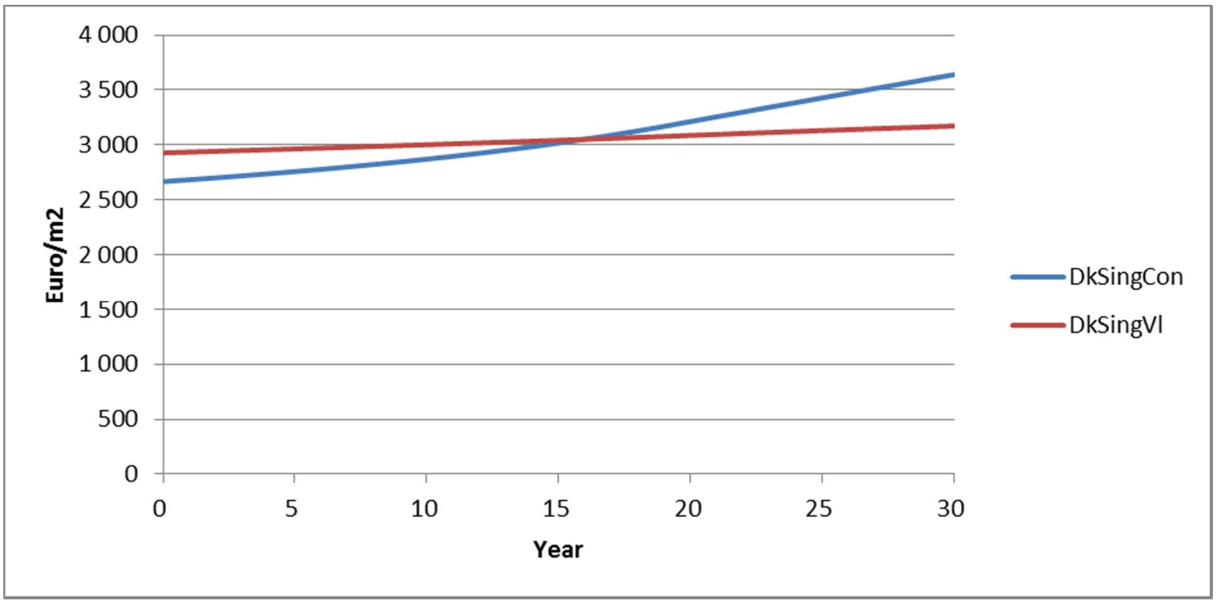


*Figure 23. Life Cycle Cost per square meter for the Danish single-family buildings for the scenario with high energy price development. Con = conventional building, Vl = very low-energy building.*

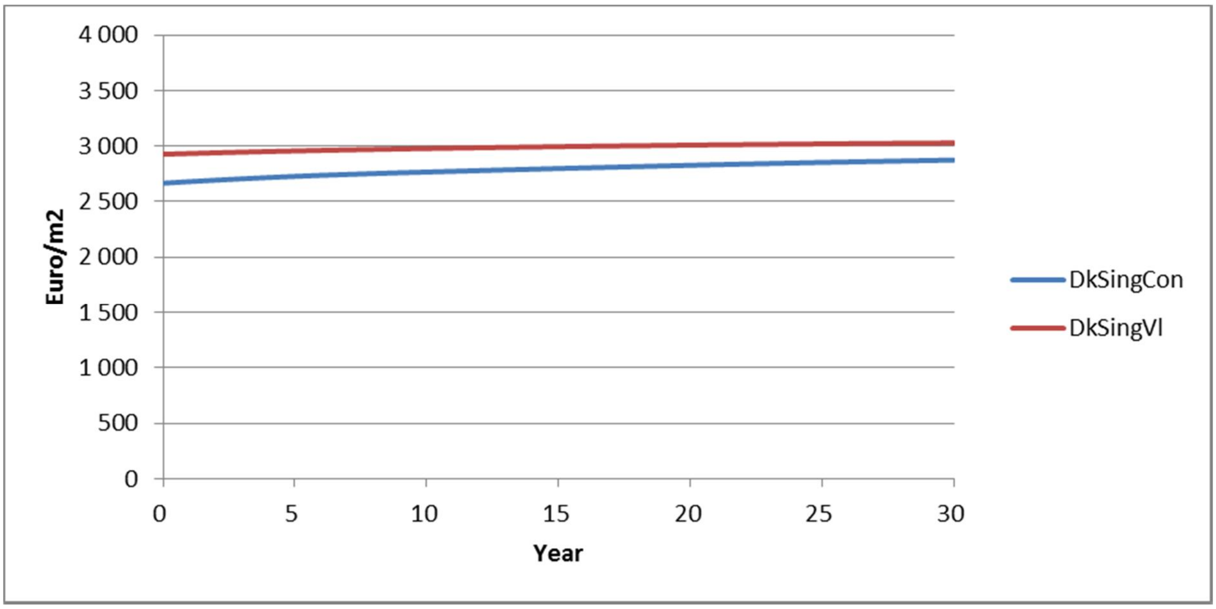


*Figure 24. Life Cycle Cost per square meter for the Danish single-family buildings for the scenario with low energy price development. Con = conventional building, Vl = very low-energy building.*

The accuracy of the life cycle cost analysis is dependent on the uncertainties in the input data and predictions of the future energy price development. The scenarios for the interest and for the energy price trend have uncertainties, since they are based on assumptions of the economic development the coming 30 years. Despite this, the economic assessment can provide useful information about the evaluated concept buildings.

In most cases the initial costs were higher for the low-energy buildings compared to the conventional buildings for both multi-family and single-family buildings. The initial cost for both multi-family buildings and single-family buildings differed between countries due to different labour costs, material prices, legislation, etc.

For the scenario with a low-energy price development the life cycle costs of very low-energy buildings were higher than the life cycle costs of conventional buildings. With the high energy price development scenario the life cycle costs of very low-energy houses were typically lower than the life cycle costs of conventional buildings after 30 years. This trend applied to both multi-family buildings and single-family buildings. These results show that the energy price trend development is an essential variable for the LCC result. With a high energy price trend most analysed very low-energy buildings were better investments than the conventional buildings with a timeframe of 30 years.

### 6.2.3 Cost benefit analysis

The simplified cost benefit analysis (CBA) of this study was based on the results from the life cycle assessment and the life cycle cost assessments, and the system boundaries were the same. Two different scenarios for the energy price were analysed in the economic assessment: a high price trend and a low price trend. The LCA was originally made for two different heating systems, district heating and electricity. In the CBA the results from the LCA with district heating were used. The LCC costs were also calculated for district heating.

Different methodological approaches can be used to monetize environmental effects in CBA. In this simplified CBA only emissions of greenhouse gases were monetized. In a comprehensive CBA other environmental effects, e.g. water emissions are monetized. This simplified CBA did not include all environmental costs and is thus an underestimation of the environmental costs. In the assessment it was assumed that the greenhouse gas emissions (unit kg $CO_2$-eq) were approximately equivalent to carbon dioxide emissions (unit kg $CO_2$). This is a simplification, because even though the greenhouse gas emissions mainly consist of carbon dioxide, there are also other greenhouse gases involved, e.g. methane.

For the monetization of the greenhouse gas emissions in this study three methodological approaches were used, the EPS method, the New-Ext method and avoidance costs. The monetary indexes of these methods are presented in Table 9.

The EPS method is a willingness to pay method (Steen, 1999). People’s willingness to pay to avoid damages on five safeguard objects is estimated. The safeguard objects are human health, the production of eco systems, abiotic stock resources, biodiversity and cultural and recreational value. The index for the EPS method is measured in Environmental Load Units, ELU:s. One ELU is equivalent to one Euro.

The New-Ext method gives an estimation of the external (environmental costs) of energy production (Pilz et al., 2007). The external costs vary on different geographical locations. In this report the index used for the New-Ext method is specific for Sweden (Pilz et al., 2007). It was assumed to be valid for the other NorthPass countries.

Avoidance costs represent costs that could be invested in something else to prevent the same amount of emissions. The index for avoidance costs that is used in this report was presented in Pilz et al., (2007). The index is based on the avoidance costs for carbon dioxide emissions in Sweden depending on the targeted carbon emission reduction in the Kyoto protocol (relative to year 2000). This index was assumed to be valid for the other NorthPass countries also.

*Table 9. Index used in the simplified CBA for the monetization of the GHG emissions*

| **Index** | **Cost, €/kg $CO_2$** |
|---|---|
| EPS | 0.108 |
| New-Ext | 0.044 |
| Avoidance costs | 0.075 |

Figure 25 and Figure 26 show the results for the Danish single-family buildings. For the low-energy price trend the conventional single-family building has lower total costs than the low-energy single-family building. The total costs refer to the economic costs and the environmental costs monetized with the EPS-method. For the high energy price trend the low-energy building has lower total costs than the conventional building.

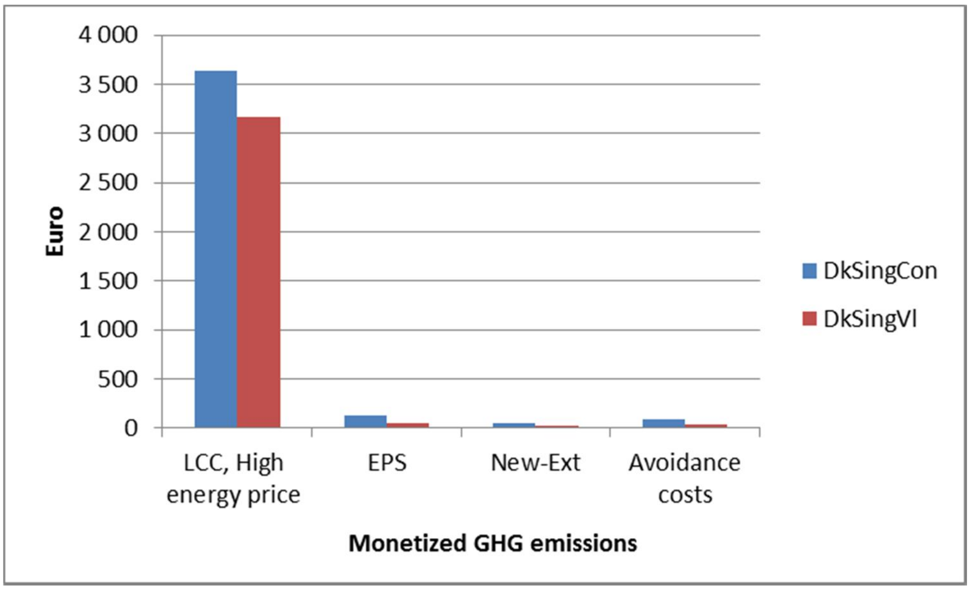


*Figure 25. CBA for the Danish single-family buildings with a high energy price trend. Con = conventional building, Vl = very low-energy building.*

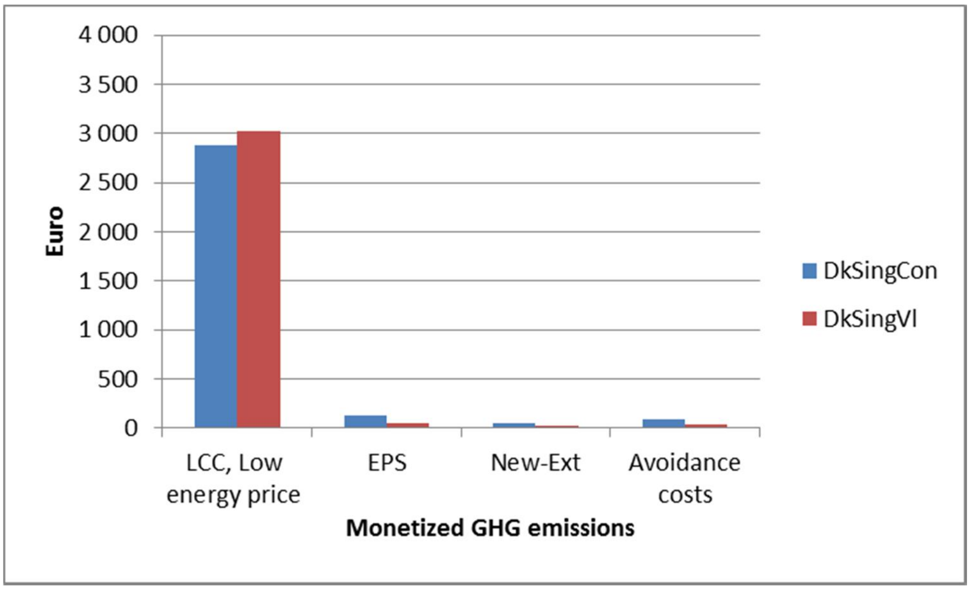


*Figure 26. CBA for the Danish single-family buildings with a low energy price trend. Con = conventional building, Vl = very low-energy building.*

As a simplified CBA method was used, the results do not present a single truth, but they can give some general information of the costs and benefits with the analysed buildings. The LCC result has a great influence on the CBA result. The energy price trend often dictates which building type has the lowest total costs. With a low-energy price trend the conventional buildings tend to have lower total costs, and with a high energy price trend the low-energy buildings tend to have lower total costs. Based on this study, if the energy price is considered to rise fast in the coming years, a very low-energy building is a good investment.

In general, the monetized greenhouse gas emissions were low compared to the economic costs for all methodological approaches. The EPS method gave the highest environmental costs and the New-Ext method the lowest costs. The choice of index for monetization of the environmental costs influences the result of the CBA. For almost all buildings the very low-energy buildings had lower environmental costs than the conventional buildings. This indicates that from an environmental point of view, a very low-energy building tends to be a better option than a conventional building.

## 6.3 NorthPassTool - a demonstration tool to promote very low-energy houses

NorthPassTool is a demonstration tool based on Excel spread-sheet developed within the NorthPass project. The aim of the tool is to give a simplified comparison between very low-energy and conventional houses in order to promote more energy efficient solutions with lower environmental impact. The tool can be used to give an overview of the different parameters affecting the economic and environmental impacts of the building. Other calculation methods should be utilized for detailed design purposes.

NorthPass report “NorthPass tool, a demonstration tool to promote very low-energy houses” presents the basic assumptions and methodology behind the demonstration tool, which was developed to promote very low-energy houses from an environmental and economic life cycle perspective. The user manual for NorthPassTool is integrated in the report.

The report also includes a catalogue with a description the building components available to choose from in the tool. These components are extracted from the contributions to the LCC and LCA calculations explained in the previous chapter.

The NorthPassTool was developed by IVL Swedish Environmental Research Institute based on the contributions regarding material choices, energy consumption and building and operational costs from all partner countries. The building details used in the calculator were gathered from all the participating partners in the NorthPass project.

In the calculator a building can be simulated and the building’s life cycle cost and environmental impact in terms of global warming potential are calculated and compared with a national reference building.  The national reference buildings are based on the input describing typical conventional buildings in each country and should not be confused with reference buildings used in national regulations.

The output in the calculator gives information about the buildings:

- Transmission losses
- Ventilation losses
- Heating demand (including solar and internal gains)
- Heat produced with solar collectors
- Electricity produced with solar cells
- Energy cost
- Global Warming Potential

The data regarding building components, operational costs and energy use was collected during 2010. Two concept houses one for single family houses and one for multifamily houses were used, allowing for variation on building component level to reflect different building traditions. Even if a variety of different building components were used in the NorthPassTool, the data is based on today’s building techniques and it may be the case that the tool will be less suitable for comparing conventional and very low energy houses when future building techniques change.

The functional unit is 1 $m^2$ heated floor area defined as the internal area conditioned by the heating system, which means that full width of the exterior walls are excluded. The Life Cycle for LCC and LCA was calculated for a time period of 30 years. The initial cost for a low energy house was set to be 10 % higher than the initial cost of a conventional house, based on the results of the NorthPass report "*Economic and environmental impact assessment of very low-energy house concepts in the North European countries*".

The user can choose the location and climate from ten different cities in Northern Europe:

- Copenhagen, Denmark (Dk)
- Jyväskylä, Finland (Fi)
- Kiruna, Sweden (Se)
- Oslo, Norway (No)
- Riga, Latvia (Le)
- Stockholm, Sweden (Se)
- Tallinn, Estonia (Est)
- Trondheim, Norway (No)
- Warszaw, Poland (Pl)
- Vilnius, Lithuania (Li)

Figure 27 shows the input data sheet of the NorthPassTool. The tool can be uploaded from the project website www.northpass.eu . The language of the tool can be chosen from the main languages spoken in the participating countries.

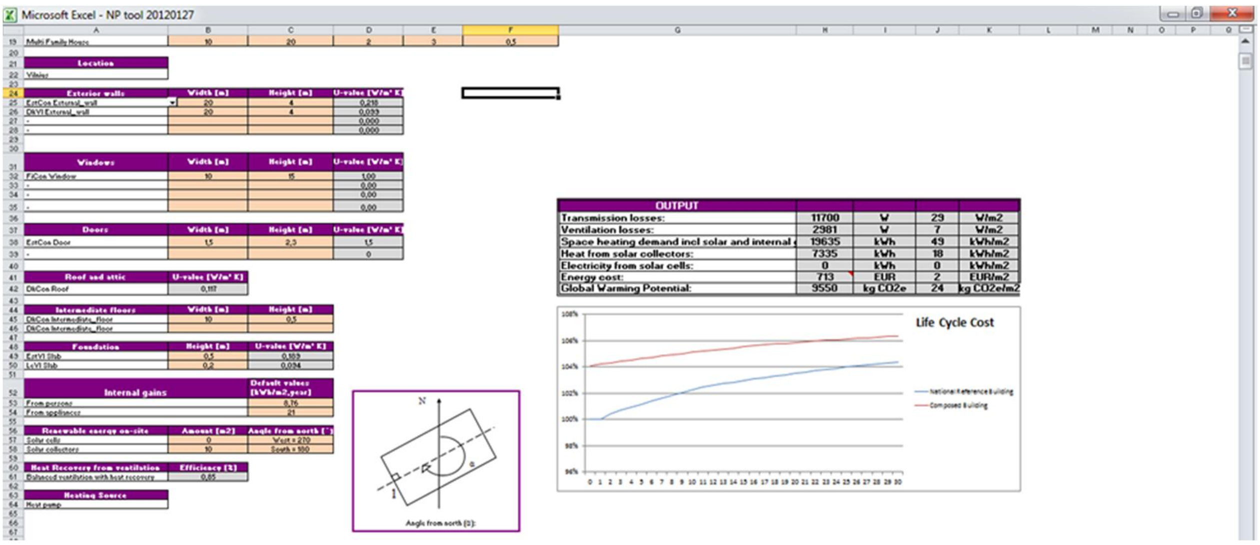


*Figure 27. Input data sheet of the NorthPassTool*

# 7 OVERCOMING BARRIERS TO IMPLEMENTATION OF VERY LOW-ENERGY HOUSES

## 7.1 Methods

Main technological and non-technological barriers to implementation of very low energy residential buildings were determined for the participating countries by means of problem detection studies (PDS) and literature studies. Every participating country organized a PDS meeting with a national group of experts. As a background the Swedish PDS was used.

A SWOT analysis was then carried out to structure the information and data prior to making suggestions on how to overcome the barriers. In the SWOT analysis the key questions were put enabling to assess and determine whether low energy housing will have real possibilities on the market and which are the limitations/barriers obstructing a market establishment. Each participating country also carried out a national SWOT analysis and made suggestions as to how to overcome the barriers.

The PDS method (Problem Detection Study) is a structured approach to estimate and determine existing problems with and basic requirements on a product, building, organization etc. (Engvall 2010). The method has previously been used in connection with market analysis's of different kinds but has been further developed by the city of Stockholm in connection with the evaluation of the built environment e.g. housing for elderly, housing for people with allergies, feedback from new construction, before reconstruction as well as for renewal of city districts. The method is distinguished from traditional questionnaires by the fact that the planned target group itself takes part in the choice and formulation of problems. This form of problem inventory can therefore reveal additional needs and solutions and give an impartial and detailed description of requirements e.g. on dwelling solutions and design.

In NorthPass project the method was adapted to low energy dwelling projects. A reference group of experts (users, building and HVAC consultants, installers, operations engineers, architects, property owners/developers/managers) was brought together for a first meeting in order to highlight the problems of today's low energy housing seen from their own perspective. From this first meeting an interview guide was compiled with the areas of problems and connecting keywords, which had been brought up during the meeting. This interview guide was then sent to the expert group, who checked that everything has been included and evaluated from their own perspective what was most important to highlight. It was also possible for the members of the expert group to add areas of problem, which were thought of after the meeting.

SWOT is an abbreviation of "Strengths", "Weaknesses", "Opportunities" and "Threats". "Strengths" and "Weaknesses" study internal resources of the product, in this case a residential low energy building, by comparing it with other products of the same kind, in this case other residential buildings. The key questions were:

- What are the main advantages of low energy residential buildings compared to traditional residential buildings?
- What are the main disadvantages of low energy residential buildings compared to traditional residential buildings?
- Issues addressed concerns financial, physical, human and technical resources, processes and brand.

"Opportunities" and "Threats" focused on external resources beyond the immediate control of the manufacturer e.g. opportunities and barriers posed by the surrounding world, such as the market, stakeholders, sociological and behavioural aspects, regulations, political influence etc. The key questions were:

- What are the major opportunities posed by the outside world for low energy residential buildings?
- What are the main threats to low energy residential buildings from the outside world?
- Issues addressed concerns influence by the industrial structure, stakeholders outside the client – manufacturer supply chain as well as the surrounding world.

## 7.2 Barriers and solutions to implementation of very low-energy buildings

Several problem areas were considered to have a high priority. Many of the problem areas were common for a number of countries: market, requirements/regulations, knowledge, costs, instruments of control, design, technical solutions/concepts, function/performance, user/behaviour and risks. There were no major differences in problems between the countries with several very low-energy residential buildings built and the countries with only a few. There is of course a difference in the number of good examples which influences the market, the level of knowledge and instruments of control. The magnitude of some of the problems is likely to be different. The non-technological problems/barriers were mainly within the following areas: market, requirements/regulations, knowledge, costs, instruments of control, responsibility, policy, society and incentives. These problems can be either perceived or actual problems. The perceived problems can often be solved with information.

The SWOT analyses resulted in potential internal strengths of low energy residential buildings valid for several participating countries: good indoor environment, low running costs, high energy efficiency, low LCC and a growing market.

Common potential internal weaknesses of low energy residential buildings were: inadequately spread competence to build, lacking robustness and quality, indoor environment problems, operation and use problems, bad experience of low energy houses and planning and designing mistakes. Some of these weaknesses e.g. lacking robustness and quality, indoor environment problems, operation and use problems can occur in traditional buildings as well.

To overcome the perceived or actual potential internal weaknesses of low energy dwellings several suggestions were made. Some suggestions were highlighted by several countries e.g.:

- Methods:
  - Introduce and apply LCC-analysis, which was mainly highlighted by the Baltic states and Poland
- Knowledge:
  - Feedback from previous knowledge; Update the educational level of designers and contractors; Introduce low energy house design at universities
- Market:
  - Publish more good examples, which was mainly highlighted by the Baltic states; Expand the market and import partly from and export to other countries; Increase the international market

There were many different potential external threats to low energy residential buildings. The threats differed from country to country; some however existed in two countries or more: low interest in low energy buildings, inadequate customer awareness and inadequate knowledge of construction.

To overcome the perceived or actual potential external threats to low energy dwellings several suggestions were made of which some were highlighted by more than one country e.g.:

- Market:
  - Market well documented good examples
- Incentives:
  - Political lobbying and information activities; Lobby for tax credits and specific loans

To promote low energy residential buildings it is important to:

- maintain and improve the strengths of low energy residential buildings
- minimise the weaknesses of the low energy residential buildings
- make use of the opportunities for low energy residential buildings
- forestall and neutralize the threats to low energy residential buildings

The following has to be fulfilled to ensure that a low energy house is accepted by the occupant:

- guidelines of use for the occupant
- information on the possibilities and function of a low energy house to the occupant
- the low energy house must:
  - be introduced to the occupants; function as expected; be user friendly; ensure good comfort; deliver expected energy savings; supply good living conditions

## 7.3 Availability of components for very low energy residential buildings on the North European Building Market

The NorthPass report "*Barriers to implementation of very low energy residential buildings and how to overcome them*", shortly presented in the previous chapter, concluded that in some of the participating countries there is to some extent a lack of suitable components for very low energy residential buildings. The report also stated that some of the existing products are not fully suitable for very low energy residential buildings. Besides, the components are not always easy to find.

Therefore a study was carried out to determine the state-of-the-art and need for further development of components for very low energy residential buildings in Sweden, Finland, Denmark, Norway, Poland, Latvia, Estonia and Lithuania. Analyses of existing very low energy buildings and reports on very low energy buildings were made. Designers and contractors of very low energy buildings were interviewed. Discussions were carried out with the expert groups involved in the NorthPass study on barriers to implementation of very low energy residential buildings and how to overcome them. The target groups were participants of the NorthPass project, designers, contractors and building industry.

According to this study, however, most components needed for very low energy residential buildings are available on the markets in Sweden, Finland, Denmark, Norway, Poland, Latvia, Estonia and Lithuania (Table 10). Most products for thermal insulation are available. Most airtightness products are available, except for in the Baltic States where only some products are available. Almost all countries have windows with a U-value lower than 0.6 W/m²K, except for Latvia with known best windows with a U-value lower than 1.0 W/m²K. Different kinds of solar shading systems exist in all countries. Entrance doors with a U-value lower than 1.0 W/m²K can be found in all countries. Structural frame components, which minimize thermal bridges, are on the market in most countries. Air-to-air heat recovery units should operate at an efficiency better than 80 %. Units fulfilling this requirement are available in all countries. Energy efficient heat pumps, pumps and household appliances are available on all markets. This is also true for heat distribution systems, domestic hot water heaters and control systems for very low energy houses. So far the demand for components for very low energy residential buildings is rather low. Whether there will be enough components in a growing market is difficult to know. The available components for very low energy residential buildings obviously have to be better marketed, to ensure that e.g. more designers are aware.

*Table 10. Availability of components for very low-energy residential buildings*

| Component | Sweden | Finland | Den-mark | Norway | Poland | Latvia | Estonia | Lithuania |
|---|---|---|---|---|---|---|---|---|
| Thermal insulation | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products |
| Airtightness products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, some products | Yes, of most products | Yes, some products |
| Windows | Yes, U-value 0.6 W/m²K | Yes, U-value 0.6 W/m²K | Yes, U-value 0.6 W/m²K | Yes, U-value 0.7 W/m²K | Yes, U-value 0.7 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value 0.65 W/m²K | Yes, U-value 0.7 W/m²K |
| Solar shading | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Doors | Yes, U-value 0.9 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value 1.0 W/m²K |
| Structural frame components | Yes, e.g. light studs | Yes, e.g. light studs | Yes | Yes | Yes | ? | Yes | Yes |
| Ventilation with heat recovery | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % |
| Heat pumps | Yes, COP > 3 | Yes, COP > 3, often oversized | Yes, COP > 3 | Yes | Yes, COP > 3 | Yes, COP > 3 | Yes, COP > 3 | Yes, COP > 3 |
| Heat distribution system | Yes | Yes | Yes, several products | Yes | Yes | Yes | Yes? | Yes |
| Pumps | Yes, efficiency 10-60 % | Yes, efficiency up to 60 % | Yes | Yes | Yes | Yes | Yes | Yes |
| Domestic hot water heaters | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Control systems | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Household appliances | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Tapwater taps | Yes | Yes | | | | | | |

The lack of components was also examined (Table 11). The lack of components can be solved to some extent with an international market, making components available not only in some countries.

*Table 11. Lack of components for very low-energy residential buildings*

| Component | Sweden | Finland | Den-mark | Norway | Poland | Latvia | Estonia | Lithuania |
|---|---|---|---|---|---|---|---|---|
| Thermal insulation | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products |
| Airtightness products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, of most products | Yes, some products | Yes, of most products | Yes, some products |
| Windows | Yes, U-value 0.6 W/m²K | Yes, U-value 0.6 W/m²K | Yes, U-value 0.6 W/m²K | Yes, U-value 0.7 W/m²K | Yes, U-value 0.7 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value 0.65 W/m²K | Yes, U-value 0.7 W/m²K |
| Solar shading | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Doors | Yes, U-value 0.9 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value ≤ 1.0 W/m²K | Yes, U-value 1.0 W/m²K |
| Structural frame components | Yes, e.g. light studs | Yes, e.g. light studs | Yes | Yes | Yes | ? | Yes | Yes |
| Ventilation with heat recovery | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % | Yes, effici-ency > 80 % |
| Heat pumps | Yes, COP > 3 | Yes, COP > 3, often oversized | Yes, COP > 3 | Yes | Yes, COP > 3 | Yes, COP > 3 | Yes, COP > 3 | Yes, COP > 3 |
| Heat distribution system | Yes | Yes | Yes, several products | Yes | Yes | Yes | Yes? | Yes |
| Pumps | Yes, efficiency 10-60 % | Yes, efficiency up to 60 % | Yes | Yes | Yes | Yes | Yes | Yes |
| Domestic hot water heaters | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Control systems | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Household appliances | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Tapwater taps | Yes | Yes | | | | | | |

The need for development of components for very low energy residential buildings varied from country to country (Table 12). Obviously there are components, which can be further improved and an international competition and bigger market are likely to speed up the development. To promote the availability of very low-energy house components, a database with links to web sites of suppliers/manufacturers was created within the NorthPass project. The database includes the major components needed for very low energy houses, and it is located at the project website www.northpass.eu .

*Table 12. Need for development of components for very low energy residential buildings in the participating countries*

| Component | Sweden | Finland | Den-mark | Norway | Poland | Latvia | Estonia | Lithuania |
|---|---|---|---|---|---|---|---|---|
| General | | More cost efficient systems | Further develop-ment of many compon-ents | | More cost efficient systems | | More cost efficient systems | More cost efficient systems |
| Airtightness products | | | Air tight-ness of prefabric ated building elements | | | | | |
| Windows | | | | | | Low cost | Estonian | |
| Solar shading | | | | More cost efficient systems | | Low cost automatic external shading systems | | |
| Doors | Airtight doors with lower price | | | | | Airtight and well-insulated doors | | |
| Frame components | | | | | Further develop-ment | | | |
| Ventilation with heat recovery | User friend-liness, supply atd, with low use of electricity | User friend-liness | | User friend-liness | | Low cost | Estonian | |
| Heat pumps | | Frost resistant heat pumps | | | | | | |
| Heat distribution systems | Better insulated ground pipes, district heating sub-centres | User friend-liness | Individ-ual control of air heating | More cost efficient systems, user friend-liness | Polish systems | User friend-liness | | |
| Pumps | More efficient pumps | | | | | | | |
| Control systems | | | | | | Low cost | | |

# 8 User-oriented market penetration of North European very low-energy house

## 8.1 Very low-energy house markets

NorthPass reports "*Report on low-energy building market situation, trends, and influencing factors*" and "*Country-specific market analysis, success factors, marketing approach and market situation*", present information about the market situation of low-energy construction in the participating countries of the NorthPass project. In "*Report on low-energy building market situation, trends, and influencing factors*" the situation is explained by defining the attitudes, beliefs and preferences of both builders and real estate experts whereas in "*Country-specific market analysis, success factors, marketing approach and market situation*" the focus is on finding solutions to overcome market barriers and providing marketing approaches for low-energy houses.

### 8.1.1 Low-energy building market situation, trends, and influencing factors

In order to examine the attitudes of individual builders and real estate experts towards very low-energy houses two surveys were compiled. A questionnaire was sent out to individual house owners in all participating countries inquiring about details of the constructed house as well as about attitudes and beliefs about low-energy construction. Another questionnaire was sent out to different representatives in the construction field in order to find out the experts' attitudes. The aim was to define the (current and future) state of low-energy construction, the extent of available information, products and expertise and the beliefs related to different aspects of low-energy buildings.

The questionnaires and detailed results are presented in NorthPass report "*Report on low-energy building market situation, trends, and influencing factors*". It is surprising how similar the results of the two surveys directed to individual builders and real estate experts were in all the participating countries. Regardless of the market situation of low-energy houses in each country, the interest of builders seems to be fairly similar across northern Europe. This study does not even reveal any major differences between the Nordic countries, in which people are traditionally considered as highly aware of environmental issues, and other countries of the study, in which low-energy construction has not yet achieved a similar stage. No remarkable differences can be perceived neither between the builders' attitudes nor the experts' perceptions in different countries.

According to the survey, there exists a considerably strong interest in low-energy construction among individual builders in most of the participating countries. In general, the individual house builders were interested in the opportunity to construct a house according to low-energy standards, even if extensive measures might not have been implemented yet. In most countries, respondents were also quite interested in the energy performance certificate and believed that it would be useful, although differences remain. For example in Finland, many of the respondents already did have an energy performance certificate in their houses whereas, in some other countries, the certificate had not obtained similar popularity yet (Figure 28).

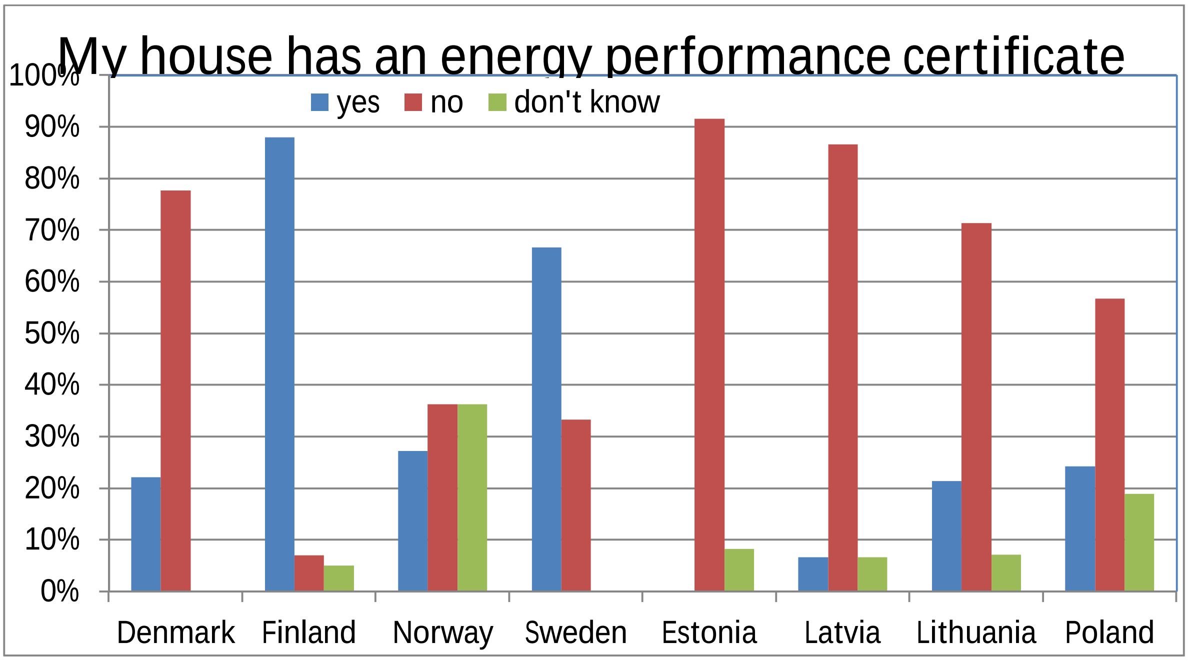


*Figure 28. Popularity of the energy performance certificate.*

Many of the respondents in all countries stated that they would be willing to pay an extra investment cost for low-energy buildings but in many cases the amount was not remarkably high and it might not reach the actual extra investment costs estimated by the experts (Figure 29). Differences between the availability of information among the participating countries do exist, to certain extent, but in most countries the individual builders had experienced that information, products and services regarding low-energy construction do exist but that they might be difficult to find (Figure 30). In many countries more demonstration projects are wanted and according to a previous study the demonstration projects need to be impartially and reliably performance monitored, documented and evaluated.

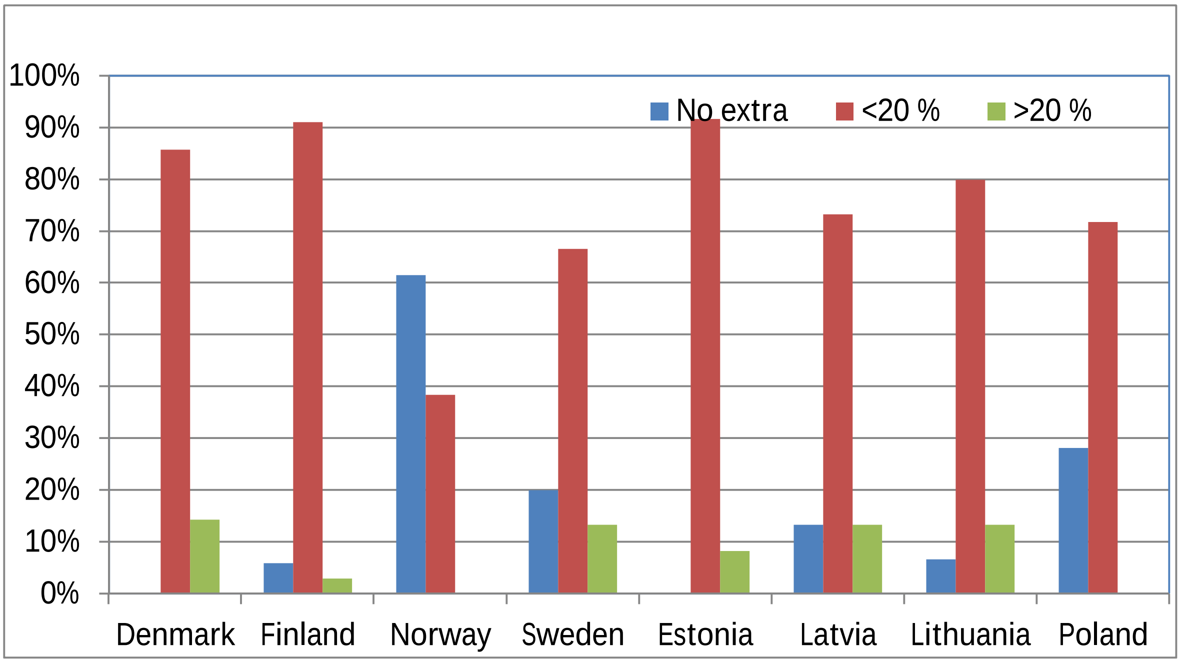


*Figure 29. Willingness to pay extra in order to build a low-energy house.*

Also the real estate experts were somewhat optimistic about the situation of low-energy building market in their countries. According to the survey it seems that products and services as well as information are available to a certain extent, but that this information might be difficult to access.

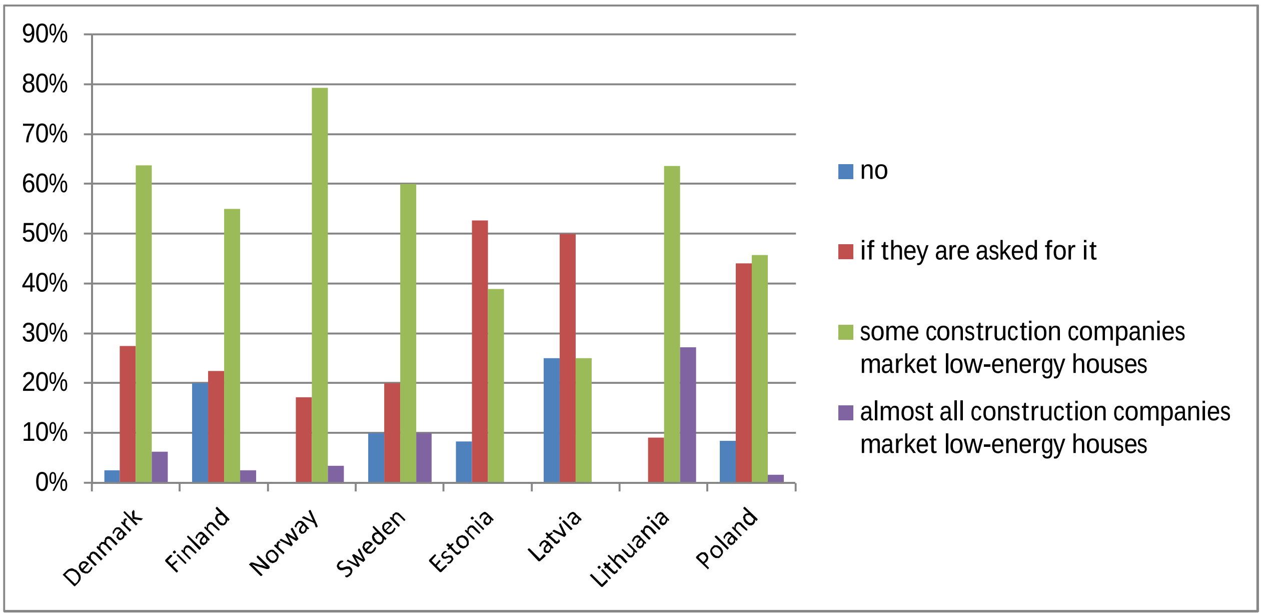


*Figure 30. Do companies inform about/ provide low-energy houses?*

The future trend for low-energy construction seems clear: there is a strong belief in the increase of low-energy construction among the experts, and most of the respondents also foresaw that low-energy buildings will be more valuable in the future. The experts did share different views on how to reach this development regarding different financial measures, for example. However, in most countries the experts strongly favoured measures by the authorities although the respondents also believed that the development towards enhanced energy efficiency in construction would take place also without obligations by law.

It is possible that in some countries, the low number of people responding to the questionnaire distorted the results to some extent. The number of respondents varied a lot across countries and therefore it is not possible to draw many trustworthy conclusions of these responds. Also, some of the results of this study are not compatible with the information presented in NorthPass report *"Country-specific market analysis, success factors, marketing approach and market situation"* and this fact might increase doubts about the validity of the surveys. However, some trends are still possible to be outlined from the surveys, which can help to evaluate the current situation as well as predict future development of low-energy construction.

### 8.1.2 Country-specific market analysis and marketing approach

NorthPass report "*Country-specific market analysis, success factors, marketing approach and market situation*" examined the market situation of very low-energy houses in participating countries, and suggested relevant marketing approaches in each country. The country participants contributed to the study by providing general and also more specific information about the market situation in their countries and about cases in which improvements in energy efficiency had already been implemented successfully.

PEST analysis was used for creating a marketing approach for low-energy houses in each country. This analysis includes examining the macro-environment of the market which consists of political (and legal) forces, economic forces, socio-cultural forces, and technological forces:

- The political arena has a huge influence on the regulation of businesses as well as on the spending power of consumers and other businesses. When analysing the stability of the political environment issues such as laws regulating or taxing the business, government's position on marketing ethics, government's policy on the economy, government's view on culture and its involvement in trading agreements should be considered.
- Factors impacting the economic environment include, among others, interest rates, the level of inflation, employment level per capita, long-term prospects for the economy and GDP.
- How socio-cultural forces influence the market, varies to a great extent across the country. Therefore, it might be important to consider issues such as dominant region, attitudes towards foreign products, the impact of language on diffusion of products, the time available for leisure, the roles of men and women within the society, the age distribution and wealth of population and the attitudes towards green issues.
- Examining the technological factor means paying attention to the possibilities of the technology for cheaper and better production, whether the technologies do offer consumers and businesses more innovative products and services, how the distribution of some items have been changed by new technologies and if technology offer companies a new way to communicate with consumers.

In the PEST analysis, all these four environments were examined and their relevance considered in this specific case. Only the most important circumstances were contemplated in more details.

*Table 13. The Political, Economic, Socio-cultural and Technological market environments in the PEST analysis (Johnson and Scholes 1993).*

| **PEST analysis** | |
|---|---|
| **Political**<br>• monopolies<br>• legislation<br>• environmental protection laws<br>• taxation policy<br>• foreign trade regulations<br>• employment law<br>• government stability<br>• government spending on research<br>• government and industry focus on technological effort | **Economic**<br>• business cycles<br>• GNP trends<br>• interest rates<br>• money supply<br>• inflation<br>• unemployment<br>• disposable income<br>• energy availability and cost |
| **Socio-cultural**<br>• population demographics<br>• income distribution | **Technological**<br>• new discoveries/development<br>• speed of technology transfer |

| | |
|---|---|
| • social mobility<br>• lifestyle changes<br>• attitudes to work and leisure<br>• consumerism<br>• levels of education | • rates of obsolescence |

With the help of PEST analysis, different marketing approach propositions were provided for each country. A suitable marketing channel for low-energy buildings was explored by evaluating the opportunities that the political, economic, socio-cultural and technological environments already offer. The marketing approach proposals concentrated on the market opportunities that already exist in each country, but suggestions on how to remove barriers for promoting low-energy construction were also offered. The country-specific reports are found in NorthPass report "*Country-specific market analysis, success factors, marketing approach and market situation*".

The eight countries examined in this study differ from each other to a large extent in terms of political environment, state support, availability of very low-energy houses and products needed for construction, environmental awareness and the level of knowledge. Therefore suggestions on how to market low-energy buildings varied across these countries.

In the four Nordic countries state support and requirements for energy efficiency as well as environmental awareness of people are considerably high. In all these countries very low-energy residential buildings already have entered the market and several companies are committed to or interested in energy efficient construction. In these countries finding proper marketing channels and spreading information in order to increase the demand of the house buyers are the essential next steps. For example in Finland the annually organized Housing Fair as well as the popularity of prefabricated houses could be utilized more efficiently for marketing purposes, and other Nordic Countries could try to follow the Finnish example. Coordinating knowledge and facilitating cooperation across different actors is also important, and measures have already been implemented in some countries.

In the Baltic countries and Poland the situation is considerably different and a distinctive marketing approach is needed. In some of these countries environmental awareness of people is still low and only few very low-energy pilot projects might exist. Therefore the first stage would be to increase the level of information and interest in energy conservation among people and promote the very-low energy building concept among real estate professionals.

The activity of the state varies a lot: In some Baltic countries there have not been any (or only few) government projects so far whereas in other countries the state has taken an active role in renovating old blocks of flats from the Soviet era. On the other hand, in Poland, introducing very low-energy houses has been initiated by the private sector. The most famous example is Lipincy Domy, which built a passive house which received a large amount of visibility across the country and encouraged also other companies to take energy efficiency into account in construction. This could serve as an example also for the Baltic States which do not have enough of decent examples or available data about passive houses. Even if some funding is provided for energy efficiency improvements in buildings, more financial support is still needed. Also legal definitions about the passive house concept and proper guidelines are essential in all these countries.

In some of the countries, especially in some of the Nordic countries, the state has taken an active role in promoting low-energy construction with implementing extensive projects or committing to decreasing energy consumption and CO2 emissions to a certain level. In these cases the state is a frontrunner who encourages and speeds up the process of moving towards very low-energy construction. Even if this has proven to be successful, in all societies a similar state-led development would not be possible and the changes need to be initiated by the private sector (or the demand of people). Nevertheless, the state needs to be involved to some extent, for example to administrate funding, allow tax reliefs or encourage banks to allow grants related to energy efficiency improvements.

The fact that in some countries very low-energy buildings have already reached a considerably good position in the market is advantageous for countries with an inferior situation. The latter countries might facilitate the promotion of low-energy houses by implementing measures and marketing channels that have already proven successful in other countries. On the other hand, some measures which have functioned in one country might not be successful in another with a different political, economic and social environment, and in these occasions learning from the success in other countries will not be possible.

Despite the differences across the countries some similar measures are still needed everywhere. It seems that providing a suitable social environment with raising the awareness of people is one of the most important actions in all countries. Also coordinating knowledge and facilitating cooperation across different actors is essential for establishing a functioning economic environment for the very low-energy housing market. Introducing legal requirements about energy efficiency and defining legal concepts for low-energy construction would be important for creating a suitable political environment whereas a decent technical environment should be obtained by bringing necessary products and expertise to the market to a sufficient extent.

### 8.1.3 Scenarios, business models and examples

The NorthPass report "*Scenarios, business models and examples for very low-energy housing markets*" presents three different scenarios of reaching the EU 2020 target (EPBD according to which all new buildings are expected to be nearly zero-energy buildings in year 2020):

1. Business as Usual scenario (failing in the EU 2020 target).
2. Fast Change scenario (reaching the EU 2020 target)
3. Change in Market Modes of Operation scenario (reaching the target already by 2016)

In the Business as Usual scenario the construction business will simply continue its present building practices to perpetuity. Very low-energy houses will not experience rapid growth, and therefore the EU 2020 target will not be met. New buildings will simply continue to be built according to the present practices, the share of low energy buildings neither increasing nor decreasing. This scenario offered the possibility to, on one hand, evaluate the effects of a policy failure and, on the other hand, compare the effects of the other scenarios to an alternative where there is no change.

Fast Change scenario means the success of EU 2020 goals, whereby all new residential buildings in 2020 will be built as near-zero energy buildings. In the study the near-zero energy buildings were equated with very low-energy buildings, as they bring the energy consumption close to zero. The scenario was built as a simple linear development from the present shares of building types so that new construction in 2020 reaches 100 % very low-energy buildings.

The Change in Market Modes of Operation scenario assumed a fast change in the practices of the market actors that totally reforms the market situation over a period of five years, perhaps driven by a sharp rise in public awareness (market pull) or disruptive product innovation by companies competing fiercely with each other (technology push). Thus the EU 2020 target would be reached ahead of time. This would technically be possible as the necessary products and technologies are already available. However, it would require significant changes in the behaviour of people as well as companies which participate in the production chain. Generally, the growth rates needed for the market shares of very-low energy buildings in this scenario are very ambitious and presently seem unlikely. However, in the past there have been cases where similar sudden unexpected changes have quickly overtaken markets (e.g. downloaded music grew from near 0% share to market leader in less than five years). This scenario offered the possibility to evaluate the effects of changes faster than those presently promulgated by the EU policies.

SWOT-analyses for companies were created for each country separately in order to depict the market potential of, and main drivers and barriers for very low-energy construction. Internal and external issues were separated in the analysis; internal issues are strengths and weaknesses of the company while external issues refer to opportunities and threats that exist in the company's external environments.

While in NorthPass report "*Barriers to implementation of very low energy residential buildings and how to overcome them*" the focus of the SWOT-analysis was on very low-energy residential buildings, in NorthPass report "*Scenarios, business models and examples for very low-energy housing markets*" targets of the analysis were the companies which are offering very low-energy buildings or which are involved in the production chain. Therefore some of the information used for SWOT-analysis was extracted from this previous deliverable but because of the different focus, the market situation was defined from a distinct angle.

When studying the strengths and weaknesses of very low-energy construction, the questions were:

- What are the main benefits that a company can receive from being involved with very low-energy house construction?
- What are the main disadvantages of companies that are involved with very low-energy house construction?

When contemplating the opportunities and threats the questions were:

- What are the main external opportunities for a company that is involved with very low-energy house construction?
- What are the main external threats for a company that is participating in very low-energy construction chain?

The results of the PEST-analysis from the NorthPass report "*Country-specific market analysis, success factors, marketing approach, and market situation*" were used as background information for creating a marketing approach for very low-energy houses in each country.

For each participating country the current situation of the very low-energy house market and a SWOT analysis for companies involved with constructing/providing very low-energy residential buildings were presented. Measures which need to be implemented in order to reach the targets of the three different scenarios in each country were presented, and the credibility of each scenario was discussed.

As examples of the results, Table 14 presents the SWOT analysis for Estonian companies and Figure 31 presents the Business model for the Fast Change scenario in Estonia. The rest of the results are presented in NorthPass report "*Scenarios, business models and examples for very low-energy housing markets*".

*Table 14. SWOT analysis for companies in Estonia*

| |
|---|
| Strengths:<br>- An increasing interest in energy efficiency of buildings exists.<br>- Information about profitability of low-energy construction is available. |
| Weaknesses:<br>- An Estonian passive house standard has not been created yet (Blomsterberg 2011).<br>- Insufficient or false information about low-energy construction might be presented.<br>- Very high prices of very low-energy buildings might discourage investments.<br>- Designers and engineers are considerably old fashioned.<br>- Required components might be difficult to find. |
| Opportunities:<br>- LCC is becoming more popular and better known (although very few are implementing these practices) (Blomsterberg 2011).<br>- The European Energy Performance Directive (with the law about Energy Performance Certificate) will further promote very low-energy construction.<br>- Energy consumption for heating in blocks of flats is very high which means high energy bills.<br>- Old blocks of flats which are in need of repair (and improvements in energy efficiency) constitute a large share of the housing stock.<br>- The state has implemented several measures to promote energy efficiency of buildings, e.g. regulations, trainings, workshops, funding.<br>- Kindergarden Kaseke, which was built according to very low-energy standards, serve as a successful example. |
| Threats:<br>- Only few low-energy building examples have been built so far -> No monitored data and experience about low-energy buildings exist (Blomsterberg 2011).<br>- Further slowdown in the economy and in the construction field will form a barrier for very low-energy construction to spread. (Blomsterberg 2011).<br>- The distribution of income is very uneven and only the affluent part of the population has the possibility to invest in low-energy buildings.<br>- The level of education and information considering low-energy construction is low. |

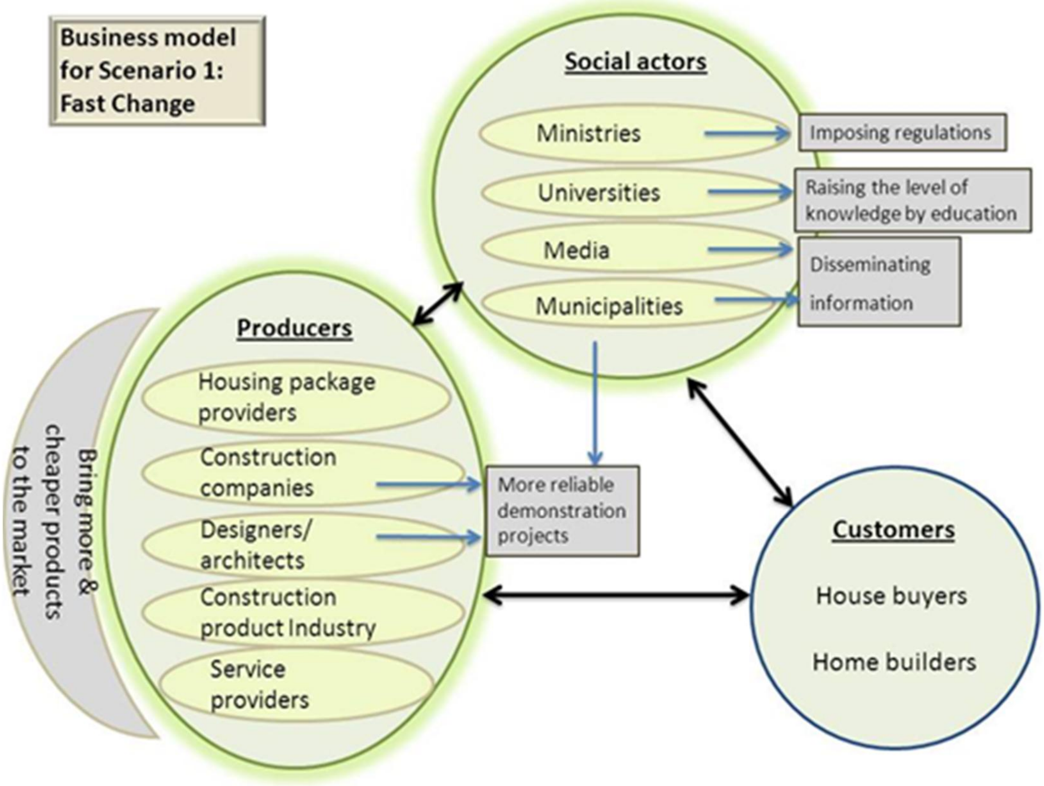


*Figure 31. Business Model for Fast Change scenario in Estonia*

The number of low-energy houses, the level of energy consumption in each building type as well as the cost of constructing low-energy and very low-energy houses vary a lot between the participating countries. Similarities exist between the Nordic countries but they vary to a great extent from the Baltic states and Poland, in which both energy consumption and the additional cost of constructing a more energy efficient house are much higher (Figure 32, Figure 33).

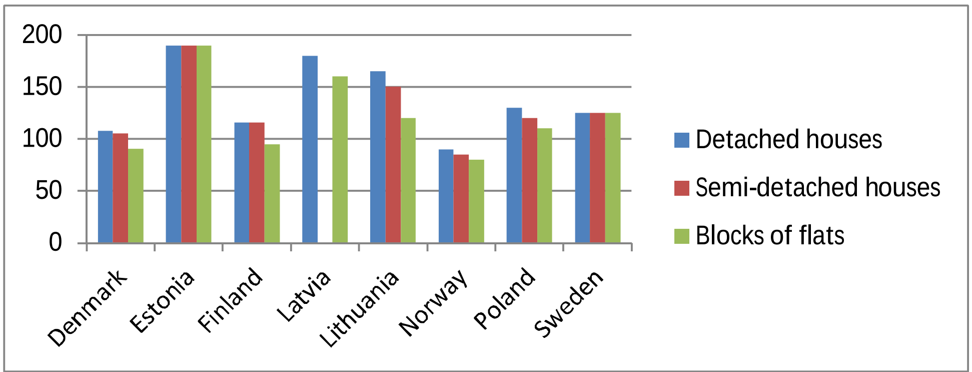


*Figure 32. Average energy consumption kWh/a/m² in standard houses in each country.*

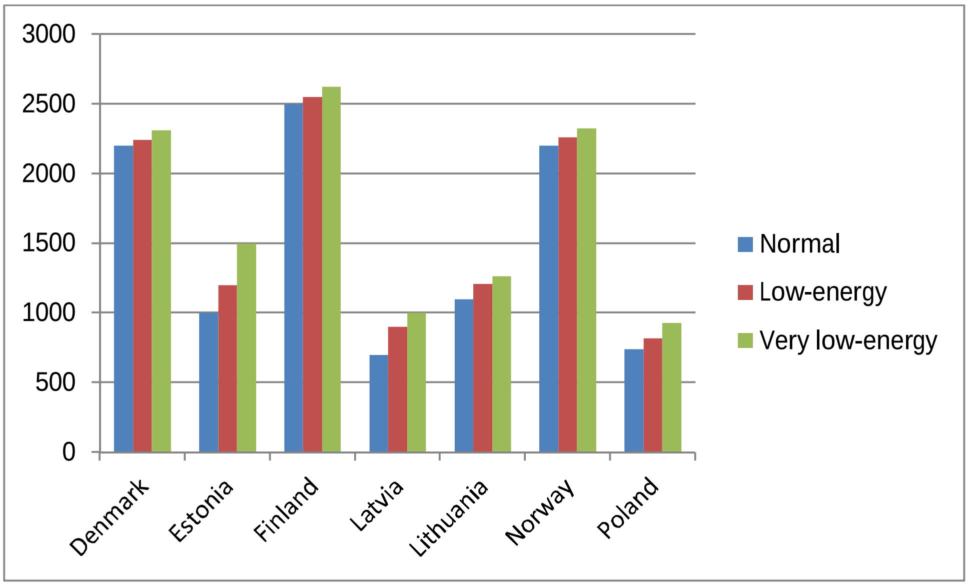


*Figure 33. Average construction cost (€/m²) for normal, low-energy and very low-energy detached houses in each country (excluding Sweden).*

The Fast Change scenario (reaching the EU 2020 target) seems to be plausible for all eight countries, although in some of them, remarkable measures will be extremely important. In the Nordic countries, the path towards the EU 2020 target has already been chosen and if the political, economic, socio-cultural and technological market environment will not deteriorate, failing in the target (Business as Usual scenario) will not be very likely. In the Nordic countries, the Change in Market Modes of Operation scenario is not completely far-fetched, but this will require very quick and remarkable changes in customer preferences, which would lead into a growing demand of very low-energy residential buildings.

The situation in the Baltic countries and Poland is more challenging, as in all of them, only few very low-energy houses have been built so far. However, there seems to exist a growing interest in energy saving (as the energy consumption is considerably high and the prices are rising), and therefore it can be assumed that with a remarkable change in the supply of affordable low-energy house solutions, reaching the target of the Fast Change scenario is not impossible. Reaching the EU 2020 target already four years earlier is highly unlikely, but measures which would be needed in order to reach this target, can still be considered. This would not require changes only in the customers' values and an increasing interest in the supply side, but also governmental bodies should be activated as well as some technological aspects of the market environment would need to be improved. Different actors should be convinced about the additional value that being involved with the very low-energy house production chain could offer, and that the preferences of so many stakeholders would change, is very unlikely.

Some measures are needed in all countries and in order to reach both Fast Change and Change in Market Modes of Operation scenario. It cannot be highlighted enough that improving the availability of information and taking up energy-efficiency issues in the education are main measures which would increase the interest of actors from both demand and supply side. Promoting low-energy construction and the market penetration of very low-energy houses do not necessarily need to be aided by the state (it can also happen market-led), but the state being involved with providing financial aid (e.g. tax reliefs) would certainly be highly beneficial in all countries.

It can be expected that the implementation of very low-energy construction standards will follow the S-curve in Figure 34, first introduced by Rogers (1962).This means that the new innovation (very low-energy buildings in this case) will first be implemented by only a small part of the population: *innovators* and *early adapters*. In the next phase the s-curve will experience an upward slope as *early majority* and *late majority* (which contains the majority of the population) will implement the innovation. In the final phase also the *laggards* will implement the new innovation.

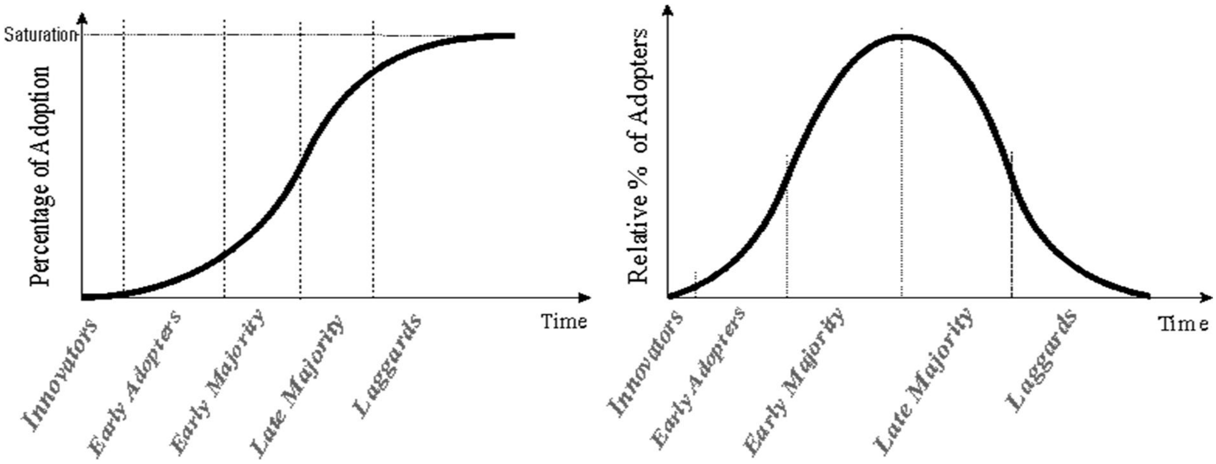


*Figure 34. The "S-curve". The process of diffusion of innovations (BoBr 2003).*

It is evident that in none of the countries very low-energy houses have reached a high stage on the curve, although in some countries reaching the Early Majority stage does not seem impossible in the following few years. According to an estimation, in most Nordic countries, energy efficient construction have already entered the market to a large extent as a remarkable percentage of the newly built houses are low-energy houses (for example in Finland 31% and in Denmark 25%). Also the very low-energy houses have entered the market to some extent: In Finland 8% and in Denmark 5% of houses built in 2011 were very low-energy houses. In these countries it can be suggested that very low-energy houses have already reached the Early Adopter stage, and that Early Majority will adopt very low-energy houses during the next couple of years, and Late Majority before year 2020.

In the Baltic countries and Poland the situation is not as good, as there are only few or no very low-energy houses, and also low-energy houses have reached a market share of only few percentages. In these countries, it can be suggested that only Innovators have adopted very low-energy houses, and that low-energy houses have perhaps reached only the Early Adopters level. However, a promising market potential seems to exist and therefore it can be assumed that Early Adopters and even Early Majority will adopt very low-energy houses in the following years, at latest in 2020.

## 8.2 National roadmaps for promotion of very low-energy house concepts

NorthPass report "*National Roadmaps for promotion of very low-energy house concepts*" gives a short overview of the current situation for each participating country including current building codes, building standard definitions, market share of energy-efficient buildings and incentives to promote energy-efficient buildings. The report proposes market uptake measures for each country to support the implementation of the nearly Zero-Energy Building level, as described in the recast of the Energy Performance of Building Directive. Necessary steps towards a successful implementation vary within the participating countries, involving technological, financial and policy implications in various degrees.

As stated in previous chapters, the participating countries in the NorthPass project have similarities and differences regarding very low-energy house markets. The four Nordic countries have several similarities regarding market penetration of very low-energy houses, as well as activities implemented by the authorities. Poland and the Baltic States have similarities in terms of market situation which is different from the Nordic countries.

In the Nordic countries, the path towards the EU 2020 targets has, to a large extent, been chosen, focusing on step by step tightening of building codes, financial incentives and training of actors in the building sector. A discussion is going on about how to affect changes in customers' preferences, which would lead to a growing demand for very low-energy residential buildings.

The situation in Poland and the Baltic countries is more problematic, as only few very low-energy houses have been built so far. However, a growing interest in energy savings seems to arise, as the energy consumption is considerably high and the prices are increasing. It might therefore be assumed that a growing demand of very low-energy residential buildings will occur when affordable low-energy house solutions enter the market. Different actors should be trained in the very low-energy house production, some technological aspects of building tradition have to be developed, and major changes on the energy supply side should be addressed. Customers and contractors are hoping for financial incentives to be established by the authorities.

All countries have to tighten building codes to reach the EU targets, and address renewable energy production. Financial incentives may perhaps not be necessary regarding market penetration of very low-energy houses, but it will certainly contribute to a more rapid implementation. In all countries education, training and dissemination of information are listed as key issues to increase the interest of dwelling providers, tenants and buyers.

## 8.3 Suggestions for the reachable minimum performance requirement to be utilized in the update process of the Energy Performance of Buildings Directive

NorthPass report "*Suggestions for the reachable minimum performance requirement to be utilized in the update process of the Energy Performance of Buildings Directive*" focuses on the transpose of EPBD into national legislation, presenting in brief some national plans and general recommendations regarding energy use in buildings.

On 18 May 2010 a recast of EPBD (2002/91/EC) was adopted in order to clarify, strengthen and extend the scope of the Directive, and to reduce the large differences between Member states' practices in this sector. The recast prescribes that all new buildings must be nearly zero-energy buildings by 31 December 2020, that Member States should set intermediate targets for 2015, and that new buildings occupied and owned by public authorities have to be nearly zero-energy buildings after 31 December 2018.

The Directive on Energy Performance in Buildings (EPBD), adopted in 2002, is the main legislative instrument affecting energy use and efficiency in the building sector in the EU. The Directive is designed to promote the energy performance of buildings in Member States through:

- Introduction of a framework for an integrated methodology for measuring energy performance
- Application of minimum energy performance standards in new buildings and certain renovated buildings, and regular updating of these standards

- Energy certification and advice for new and existing buildings
- Inspection and assessment of boilers and heating/cooling systems.

Buildings differ significantly across Europe as they depend on the culture, the climate, the construction materials available, the differing legal frameworks and the economic development. Considering the differences, it is not suitable to have a common approach at EU level. The Directive EPBD therefore states the objectives and principles, but it is left to Member States to determine the concrete requirements, performance levels and ways of implementation.

Very low energy houses must be designed according to local climate and conditions. The energy and power demand can be considerably higher in regions with cold climate compared to the milder ones. But with the expected technological development, it will be possible to build very low energy houses also in cold regions. It will therefore make sense to revise the criteria for buildings in cold climate, in accordance with the technological development.

The minimum requirement regarding renewable energy should be gradually sharpened. The share of renewable energy should be considered independent of the concepts of low energy house and passive house, because these concepts are connected to net energy use. It should be possible to regulate requirements on renewable energy share and other energy related requirements separately, without the one influencing the other. In the near future, 5–10 years, it seems reasonable to require very low energy buildings in the regulations. In the longer run, 10–20, it seems possible to require zero-energy / zero-emission buildings for new constructions.

Regarding the net energy demand (thermal energy and electricity) the very low energy house is considered as a reasonable level for dwellings. Further efforts to reduce heating demand might require more resources without much savings in energy costs (Lassen et al 2009). From the very low energy level to approach the zero-energy or zero-emission level, the efforts should be placed on the energy supply side, which mean local, renewable energy production. Technological development of elements for buildings, producing electricity, is expected to speed up (photovoltaic cells, co-generators, and mini wind turbines).

Even though passive houses can be considered as State-of-the-Art regarding energy efficient buildings, there are already examples of buildings called passive house+ (passive house with local renewable energy production covering the heating demand) and zero-energy / zero-emission building (building with local renewable energy production covering both heating and electricity demand, during the year).

Thus far, energy efficiency is often defined as doing the same with less energy, or doing more with the same energy. Stricter regulations on energy consumption per square meter will slow down the rate of growth in energy consumption, compared to a business-as-usual scenario. But the absolute energy consumption or greenhouse gas emissions might not consistently be turned downward by this kind of regulations, because of the ever increasing comfort level. There are two more ways to reduce the $CO_2$-emissions related to energy consumption in buildings; focus on sufficiency instead of efficiency, and emphasizing the utilization of environmentally friendly energy sources.

# 9 DISSEMINATION MATERIAL

The project website www.northpass.eu serves the target audience (producers, designers, authorities, building owners and builders) by providing information relevant to very low energy houses and their markets. The website provides clear information about the very low-energy house concepts promoted through this project, easy accessible downloads of all project publications, and furthermore relevant national links and contacts. The website has collected information on events of interest to people and stakeholder groups interested in very low-energy housing.

The website contains e.g. introductory pages, information on the project results, NorthPassTool for a simplified comparison between very low-energy and conventional houses and a database including the major components needed for very low energy houses with links to web sites of suppliers/manufacturers. The website also contains national pages with information in main national languages of the participating countries including the translated versions of following NorthPass reports:

- *NorthPassTool a demonstration tool to promote very low-energy houses*
- *Very Low-Energy House Concepts in North European Countries* –booklet
- *Very Low-Energy House Concepts in North European Countries* –slide show
- *Scenarios, business models and examples for very low-energy housing markets*
- *Barriers to implementation of very low energy residential buildings and how to overcome them*

The *"Very Low-Energy House Concepts in North European Countries"* booklet and slide show gather along the main results of NorthPass and they are especially targeted for the large audience.

The consortium has promoted the project's findings and outcomes on the new BUILD UP portal which aims to promote better and smarter buildings across Europe by gathering building professionals, local authorities and citizens through a newly interactive communication portal.

# 10 SUMMARY AND CONCLUSIONS

A very low-energy building criteria exists locally in Denmark, Norway, Sweden and Finland. Only Norway and Denmark have official criteria for very low energy buildings. The criteria for passive houses by PHI are being used in most of the countries, and are practically the only definition that is used across borders.

The overall comparison of existing national building regulations and the existing low energy building definitions of the participating countries showed that while the minimum criteria according to existing building regulations in the Northern European countries are of different types and levels, the existing very low energy definitions and criteria are less different, aiming at a low energy demand.

The comparison also emphasized the decisive differences between boundary conditions in terms of reference area, internal heat gain and weighting of electricity and different heat sources. These different requirements constitute an unnecessary technical barrier to trade and can be seen as a challenge for a market driven penetration of very low energy houses across the borders in the Northern European countries.

The general principles of the very low energy design can be summarized to

1) Minimise losses and consumption
2) Maximize gains and
3) Substitute the remaining energy need with renewable and environmental friendly energies.

The special challenges of designing a very low energy house in the Northern European countries are e.g. the colder air temperature and less sun light during the winter when compared to most of the Middle European conditions. Therefore the following design rules are emphasized:

1. U-values of opaque constructions 0.06 – 0.12 $W/m^2K$, depending on the climate
2. Even in the coldest and darkest climates an orientation of the windows to the South is preferable. The thermal quality of the window is decisive: Very low U-values are preferred. External shading should be used to prevent extreme summer situations, and to consider daylight and view in the window design
3. It is important to have the best possible ventilation heat recovery, > 80-85%. To avoid freezing of the heat exchanger it is recommended in all Northern European climates to use a system to prevent freezing. One of the possibilities is to use a ground-coupled heat exchanger (direct or indirect).

The Life Cycle Assessment results for conventional and very low-energy buildings demonstrate that although variations in building techniques, materials used, energy supply and heating system very low-energy buildings in general have a lower environmental impact compared to conventional buildings. The production of the very low-energy building gives a higher potential contribution to global warming and uses more primary energy than the production of a conventional building. This is primarily caused by the use of more insulation in the foundation, exterior walls and attic joist. However, the total potential contribution to global warming and the total use of primary energy is higher for the conventional building than for the very low-energy building due to the higher energy use during the operation. The results also emphasized that in order to reduce the impact to global warming and the use of primary energy, besides reducing the amount of energy required for the operation of the building, it is also important to choose an energy source with low greenhouse gas emissions and a low primary energy factor.

The Life Cycle Cost (LCC) calculation accentuated the effect of the energy price trend to the cost-efficiency of very low-energy buildings. For the scenario with a low-energy price development the life cycle costs of very low-energy buildings were higher than the life cycle costs of conventional buildings. With the high energy price development scenario the life cycle costs of very low-energy houses were typically lower than the life cycle costs of conventional buildings after 30 years. In most cases the initial costs were higher for the low-energy buildings compared to the conventional buildings for both multi-family and single-family buildings. The initial cost for both multi-family buildings and single-family buildings differed between countries due to different labour costs, material prices, legislation, etc.

The simplified Cost Benefit Analysis (CBA) was performed with three different methods for monetizing the environmental effects. The results showed that the LCC result has a great influence on the CBA result. The energy price trend often dictated which building type had the lowest total costs. With a low-energy price trend the conventional buildings had lower total costs, and with a high energy price trend the low-energy buildings had lower total costs. The choice of index for monetization of the environmental costs influences the result of the CBA. In general, the monetized greenhouse gas emissions were low compared to the economic costs for all methodological approaches. For almost all buildings the very low-energy buildings had lower environmental costs than the conventional buildings. Based on this study, if the energy price is considered to rise fast in the coming years, a very low-energy building is a good investment.

NorthPassTool, a demonstration tool based on Excel spread-sheet, was developed within the NorthPass project. The aim of the tool is to give a simplified comparison between very low-energy and conventional houses in order to promote more energy efficient solutions with lower environmental impact. The tool can be used to give an overview of the different parameters affecting the economic and environmental impacts of the building. Other calculation methods should be utilized for detailed design purposes.

NorthPass project results showed that the main non-technological barriers to implementation of very low-energy buildings exist mainly within the following areas: market, requirements/regulations, knowledge, costs, instruments of control, responsibility, policy, society and incentives. There were no major differences in problems between the countries with several very low-energy residential buildings built and the countries with only a few.

The potential internal strengths of low energy residential buildings, valid for several participating countries, are good indoor environment, low running costs, high energy efficiency, low LCC and a growing market.

Common potential internal weaknesses were inadequately spread competence to build, lacking robustness and quality, indoor environment problems, operation and use problems, bad experience of low energy houses and planning and designing mistakes. Some of these weaknesses e.g. lacking robustness and quality, indoor environment problems, operation and use problems can occur in traditional buildings as well. To overcome the perceived or actual potential internal weaknesses of low energy dwellings following suggestions were made:

- Methods: Introduce and apply LCC-analysis, which was mainly highlighted by the Baltic states and Poland
- Knowledge: Feedback from previous knowledge; update the educational level of designers and contractors; introduce low energy house design at universities
- Market: Publish more good examples, which was mainly highlighted by the Baltic states; Expand the market and import partly from and export to other countries; Increase the international market

The potential external threats differed from country to country; some however existed in two countries or more: low interest in low energy buildings, inadequate customer awareness and inadequate knowledge of construction. To overcome the perceived or actual potential external threats to low energy dwellings following suggestions were:

- Market: Market well documented good examples
- Incentives: Political lobbying and information activities; Lobby for tax credits and specific loans

To promote low energy residential buildings it is important to:

- Maintain and improve the strengths of low energy residential buildings
- Minimise the weaknesses of the low energy residential buildings
- Make use of the opportunities for low energy residential buildings
- Forestall and neutralize the threats to low energy residential buildings

The following has to be fulfilled to ensure that a very low-energy house is accepted by the occupant:

- Guidelines of use for the occupant
- Information on the possibilities and function of a low energy house to the occupant
- Very low-energy house must be introduced to the occupants, function as expected, be user friendly, ensure good comfort, deliver expected energy savings and supply good living conditions

A study was carried out to determine the state-of-the-art and need for further development of components for very low-energy residential buildings in Sweden, Finland, Denmark, Norway, Poland, Latvia, Estonia and Lithuania. According to the study most components needed for very low-energy residential buildings are available on the markets in Sweden, Finland, Denmark, Norway, Poland, Latvia, Estonia and Lithuania. So far the demand for components for very low-energy residential buildings is rather low. Whether there will be enough components in a growing market is difficult to know. The available components for very low-energy residential buildings obviously have to be better marketed, to ensure that e.g. more designers are aware. To promote the availability of very low-energy house components, a database with links to web sites of suppliers/manufacturers was created within the NorthPass project. The database includes the major components needed for very low-energy houses, and it is located at the project website www.northpass.eu .

In order to examine the attitudes of individual builders and real estate experts towards very low-energy houses two surveys were compiled. A questionnaire was sent out to individual house owners in all participating countries inquiring about details of the constructed house as well as about attitudes and beliefs about low-energy construction. Another questionnaire was sent out to different representatives in the construction field in order to find out the experts' attitudes. The aim was to define the (current and future) state of low-energy construction, the extent of available information, products and expertise and the beliefs related to different aspects of low-energy buildings.

Regardless of the market situation of very low-energy houses in each country, the interest of builders seems to be fairly similar across northern Europe. According to the survey, there exists a considerably strong interest in very low-energy construction among individual builders in most of the participating countries. In general, the individual house builders were interested in the opportunity to construct a house according to low-energy standards, even if extensive measures might not have been implemented yet. In most countries, respondents were also quite interested in the energy performance certificate and believed that it would be useful, although differences remain.

Many of the respondents in all countries stated that they would be willing to pay an extra investment cost for very low-energy buildings but in many cases the amount was not remarkably high and it might not reach the actual extra investment costs estimated by the experts. Differences between the availability of information among the participating countries do exist, to certain extent, but in most countries the individual builders had experienced that information, products and services regarding low-energy construction do exist but that they might be difficult to find. In many countries more demonstration projects are wanted and according to a previous study the demonstration projects need to be impartially and reliably performance monitored, documented and evaluated.

The future trend for very low-energy construction seems clear: there is a strong belief in the increase of very low-energy construction among the experts, and most of the respondents also foresaw that very low-energy buildings will be more valuable in the future. The experts did share different views on how to reach this development regarding different financial measures, for example. However, in most countries the experts strongly favoured measures by the authorities although the respondents also believed that the development towards enhanced energy efficiency in construction would take place also without obligations by law.

In the Nordic countries state support and requirements for energy efficiency as well as environmental awareness of people are considerably high. In all these countries very low-energy residential buildings already have entered the market and several companies are committed to or interested in energy efficient construction. In these countries finding proper marketing channels and spreading information in order to increase the demand of the house buyers are the essential next steps. Coordinating knowledge and facilitating cooperation across different actors is also important, and measures have already been implemented in some countries. Especially in the Nordic countries the state has taken an active role in promoting low-energy construction with implementing extensive projects or committing to decreasing energy consumption and $CO_2$ emissions to a certain level. In these cases the state is a frontrunner who encourages and speeds up the process of moving towards very low-energy construction.

In the Baltic countries and Poland the situation is considerably different and a distinctive marketing approach is needed. In some of these countries environmental awareness of people is still low and only few very low-energy pilot projects might exist. Therefore the first stage would be to increase the level of information and interest in energy conservation among people and promote the very-low energy building concept among real estate professionals. In some Baltic countries there have not been any (or only few) government projects so far whereas in other countries the state has taken an active role in renovating old blocks of flats from the Soviet era. On the other hand, in Poland, introducing very low-energy houses has been initiated by the private sector. Even if some funding is provided for energy efficiency improvements in buildings, more financial support is still needed. Also legal definitions about the passive house concept and proper guidelines are essential in all these countries.

Despite the differences across the countries, some similar measures are needed everywhere:

- Providing a suitable social environment with raising the awareness of people
- Coordinating knowledge and facilitating cooperation across different actors for establishing a functioning economic environment for the very low-energy housing market
- Introducing legal requirements about energy efficiency and defining legal concepts for low-energy construction for creating a suitable political environment
- A decent technical environment should be obtained by bringing necessary products and expertise to the market to a sufficient extent

The EU has committed to reducing greenhouse gas emissions to 80–95% below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group. This commitment will require a revolution in energy systems. The Energy Roadmap 2050, providing the framework for the longer term action in the energy sectors, is part of the Resource Efficiency Flagship of the Europe 2020 strategy (EC COM 885/2).

In the Nordic countries, the path towards the EU 2020 targets has, to a large extent, been chosen, focusing on step by step tightening of building codes, financial incentives and training of actors in the building sector. The situation in Poland and the Baltic countries is more problematic, as only few very low-energy houses have been built so far. However, a growing interest in energy savings seems to arise, as the energy consumption is considerably high and the prices are increasing. It might therefore be assumed that a growing demand of very low-energy residential buildings will occur when affordable low-energy house solutions enter the market.

All countries have to tighten building codes to reach the EU targets, and address renewable energy production. Financial incentives may perhaps not be necessary regarding market penetration of very low-energy houses, but it will certainly contribute to a more rapid implementation. In all countries education, training and dissemination of information are listed as key issues to increase the interest of dwelling providers, tenants and buyers.

Three different scenarios of reaching the EU 2020 target (EPBD according to which all new buildings are expected to be nearly zero-energy buildings in year 2020) were examined in the NorthPass project

1. Business as Usual scenario (failing in the EU 2020 target).
2. Fast Change scenario (reaching the EU 2020 target)
3. Change in Market Modes of Operation scenario (reaching the target already by 2016)

In the Business as Usual scenario the construction business will simply continue its present building practices to perpetuity. Very low-energy houses will not experience rapid growth, and therefore the EU 2020 target will not be met. Fast Change scenario means the success of EU 2020 goals, whereby all new residential buildings in 2020 will be built as near-zero energy buildings. The Change in Market Modes of Operation scenario assumed a fast change in the practices of the market actors that totally reforms the market situation over a period of five years, perhaps driven by a sharp rise in public awareness (market pull) or disruptive product innovation by companies competing fiercely with each other (technology push). Thus the EU 2020 target would be reached ahead of time.

The Fast Change scenario (reaching the EU 2020 target) seems to be plausible for all eight countries, although in some of them, remarkable measures will be extremely important. In the Nordic countries, the path towards the EU 2020 target has already been chosen and if the political, economic, socio-cultural and technological market environment will not deteriorate, failing in the target (Business as Usual scenario) will not be very likely. In the Nordic countries, the Change in Market Modes of Operation scenario is not completely far-fetched, but this will require very quick and remarkable changes in customer preferences, which would lead into a growing demand of very low-energy residential buildings.

Some measures are needed in all countries and in order to reach both Fast Change and Change in Market Modes of Operation scenario. It cannot be highlighted enough that improving the availability of information and taking up energy-efficiency issues in the education are main measures which would increase the interest of actors from both demand and supply side. Promoting low-energy construction and the market penetration of very low-energy houses do not necessarily need to be aided by the state (it can also happen market-led), but the state being involved with providing financial aid (e.g. tax reliefs) would certainly be highly beneficial in all countries.

Energy efficiency in the building sector is found to be very valuable in reducing the cost of decarbonisation. Necessary steps towards a successful implementation of the nearly Zero-Energy Building level by 2020, as described in the recast of the Energy Performance of Building Directive, will vary within the countries participating in the NorthPass project; involving technological, financial and policy implications in various degrees. The national roadmaps presented in this report include a number of aspects that are required to get on track to reduce energy consumption in new dwellings, pointing at regulatory push, incentives, information and training to overcome implementation challenges.

The social dimension of the energy roadmap is important in all countries. The transition to very low-energy houses will affect employment and jobs, requiring education and training and a more vigorous social dialogue. In order to efficiently manage change, involvement of all partners in the building sector, at all levels, will be necessary. Mechanisms are needed to help planners and workers confronted with job transitions to develop their know-how and skills.

Technology is an essential part of the solution to the decarbonisation challenge. Renewable heating and cooling are vital. Fuel mixes have to change significantly over time. Establishing energy markets fit for purpose will also require new grid technologies. Technological progress is expected to reduce costs and give economic benefits. All the NorthPass countries emphasise the need for research and demonstration.

Energy system developments in Europe will be driven by the need for energy security, sustainability and competitiveness in a changing global energy context. Reduction in energy consumption and a shift to renewable energy sources may bring along new job opportunities and involve business models like energy services companies and energy performance contracts. The very low-energy house production chain could thus offer additional values.

So far, the Nordic and Baltic countries have looked to Austria, Germany and Switzerland for know-how and technologies regarding very low energy buildings. However, the climate conditions are different, so there are great opportunities for the North European countries for innovation regarding development of building components. More cooperation within the Nordic and Baltic countries to harmonize codes, standards and documentation/certificates would make it easier for companies to adapt and market their products and services across borders.

Very low energy houses must be designed according to local climate and conditions. The energy and power demand can be considerably higher in regions with cold climate compared to the milder ones. But with the expected technological development, it will be possible to build very low energy houses also in cold regions. It will therefore make sense to revise the criteria for buildings in cold climate, in accordance with the technological development.

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