

Nordic Analysis of Climate Friendly Buildings

Appendix – Detailed Report



June 27, 2010

Main authors

Inger Andresen, SINTEF Building and Infrastructure, Norway

Kirsten Engelund Thomsen, SBI, Denmark

Åsa Wahlström, CIT Energy Management, Sweden

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A1 Introduction

This Appendix presents the detailed findings of the work conducted within the project "Nordic Analysis of Climate Friendly Buildings". The work is summarized in the "Summary Report". The project was initiated in March 2010 by a steering group representing the Nordic Council of Ministers. The steering group was composed of the following members:

- Anne Sofie Bender, Nordic Council of Ministers
- Marie Louise Hansen, Erhvervs- og Byggestyrelsen, Denmark
- Marie Kring, Erhvervs- og Byggestyrelsen, Denmark
- Lennart Andersen, Energistyrelsen, Denmark
- Michael Rantil, Energimyndigheten, Sweden
- Björn Marteinsson, Innovation Center Iceland
- Lisbeth Landfald, Statens Bygningstekniske Etat, Norway
- Pekka Kalliomäki, Miljöministeriet, Finland
- Jørn Bang Andersen, Eili Vigestad Berge, Nordic Innovation Centre
- Janus Køster, Departement for Boliger, Greenland
- Ewald Kjølbro, Den offentlige bygningsmyndighed, Faroe Islands

The work has been conducted by a project consortium composed of Statens Byggeforskningsinstitut, SBI, Denmark, CIT Energy Management, Sweden and SINTEF Building and Infrastructure, Norway. The consortium has received input to the work from the steering group, and from VTT in Finland. Also, the group has received valuable input from 45 representatives of the Nordic building industry that have been interviewed.

Apart from the members for the steering group, the following persons have contributed to the report:

- Inger Andresen (project leader), Mark Murphy, Igor Sartori and Peter Schild, SINTEF Building and Infrastructure, Norway
- Kirsten Engelund Thomsen (project leader Denmark), Niels Christian Bergsøe, Jørgen Rose and Harpa Birgisdottir, SBI, Denmark
- Åsa Wahlstrøm (project leader Sweden), Lennart Jagemar and Daniel Olsson, CIT Energy Management, Sweden
- Jyri Nieminen, VTT, Finland

The work has been financed by the Nordic council of Ministers. The project consortium would like to express gratitude to all the contributors to the work.

A2 Codes and Regulations

Nordic overview

In the following tables, some perspectives of the national building codes are highlighted and compared. The relevant parts of the energy requirements in the current national building codes are described shortly for each country. The building codes mentioned in this section were valid **January 1st, 2010**.

Table A2.1 Information about calculation values

	Data source	Requirement / Method	Indoor temp.	Internal heat gains appliances and persons	Area for calculation
Denmark	SBi-anvisning	Total energy consumption (EN 13790) combined with max. U-values and specific maximum losses of building envelope	20 °C	5 W/m ²	gross floor area
Finland	C3-2007, D3-2007	U-values calculated in a monthly method (EN 13790)	21 °C	According to building type and use ^a	gross floor area
Iceland	The Icelandic building regulation (no 441:1998)	U-values calculated with IST EN 6946 and IST 66 combined with requirements on maximum thermal losses and air tightness.	no information	no information	no information
Norway	NS3031 (2007) ^b	Maximum U-values or total net energy consumption combined with max. U-values (EN 13790)	21 °C, night set-back to 19°C	According to building type and use	overall internal dim.
Sweden	Boverket 2009; BBR 16 (BFS 2008:20)	Calculation of total energy by own building regulation and monitoring.	22 °C	the given values from EN 13790 are used	overall internal dim.

a) Tabular values given in National building code, parts D3 and D5

b) Tabular values given in NS 3031:2007

Table A2.2 Maximal limits for U-values

	Average U-value [W/m ² K]	U-value roof [W/m ² K]	U-value wall [W/m ² K]	U-value floor slab [W/m ² K]	U-value window (incl. frames) [W/m ² K]	Thermal bridges [W/mK]
Denmark		0.25	0.40	0.30	2.0	different values
Finland ^{ab}		0.09	0.17/ 0.40 ^b	0.09/ 0.16 / 0.17 ^c	1.0 (including skylights, doors)	Included in the U-values
Iceland	0.85 (walls, windows and doors)	0.2	0.4 0.3 (light wall)	0.3 0.2 (if crawl space)	2	
Norway ^b		0.13/ 0.18 ^d	0.18 / 0.22 ^d	exposed floor 0.15 / 0.18 ^e	1.20 / 1.60 ^d	0.03 for detached dwellings, 0.06 for other buildings (norm)
Sweden	Dwellings: 0.5 Dwellings heated with electricity: 0.4 Premises: 0.7 Premises heated with electricity: 0.6					included

a) Reference U-values for the reference heat space demand. Maximum U-value of a wall, floor or roof 0.6 W/m²K, window 1.8 W/m²K. Heat loss to be compensated.

b) Special requirements for timber log houses and leisure dwellings

c) U-Value for heated spaces/"semi-heated" spaces

d) Moderated criteria when total net energy criteria is fulfilled

Table A2.3 Definitions for space heat demand or heat load

	Space heat demand [kWh/m ²]	Heat load or heat loss [W/m ²]
Denmark	no requirements	All U-values have to stay below a specific design heat loss of the building envelope: "Even if the energy performance framework has been complied with, the design transmission loss from single storey buildings, excluding the loss from windows and doors may not exceed 6 W/m ² of the building envelope, excluding windows and doors. For two-storey buildings, the corresponding transmission loss may not exceed 7 W/m ² , and for buildings of three or more storeys, the corresponding design transmission loss may not exceed 8 W/m ² of the building envelope." (at -12 °C)
Finland	Calculated with required U-values	Reference building method applied. The design solution's specific heat loss equal or less than with the reference building according to U-values in table A2.2. Yearly values for ventilation heat recovery efficiency for the reference building 45%. Air tightness for the reference building n ₅₀ =1 h ⁻¹ , and for the design solution 4 h ⁻¹ or proven value.
Iceland	no requirements	no requirements
Norway	no requirements	In the energy measure model, if one ore more of the measures exceeds the requirements; the total heat loss factor must not exceed the heat loss factor corresponding to the base requirements.
Sweden	no requirements	no requirements

Table A2.3 Verification of energy performance

	Verification by measurement
Denmark	no requirements
Finland	no requirements
Iceland	no requirements
Norway	no requirements
Sweden	The building's energy performance should be measured during a continuous period of 12 months and completed, at the latest, 24 months after the building has been taken into use.

Table A2.4 Definitions for total or primary energy demand including weighting factors

	Total (primary) energy demand [kWh/m ²]
Denmark	The total primary energy demand of the building for supplied energy for heating, ventilation, cooling, domestic hot water and, where appropriate, lighting. The limit is expressed as follows: (70+2200/A) kWh/m ² per annum, where A is the heated floor area in m ² Weighting factor for heat in the primary energy calculation is 1.0 and for electricity 2.5.
Finland	no requirement in BC2010, primary energy in BC2012
Iceland	no requirements
Norway ^{a,b}	Total energy demand: Separate requirements for 13 different building categories. Examples: One family house: 125 + 1600/m ² heated floor area Apartment building: 120 As a general rule 40% of heat demand has to be supplied by other sources than grid electricity or fossil fuels, but exemptions are possible.
Sweden ^b	Delivered energy excluding household appliances. Southern Sweden. 110; Central Sweden 130; Northern Sweden 150 With electrical heating as the main source of heating: Southern Sweden. 55; Central Sweden 75; Northern Sweden 95 The weighting factors take into account the quality of the energy. The weight of electricity is in Southern Sweden. 2.0, Central Sweden 1.7 and Northern Sweden 1.6.

a) As an alternative to the requirements on specific energy consumption for buildings, the window and door area does not exceed 20 % of the floor area and there is no requirement for cooling, specific requirements may be applied relating to the thermal insulation of the building, the air tightness of the building envelope and heat recovery.

b) According to the requirements; in areas where connecting to district heating is mandatory buildings shall be equipped with heating systems to facilitate the use of district heating.

Table A2.5 Definitions for heat recovery, air tightness and cooling load

	Heat recovery in the mechanical ventilation	Air tightness by 50 Pa	Cooling demand
Denmark	65% ^a	1.5 l/sm ² ^b	Cooling demand to limit indoor temperature in summer is calculated and included no matter if a cooling system has been established (max. temperature 25 °C) or not (maximum temperature 26 °C). This motivates the designer to avoid designs that results in excessive temperatures.
Finland	45%	4.0 h ⁻¹ or verified value ^e	included for the energy efficiency category calculation
Iceland	no requirement	3 m ³ /m ² h (dwellings) 6 m ³ /m ² h (other)	no requirement
Norway	70% ^{c, d}	3.0 h ⁻¹ (minimum value) 2.5 h ⁻¹ (norm - detached dwellings) 1.5 h ⁻¹ (norm - other buildings)	Local cooling shall be avoided → automatic solar shading devices or other measures should be used to fulfil the thermal comfort requirements without use of local cooling equipment
Sweden	no requirement	no requirement	The demand for cooling shall be minimized by constructional and engineering measures. Included in the specific energy use.

a) For a unit dwelling with one kitchen and one bathroom this means that 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.

b) m² heated floor area

c) Moderated criteria when total net energy criteria is fulfilled

d) Annual mean temperature efficiency

e) $n_{50} = 4.0 \text{ h}^{-1}$ should be used if no verified value is available. $n_{50} = 2.0 \text{ h}^{-1}$ for the reference building.

Table A2.6 Definitions of energy requirements

	Boundary conditions	Energy performance requirements includes
Denmark	Delivered energy	Energy for heating, ventilation, cooling, domestic hot water and, where appropriate, lighting
Finland	Net energy consumption excluding losses Purchased energy consumption including system losses	Energy use of the buildings includes annual energy needed for heating, electricity of buildings technical systems and cooling energy. Other buildings than small residential buildings also include the use of electricity for technical systems and facilities electricity.
Iceland	No requirements	No requirements
Norway	Net energy demand	All energy uses in the budget, i.e. heating, cooling, ventilation, hot water, lighting and equipment
Sweden	Delivered energy, solar thermal or photo-voltaic systems placed on the building site is not included	Energy for heating, comfort cooling, hot tap water, and electricity for the operation of the building

Denmark

Building Regulations Stipulating Energy Performance Requirements

The new energy requirements for new buildings in relation to the EPBD are in The Danish Building Regulations, BR 08. The requirements were first introduced in 2006 in Addendum 12 to BR 95 and in Addendum 9 to BR-S 98 (regulations for small dwellings). These two previous regulations are now merged into BR 08. The energy requirements in the three regulations are almost identical. The requirements now focus on the energy performance of the building, taking into account the energy used for heating, hot water, cooling, ventilation and lighting as stipulated by the Directive. The next revision of the Danish Building Regulations will be implemented ultimo 2010.

Requirements to energy use

The Danish Building Regulations define a limit for the total primary energy demand “of the building for supplied energy for heating, ventilation, cooling, domestic hot water and, where appropriate, lighting.”. The limit is expressed as follows:

Dwellings: $(70+2200/A)$ kWh/m² per year
Other buildings: $(95+2200/A)$ kWh/m² per year
where A is the heated gross floor area in m²

For dwellings where mechanical exhaust results in an air change above 0.3 l/s pr. m², the limits mentioned above are increased accordingly, with an amount corresponding to the extra ventilation heat loss and transport of the extra air volume. The increase is calculated as follows:

$$\Delta E = 130 \cdot (q - 0.3)$$

where

ΔE is the increase in the total primary energy demand in kWh/m² per year
q is the volume of exhaust air in l/s per m² heated gross area.

For other buildings where it is necessary to accommodate either high levels of lighting, excessive ventilation, excessive domestic hot water use or where the number of occupied hours is extended in comparison to normal, the limit for the total primary energy demand can also be increased. The increase should correspond to the extra energy use, when compared to the following:

- a common lighting level of 200 lux.
- a ventilation rate of 1.2 l/s per m² heated gross floor area during occupied hours in the heating season for the sake of indoor air quality.
- a domestic hot water use of 100 litres per m² heated gross floor area per year.
- a number of occupied hours of 45 per week.

Furthermore, an increase to the primary energy demand limit can be achieved if the room height exceeds 4.0 meter. This increase is granted to e.g. industrial buildings, sports halls, if the area of the building envelope divided by the gross floor area exceeds a value of 3.

Calculation method to prove compliance with the requirements

To prove compliance with the requirements for energy performance, the kernel Be06 (SBI) must be used. This can be operated through one of the small number of available user interfaces. The program is based on EN 13790. For all locations in Denmark average monthly mean data from Copenhagen is used. All significant thermal bridges are accounted for specifically.

Important boundary conditions in the calculations/requirements

Internal heat gains are 5 W/m² for dwellings (1.5 W/m² for people plus 3.5 W/m² for other heat gains) and 10 W/m² for other buildings (4.0 W/m² for

people plus 6.0 W/m^2 for other heat gains). Weighting factor for heat in the primary energy calculation is 1.0 and for electricity 2.5.

In energy calculations an indoor temperature of 20°C is assumed. Cooling demand to limit indoor temperature in summer is calculated and included no matter if a cooling system has been established (max. temperature 25°C) or not (maximum temperature 26°C). This motivates the designer to avoid designs that results in excessive temperatures.

Requirements to transmission heat loss and thermal transmittances

“Even if the energy performance framework has been complied with, the design transmission loss from single storey buildings, excluding the loss from windows and doors may not exceed 6 W/m^2 of the building envelope, excluding windows and doors. For two-storey buildings, the corresponding transmission loss may not exceed 7 W/m^2 , and for buildings of three or more storeys, the corresponding design transmission loss may not exceed 8 W/m^2 of the building envelope.”

Thermal transmittance and linear thermal transmittance should not exceed values listed in table 2.1.

Table 2.1 Requirements to thermal transmittance of specific building envelope parts.

<i>Part of building</i>	<i>Limit</i>
External walls and basement walls in contact with the ground.	$0.40 \text{ W/m}^2\text{K}$
Partition walls adjoining rooms that are unheated or heated to a temperature more than 8 K lower than the temperature in the room concerned.	$0.50 \text{ W/m}^2\text{K}$
Suspended upper floors to rooms that are unheated or heated to a temperature more than 8 K lower than the temperature in the room concerned.	$0.40 \text{ W/m}^2\text{K}$
Ground slabs, basement floors in contact with the ground and suspended upper floors above open air or a ventilated crawl space.	$0.30 \text{ W/m}^2\text{K}$
Suspended floors below floors with underfloor heating adjoining rooms that are heated.	$0.70 \text{ W/m}^2\text{K}$
Ceiling and roof constructions, including jamb walls, flat roofs and sloping walls directly adjoining the roof.	$0.25 \text{ W/m}^2\text{K}$
Windows and external doors, including roof lights, glass walls and hatches to the outside or to rooms that are unheated or heated to a temperature more than 8 K below the temperature in the room concerned.	$2.00 \text{ W/m}^2\text{K}$
Foundations around spaces that are heated to a minimum of 5°C .	0.40 W/mK
Foundations around floors with underfloor heating.	0.20 W/mK
Joint between external wall and windows or external doors and hatches.	0.06 W/mK
Joint between roof construction and windows in the roof or roof lights.	0.20 W/mK

Requirements to existing buildings

The requirements for existing buildings undergoing renovation (Article 6) was presented in the same Addenda to the Building regulations BR 95 and BR-S 98 as the requirements for new buildings and with the same implementation schedule. As example the requirements for walls are a U-value higher than 0.20 W/K m^2 , the requirements for roofs are a U-value higher than 0.15 W/K m^2 and the requirements for windows are a U-value higher than 1.5 W/K m^2 . The requirements for existing buildings are unchanged in BR 08.

In multi-family houses and non-domestic buildings, the 25% rule (preamble 13) in the EPBD applies to all buildings, independent of floor area. Cost efficient energy saving measures are required if the renovation of the building shell, or the energy installations, is higher than 25% of the value of the building, excluding the value of the land, or if more than 25% of the building shell undergoes renovation. Also cost efficient energy saving measures not included in the original renovation plan have to be installed. Only churches, museums or protected buildings or those buildings worthy of preservation are exempted from the requirement.

“Cost efficient energy saving measures” are defined as measures that by simple pay back calculation bring at least 33% profit over the standard life time of the building (dependent on the type of the measure). The cost efficient energy saving measures are identified by the energy consultant as part of the labeling of a building.

For all buildings (also to small dwellings) there is a requirement to perform cost efficient energy saving measures to the specific component in the case of renovation of the roof, renovation of the weather shield on external walls, renovation or change of windows, installation of a new boiler or change of heat supply.

Future Trends

The Danish government and parliament has had ongoing plans for energy savings in buildings for many years. The target is to save an additional 25% and 50% respectively compared to new buildings fulfilling the requirement from April 1, 2006. This corresponds very well with the definition of low energy building Classes 1 and 2. The aim is also to achieve further savings in existing buildings.

In addition to this, the Danish Parliament decided in February 2008 that the energy consumption in new buildings by 2020 must be reduced to 25% of present consumption. This was confirmed in the government strategy for the reduction of energy consumption in buildings from April 2009.

The Danish Building Regulations 2010 was released for hearing in April 2010 and it is expected that they are implemented by the end of 2010. The limit for the total primary energy use is proposed as:

Dwellings: $(52.5+1650/A)$ kWh/m² per year
Other buildings: $(71.3+1650/A)$ kWh/m² per year
where A is the heated gross floor area in m²

A new low energy class, Low Energy 2015, will also be defined, with a limit of:

Dwellings: $(30.0+1000/A)$ kWh/m² per year
Other buildings: $(41.0+1000/A)$ kWh/m² per year
where A is the heated gross floor area in m²

The limit for the low energy class is expected to become the minimum demand in 2015

The announcement of expected future requirements has been very positively received by the industry as it allows them to prepare for and plan towards this development and thereby cooperate with the officials to achieve the overall target, instead of being presented to new requirements only a year in advance, which up until now has been the typical approach.

The building market has expanded with the introduction of products and materials that comply with the new low energy class 1 and class 2 buildings. However, there is still an urgent need to plan for the needed upgrading of the existing building stock. The necessary technology is available and proven, but more workable/practical pathways need to be developed to promote systematic upgrades in many Member States to achieve the agreed goal setting for 2050.

Finland

Building Regulations Stipulating Energy Performance Requirements

The regulations are binding, and concern the construction of new buildings. The regulations are applicable to renovation and alteration works only insofar as the type and extent of the measure and a possible change in use of the building require. The instructions are not binding but present acceptable solutions.

Regulations on Energy Certificate of buildings and on inspection of refrigeration devices of ventilation system came into force in 2008. This legislative work covered the implementation of Energy Performance of Buildings Directive.

National building code requirements concerning energy-efficiency of buildings are:

- Part C3 Thermal insulation in a building. Regulations 2010
- Part C4 Thermal Insulation. Guidelines 2003
- Part D2 Indoor climate and ventilation of buildings. Regulations and guidelines 2010
- Part D3 Energy management in buildings. Regulations and guidelines 2010
- Part D5 Calculation of power and energy needs for heating of buildings. Guidelines 2007

The National Building Code defines the basic level of energy-efficiency of new buildings. Energy assessment of a building is required in the building permission process, following the guidelines given in the building code. The conformity with the regulations is assessed with a reference building method. The assessment bases on specific heat loss of a building. The design solution's specific heat loss has to be less or equal with the specific heat loss of the reference building following the requirements given in D3. The specific heat loss calculation bases on:

- U-values of the building components
- Total window area (reference always 15% of the gross-floor area)
- Air tightness of the building envelope [n_{50} 1/h]
- Yearly heat recovery efficiency of the ventilation system.

The energy certification of buildings bases on total energy demand. The assessment of single-family houses includes all energy use, however, the inhabitants' electrical energy use bases on pre-set values. For apartment buildings, offices etc., space heating, hot water heating and electricity for systems and fixed lighting and energy use outside the building (e.g., car heaters) are included in the assessment.

National Building Code Part C3 gives the requirements for thermal insulation level of buildings. Part D3 gives the energy-efficiency requirements. The guidelines for calculation of heating power and energy demand are given in Part D5.

The Ministry of Environment publishes the official Finnish buildings regulations. According to them, from 1.1.2007 to 31.12.2009 heat load (dimensioning heating power) and electricity consumption is calculated according to part D5-2007. The method also includes a very simple method for evaluating the cooling energy and the high indoor temperatures in summertime.

The national method on how to calculate heating power and electricity was published in the year 2007 and it is based on the standard EN ISO 13790.

The method is an energy balance method and the energy use is calculated monthly. The need for cooling energy is roughly estimated monthly and does not take into account the cooling energy in different spaces.

Also the energy consumption of technical systems is handled in a quite simple level. For example the heat losses and the electricity consumption of the technical heating system in buildings are calculated using the exterior floor area of the building and tabulated values based on overall features of the buildings technical system. Energy use of the buildings includes annual energy needed for heating, electricity of buildings technical systems and cooling energy. Other buildings than small residential buildings also include the use of electricity for technical systems and facilities electricity.

The Finnish method includes both the calculation of heating energy as well as heat load, which is important for an energy efficient design of the technical systems in buildings. On the other hand it includes only a very simple and rough calculation of the cooling energy need. It also covers the calculations of the technical building systems (heat losses as well as electricity consumption) on a very common level, and there is no calculation of primary energy consumption or CO₂-emissions.

Future plans

Energy requirements for buildings have been renewed in 2003, 2008 and 2010. The change in 2010 aimed at reducing the heating demand of new buildings by 30%. The next change is planned to take place in 2012. This normative change includes new features such as a method for calculation of thermal bridges and total energy demand calculation for addressing the conformity. Also, primary energy demand will be included. The legislative work should be finished in 2010 for the order to come in force as of the beginning of 2011, and the regulations to come in force as of the beginning of 2012.

There is a preliminary plan to revise the regulations concerning public buildings. This change would come into force in 2015.

Norway

Building Regulations Stipulating Energy Performance Requirements

New Technical Regulations for the construction sector that implements the EPBD were adopted and enforced from February 1, 2007. The industry was given a 2.5 year transition period where the old regulations could be used. All new projects after August 1, 2009 have to satisfy the new regulations. A revision of the regulations has recently been issued, and is enforced from July 1, 2010

The national calculation methodology was launched in a new Norwegian Standard; NS 3031:2007 "Calculation of energy performance of buildings. Method and data". The standard complies with EN ISO 13790 and EN 15265, and gives details for a monthly method. Hourly calculation methods require validation, according to the standard. The calculation uses reference values for important input, such as internal gains, climate (Oslo), operation schedules, hot water demand etc.

The calculation method shows how to calculate net energy demand, delivered energy, primary energy and carbon emissions. The primary energy issue for electricity is somewhat complicated in Norway. Therefore, the present EPBD proposal does not include primary energy requirements, but the issue will be raised again later. For CO₂ emission, the standard refers to EN 15603.

The code requirements can be satisfied according to 2 different models: the framework requirements and the energy measure requirements.

1. The framework requirements model

This model sets a maximum framework for net energy demand for 13 different building categories, given as kWh/m²a for the heated floor area. The framework comprises all energy uses in the budget, i.e. heating, cooling, ventilation, hot water, lighting and equipment:

Table 2.2 Max net energy demand for different building categories

<i>Building category</i>	<i>Max net energy demand¹ [kWh/m² per year]</i>
Detached houses	125 (120) + 1600/heated floor area
Blocks of flats	120 (115)
Kindergartens	150 (140)
Office buildings	165 (150)
Schools	135 (120)
Colleges, universities	180 (160)
Hospitals	325 (300)
Nursing homes	335 (215)
Hotels	240 (220)
Sports buildings	185 (170)
Retail buildings	235 (210)
Cultural buildings	180 (165)
Light industry, workshops	185 (175)

2. The energy measure requirements model

This model implies that a standard set of energy conservation measures has to be incorporated in the new building, see table 2.3. These measures are the same as those used for calculating the reference values for the framework requirements above.

¹ Numbers in parentheses are valid from July 1st 2010, exemptions are made for buildings where recovery of ventilation air may induce transfer of dangerous substances

Table 2.3 Energy measure requirements in the Norwegian building code.

Part of building	Limit
Total max. area of windows, doors, glazed walls and roofs	20% of floor area
Max. U-value of external walls	0.18 W/(m ² K)
Max. U-value of roof	0.13 W/(m ² K)
Max. U-value of slab on ground	0.15 W/(m ² K)
Max. U-value of windows, glazed walls and roofs, and doors (average)	1.2 W/(m ² K)
Max. specific therm. bridging per heated floor m ²	
- for detached dwellings:	0.03 W/(m ² K)
- for other buildings:	0.06 W/(m ² K)
Air tightness: max air change at 50 Pa pressure:	
- general requirement:	1.5 ach
- for detached dwellings:	2.5 ach
Min. annual average temperature efficiency of air heat recovery	70% - 80% ²
Max. specific fan power:	
- for commercial buildings (day/night)	2.0/1.0 kWh/(m ³ s)
- for dwellings:	2.0/1.0 kWh/(m ³ s)
Automatic external shading or other measures that will ensure thermal comfort without local cooling.	
Night and weekend setback of internal temperature to 19°C (17° C for sports facilities)	

For this model, energy calculation is therefore not normally necessary. However, it is possible to reduce the level of one thermal energy measure by compensating with a higher level of another measure. For example, a higher U-value of external walls are accepted if the extra heat loss is compensated through better windows or roof insulation than the reference values above.

The regulations also demand that a substantial share (min. 40% in the regulation of 2007 and min. 40-60% in the regulation of 2011, depending on building size) of the heating load should be covered by other sources than electricity or fossil fuels. Dwellings with a total energy demand below 15000-17000³ are exempt, but must be equipped with a chimney and a closed fire-place.

Implementation of Article 7 of EPBD requiring Energy Performance Certificates was achieved by a change in the Energy Act of 1990. A proposal was issued in December 2008, and it was adopted by the Norwegian parliament in April 2009. The regulations for certificates are enforced from July 1, 2010.

For dwellings a certificate is needed for sale or rental, it can be issued by the building owner. Commercial buildings above 1000 m² will always need a certificate, and the person responsible for issuing the certificate must document his/hers competence.

The certificate gives the building a ranking on a scale similar to the one used for household appliances. Quality level C corresponds to the requirement in the building code, but is based on calculated delivered energy (while the code requirement is based on net energy demand). A web-based tool is available for the calculations necessary for the certificate (www.energimerking.no).

Requirements to existing buildings

The requirements for new buildings are also required for all additions to existing buildings, regardless of the size. They are also required for major renovations of existing buildings, but the municipality may allow renovation where adaption to the energy requirements are not possible, or have disproportionately high costs.

² 80% for non-residential buildings in the regulations of July 1st 2010, exemptions are made for buildings where recovery of ventilation air may induce transfer of dangerous substances

³ Lower value is stated in technical regulation of 2010, higher value is stated in technical regulation of 2007.

Future plans

The Norwegian Government has signaled that the energy code for buildings will be revised every 5 years, and that a passive house standard will be implemented as the minimum code requirement within 2020, or possibly earlier. From 1st July 2011, independent control of air tightness will be required.

The City of Oslo has recently decided that from 2014, all their new public buildings should be built according to the passive house standard (NS 3700).

Sweden

Building Regulations Stipulating Energy Performance Requirements

The EU- EPBD (Energy Performance Building Directive) came into force in December 2002. The directive stated, among other things, that member states were to have requirements on building energy performance in their building codes.

In Sweden, the first building regulation to include energy performance requirements came in the late 1970s (SBN75 1977 and SBN80 1982). These requirements for energy performance were written as requirements with regard to insulating properties of the building envelope. In fact, even before this, indirect requirements regarding the insulating properties of the building envelope had been in force, but these were from a health point of view to prevent draughts and condensation on walls, etc. Requirements were also set for heat recovery. It was not until 2006 that the first building regulation concerning energy use in new building came into force, stipulating requirements for energy performance per unit floor area. The latest building regulations for new buildings (BBR 2008) came into force in July 2008.

In February 2008, the Swedish government decided to amend the ordinance on Technical Requirements for Construction Works. Among other things, the amendment requires buildings with electrical heating, for example, heat pumps, direct electric heating, etc. to be constructed so that energy efficiency is promoted to an even greater extent than in buildings with no electrical heating.

The new building code

The new building code set by the National Board of Housing, Building and Planning has requirements for the building's energy performance. The requirements are described in terms of specific energy use ($\text{kWh/m}^2 A_{\text{temp}}$) and are shown in Table 2.4. A_{temp} , the temperate area, is defined as the area on the inside of the building envelope, on all floors, that is supposed to be heated to more than 10°C. The area of interior walls, openings for stairs, shafts, and similar are included. The area of the garage is not included.

The building's energy use is defined as the energy that needs to be delivered to the building (often called "bought energy"), at normal use and during a normal year, for heating, comfort cooling, hot tap water, and electricity for the operation of the building. Electricity for domestic purposes or business activities is not included. Energy from solar thermal or photovoltaic systems placed on the building site is not included.

The requirements differ depending on: in which climate zone the building is placed (Sweden is divided into three climate zones, see Figure 2.1), if the building has an occupant activity of living (dwellings) or business activities (premises), and if the building is heated by electricity or in another way.



Figure 2.1. Sweden divided into three climate zones

All premises are treated equally, independent of business activity, such as hospitals, restaurants, offices, schools, grocery stores, shopping centers, etc. The reason is that only energy for heating, comfort cooling, hot tap water, and electricity for the operation of the building is included. Electricity for business activities is not included.

Table 2.4 Requirements for specific energy use in the national building code (kWh/m² A_{temp})

Climate zone	I	II	III
Premises that are heated in a way other than with electricity	140	120	100
Dwellings that are heated in a way other than with electricity	150	130	110
All buildings heated with electricity	95	75	55

The ventilation system in dwellings and premises should be designed for an outdoor ventilation rate of 0.35 liter per second and square meter. If, for hygienic reasons, the outdoor ventilation flow is greater than 0.35 liter per second and square meter in premises, an addition may be allowed to the energy performance requirement according to Table 2.5. There is no corresponding addition for dwellings.

The code provides the option to demand control the ventilation rate. For dwellings, however, the ventilation rate may not be lower than 0.10 liter per second in a non-occupied area.

Table 2.5 Addition of energy performance for premises

Climate zone	I	II	III
Premises that are heated in a way other than with electricity	$110 \cdot (q_{\text{mean}} - 0.35)$	$95 \cdot (q_{\text{mean}} - 0.35)$	$70 \cdot (q_{\text{mean}} - 0.35)$
Premises heated with electricity	$65 \cdot (q_{\text{mean}} - 0.35)$	$55 \cdot (q_{\text{mean}} - 0.35)$	$45 \cdot (q_{\text{mean}} - 0.35)$

where q_{mean} is the mean specific outdoor flow during the heating season. q_{mean} is only allowed to be counted for up to 1.00 liter per second and square meter.

For electrical heated buildings requirements are set on maximum installed power (kW) for heating plus an addition when A_{temp} is larger than 130 m² according to:

Climate zone I: $5.5 + 0.035 \cdot (A_{\text{temp}} - 130)$

Climate zone II: $5.0 + 0.030 \cdot (A_{\text{temp}} - 130)$

Climate zone III: $4.5 + 0.025 \cdot (A_{\text{temp}} - 130)$

The building's energy performance should be measured during a continuous period of 12 months and completed, at the latest, 24 months after the building has been taken into use.

Corrections of energy performance, according to a normal year, and possible corrections from the designed use of the building (indoor temperature, hot tap water use, airing, and suchlike) should be accounted for in a special report.

Future plans

New Building Code

The Swedish building code will be revised in 2011 by the Board of Housing, Building and Planning for renovation of buildings. The present regulation for renovation of buildings has no energy requirements more than one shall endeavor to reach the same energy efficiency as at new construction. At present there is no public information on what will be revised compared to the valid building code. Thereafter the code for buildings will be revised every 5 years.

Iceland

Building Regulations Stipulating Energy Performance Requirements

The Icelandic building regulation is from 1998 (with 6 changes, only one has relation to requirements to thermal transmittance of specific building envelope parts). A new building regulation is under development and is expected in February 2011.

The building regulations (paragraph 180.3) stipulate minimum requirements for building component U-values (see values in Table 2.6) along with requirements for total transmission heat loss, including effects of thermal bridges, (paragraph 180.2). The latter may not exceed a value defined as the sum of areas multiplied by U-values based on the actual size of the building and the minimum requirements for U-values (specific requirements for thermal bridges at window-wall joints and foundations are specified elsewhere in the building regulation).

Table 2.6: Requirements to thermal transmittance of specific building envelope parts (U-values given in W/m^2K).

Part of building	Limit $T_i \geq 18^\circ C$	Limit $18^\circ C > T_i \geq 10^\circ C$
Roof	0.2	0.3
External wall	0.4	0.4
- light external wall	0.3	0.4
Windows	2.0	3.0
Doors	2.0	3.0
Floor		
- slab on ground	0.3	0.4
- adjoining unheated room	0.3	0.4
- adjoining crawl-space	0.2	0.4
External walls (weighted average walls, windows and doors)	0.85	no requirement

Calculation of U-values for building parts is done according to ÍST EN ISO 6946 and ÍST 66.

The minimum requirements of air tightness for buildings are listed in paragraph 182.2 in the building requirements. The air tightness of the building envelope of fully heated building with an indoor temperature above $18^\circ C$ tested for air tightness at a pressure of 50 Pa:

- dwellings and similar: $q_{50} < 3 m^3/m^2, h$
- other buildings: $q_{50} < 6 m^3/m^2, h$

There are no requirements regarding maximum ventilation and ventilation heat losses from buildings, but the minimum ventilation usually decided as 0.5 air changes per hour. Minimum room height is assumed to be 250 cm (paragraph 78). There are no requirements on the energy consumption of lighting.

More than 99% of the energy used for heating and electricity in buildings in Iceland is renewable energy (either hydropower or geothermal energy). For that reason Iceland has an exception for the requirements in EPBD regarding energy consumption of buildings.

Future Plans

New building regulation is under development and is expected 01.02.2011. The work group for the development of the new building regulation will deliver suggestions for chapters of the new building regulations to the minister 1 May 2010, including chapters on requirements for energy savings and environmental matters. EPBD will be used for inspiration and requirements on energy consumption of buildings will probably be tightened but due to almost

100% of renewable energy in buildings in Iceland, EPBD will not be implemented in Iceland.

About 90% of all homes in Iceland use geothermal energy for heating and the rest use electricity. During the last decades the same requirements for U-values and energy use have been used for the whole country, regardless of type of energy for heating. It is not clear so far if the new building regulation will make different requirements based on type of energy used.

A3 Incentives

Denmark

Assessment Methods Stipulating Energy Performance Requirements

Denmark is presently investigating the possibilities of implementing one of the existing methods for environmental assessment in Denmark (e.g. BREEAM, LEED). The Danish method will most likely be based on one of the existing systems and then revised in order to take into account specific national interests. A few houses have been certified with the German passivhaus method.

An energy labeling system for small buildings was implemented in Denmark already in 1997 and has thereafter been successfully used. This has implied a low demand after voluntary schemes.

Other Incentives

At present, there is no direct private financial support for energy saving measures in Denmark. The political climate has normally not been in favour of financial support.

However, some public subsidies are available. With the special view of reducing CO₂-emissions from residential buildings 400 million DKK were awarded on the Budget for replacing old oil-fired burners with more energy efficient heating systems such as heat pumps, district heating and solar heating.

Energinet.dk finances the research and development projects by charging tariffs for transport of electricity and gas in the public Net. Energinet.dk is an independent public enterprise owned by the Danish State (Ministry of Climate and Energy). The financial frame is 130 million DKK per year.

EUDP (Energiteknologisk Udviklings- og Demonstrationsprogram) is an energy technology demonstration programme supporting the development of new technologies. The Danish Energy Agency has the secretariat. The grant for 2009 is approx. 220 million DKK.

Danish energy companies have certain obligations for energy savings decided by the Danish government. Therefore, as an incentive for building owners the gas companies give them 0.42 DKK for each kWh saved energy in the following areas: windows and glazing, outer walls, insulation of pipes, roof, biomass and solar heating. Furthermore, for conversion to more energy efficient heating installations grants can be given.

Finland

Assessment Methods Stipulating Energy Performance Requirements

The Finnish energy labelling system for buildings came into force in the beginning of 2008. There are 10 categories of buildings with slightly varying requirements for energy label (energy-efficiency requirement for class A):

1. Small residential buildings with not over 6 apartments (150 kWh/gross-m²)
2. Large residential buildings with more than 6 apartments (100 kWh/gross-m²)
3. Office buildings (90 kWh/gross-m²)
4. Commercial buildings (140 kWh/gross-m²)
5. Educational buildings (120 kWh/gross-m²)
6. Nurseries (140 kWh/gross-m²)
7. Health care buildings (160 kWh/gross-m²)
8. Recreational buildings excluding swimming halls (110 kWh/gross-m²)
9. Swimming halls (300 kWh/gross-m²)
10. Other buildings (110 kWh/gross-m²)

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Todistuksen antaja: Pekka Pääsuunnittelija		Todistuksen tilaaja: Matti Meikäläinen																												
Allekirjoitus: <i>Pekka Pääsuunnittelija</i>																														
Todistuksen antamispäivä: 23.1.2008		Villainen voimassaoloaika: 22.1.2018																												

Example of energy labelling

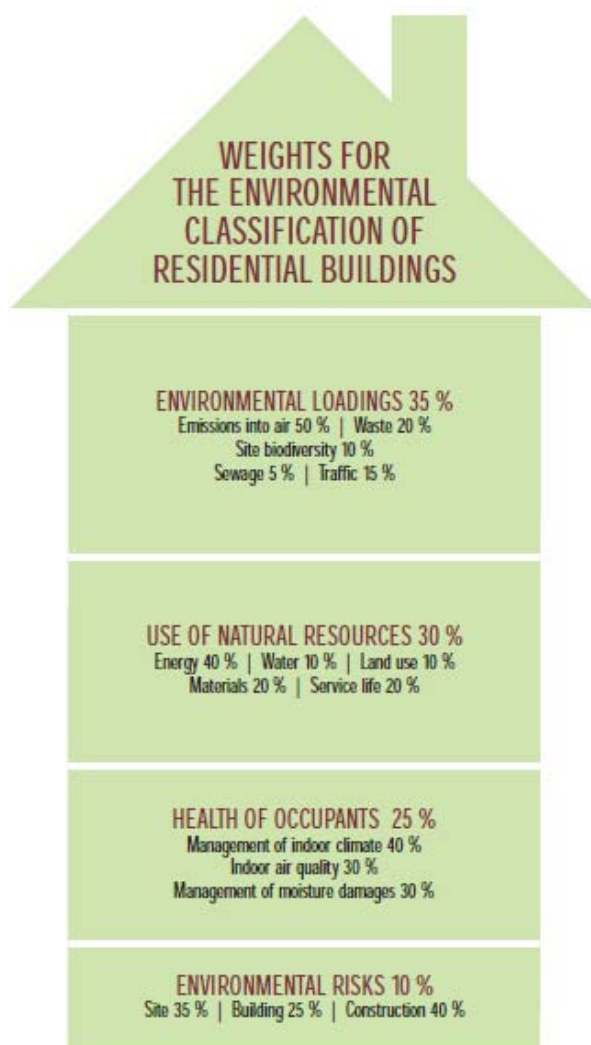
For small residential buildings the electrical energy demand includes all electricity use in a building. The electrical energy assessment bases on specific consumption values given in the Building Code part D5. Thus, the design solution's electrical systems do have an impact on energy-efficiency target, but the labelling can be improved only by reducing the heating energy consumption.

In large apartment buildings the electrical energy use includes fixed lighting, building services systems, and electricity for the facility, but it does not include electricity use in the apartments. If, e.g., an apartment based ventilation system is included in the resident's energy metering, it will be included in the electricity consumption in the energy labelling assessment.

Environmental classification of buildings

The Promise environmental classification is an Internet based tool for setting requirements and comparing properties of buildings. It has been designed for residential, office and retail buildings. The office classification can also be applied to schools and other educational buildings. Promise for projects is a tool for the systematic management of environmental and life cycle issues in new buildings and extensive renovations. Promise for properties is used to create environmental classification for existing buildings.

Promise environmental classification divides a building's environmental performance into four categories: environmental loading, health of users, consumption of natural resources, and environmental risks. Each category is divided into subcategories and further to 1 - 4 indicators. The total environmental classification is formed on the basis of classifications and weights of the main categories.



Swan labelled building is a detached house with requirements set for building process, materials and energy demand. Basically, a house with Swan labelling has a good indoor climate and low environmental impact. The assessment bases on environmental consequences from raw materials to a finished product. The impacts on the environment requires that

- agents or substances harmful for the environment are not used
- the house enables energy-efficient living
- the house has a use and maintenance plan

Requirements for a good indoor climate refer to

- materials use
- good ventilation
- construction process
- quality control



Energy assessment methods

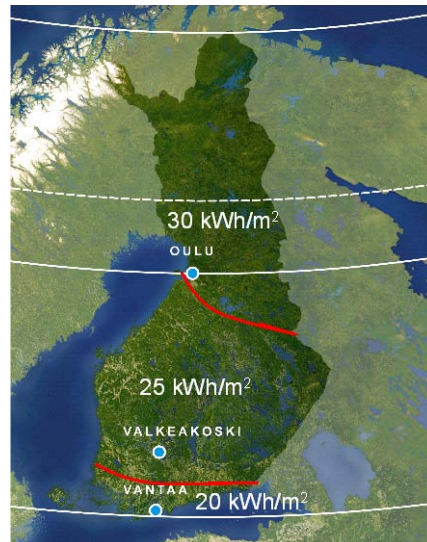
There are two Finnish energy assessment methods: Low energy building and Passive building. Low-energy building refers to the National Building code D3-2010. A low energy building's specific heat loss is less than 85% of the reference building's specific heat loss.

VTT defined a low energy building already in the early 1990's as a building which has a heating energy demand 50 % lower than with a house following the requirements of the building code of the time of construction. VTT's definition for a passive house originates from the European research project PEP Promotion of European Passive Houses. The definition of passive house differs depending on geographical location. There are three categories for heating and cooling energy demand (gross-floor area):

- o South Finland 20 kWh/(m²a)
- o Middle Finland 25 kWh/(m²a)
- o Lapland 30 kWh/(m²a)

The three categories for primary energy demand are:

- o South Finland <130 kWh/(m²a)
- o Middle Finland <135 kWh/(m²a)
- o Lapland <140 kWh/(m²a)



RIL - Finnish Association of Civil Engineers publishes instructions and norms on construction activities. RIL 249 Low Energy Handbook for Residential buildings defines a low energy building (P50) and a passive house (P25) as follows:

- LEB: space heating energy demand is 26 - 50 kWh/gross m²
- passive house: space heating and cooling energy demand is not more than 25 kWh/gross m² assessed in the climate of Jyväskylä, Central Finland

Financial Incentives

There are no financial incentives available for energy-efficient new buildings.

Limited incentives are available for energy-efficiency improvements of existing buildings stock. Energy efficiency grants concern apartment buildings and row houses. There was also a specific grant for renovation of apartment buildings (10% of the costs) for projects that started before 31.12.2009.

Demand tested (depends on total salaries of a family) grants are available for detached house owners for investments that improve the building's energy-efficiency. The grants are up to 25% of accepted costs. Grants for energy surveys for detached, row and apartment buildings are available as of April 1, 2010. These incentives are granted by cities and communities and the Housing Finance and Development Centre of Finland.

Individual municipalities or cities develop their own incentives to speed-up energy-efficient construction. E.g., the City of Tampere is planning a method for energy-efficiency dependent rent for a plot.

Norway

Assessment Methods Stipulating Energy Performance Requirements

Environmental assessment methods are not commonly used in Norway. A few projects are currently being assessed using BREEAM and LEED. The Green Building Alliance (www.byggalliansen.no), consisting of several major Norwegian developers, has decided that BREEAM should be adopted for use in Norway. A tool for calculating the greenhouse gas emission of a building project has been introduced (klimagassregnskap.no), and has been implemented in a cost calculation program with BIM integration (ISY Calcus). The tool has been used in a few building projects, and will be further used in a series of pilot building projects in the FutureBuilt program (www.futurebuilt.no).

NS 3700

In April 2010, a new Norwegian voluntary standard for low energy and passive houses was launched ("NS 3700:2010 Criteria for low energy and passive houses – Residential buildings"). Work with a similar standard for non-residential buildings has started, and is expected to be launched in 2011. The main requirement in the standard is related to energy use for heating. For low energy houses the annual energy use for heating has to be lower than half of that of a standard new house (maximum 30 kWh/m²). For passive houses, the net energy use for heating must be less than 1/4 of that of a new standard house (maximum 15 kWh/m²/yr). There is an adjustment for cold climates and small dwellings. The standard also includes requirements with respect to U-values, air-tightness (has to be measured), ventilation heat recovery, and renewable energy for heating.

Other Incentives

The Norwegian State Housing Bank has a number of instruments at its disposal to promote sustainable environmental quality in buildings; loans, grants, information and advice. Almost half of all new homes financed with the Norwegian State Housing Bank's (NSHB) basic loan had a special environmental quality. Nearly all of these have implemented energy savings. With regard to new homes, the energy saving is 40 percent or more, and for renovations, 20–40 percent.

Test and pilot projects with a particularly high ambition-level may receive grants covering up to 80-90 per cent of costs. Development projects of national importance for the construction industry can apply to the NSHB for grants to cover development and information campaigns. Up to now the NSHB has focused on increasing the construction industry's competence with respect to building low-energy homes by arranging courses, seminars and meetings for master builders, civil engineers, architects, estate agents and sellers of standard house types all over the country. An important area of focus will be to raise homebuyers' awareness of the advantages of investing in low-energy homes.

Enova SF is owned by the Ministry of Petroleum and Energy. It was established to take a leading role in promoting environmentally friendly restructuring of energy consumption and energy generation in Norway. Enova's goal is to make it easier for public and private enterprises to choose simple, energy-efficient and environmentally correct solutions. Enova's support program for the built environment aims to contribute to lasting changes within the built environment market sector. The projects covered under the program include both existing and new commercial and residential buildings, as well as construction projects such as water supply and sewage systems, road lighting and sports facilities. Enova prioritizes projects that yield a high kWh result

relative to the needed financial support. The funding level is normally from 0.2 to 0.5 NOK/kWh of reduced energy consumption and/or generated renewable heat per year. The sum of the reduced energy consumption and use of renewable heat make up the energy goal. Disbursement of funds is made in relation to the progress made in the project and the results achieved. In April 2010, Enova launched a new incentive program for projects meeting a passive house standard or lower (pilot projects). For such projects, Enova offer a fixed support rate of 450 NOK/m² for new dwellings, 600 NOK/m² for renovation of dwellings, 350 NOK/m² for new non-residential buildings and 450 NOK/m² for renovation of non-residential buildings.

Sweden

Assessment Methods Stipulating Energy Performance Requirements

Miljöklassad Byggnad is a Swedish environmental assessment method that has been developed and tested during the last years. It is now ready to be used and a few buildings have been certified.

FEBY passive house is a requirement specification for passive houses developed with Swedish requirements but is inspired of the German passivhaus method. The first two buildings have now been certified with a FEBY passive house.

The GreenBuilding certificate for premises have been more successful and about 150 buildings are now certified. The GreenBuilding program in Sweden has over 30 partners and about 15 Endorsers.

Skanska and NCC are both testing how to apply the existing models LEED and BREAM, respectively, for Swedish conditions.

One building has been certified with the Nordic Ecolabelling some years ago.

A Green Building Council has just been established in Sweden.

SS 24300, standard for energy classification of buildings

In cooperation between real estate companies, house owners, constructors, component producers and consultants a standard for energy classification of buildings have been developed.

The objective is that a clear labeling of the energy use will give Sweden more environmentally friendly buildings. The new energy classification gives buildings a clear labeling with A to E, the equal labeling that is for fridges. Outermost the goal is that the labeling will be a driving force to build and to choose more energy efficient buildings.

The EU directive about buildings' energy performance, EPBD, sets already today requirements on energy declarations of buildings. The new standards are the Swedish interpretation of those European standards that exists in order to measure buildings' energy consumption (EN 15207 and EN15603).

The standard for energy classification is considering several different aspects. One for the power need of space heating, one for energy use for heating, cooling, domestic hot water and building operation, one for environmental aspects as primary energy and emission of CO₂ and one for household electricity or activity electricity. The first two have been accepted within the standardization committee and will be published in mid 2010 (SS 24300-1, Energy performance of buildings — Part 1: Power classification of space heating need and SS 24300-2, Energy performance of buildings — Part 2: Classification of energy use).

Other incentives

Private financial incentives

There are no private financial incentives in Sweden staged by banks or insurance companies. Previous studies and interviews about this show that financial institutes need to be better informed about the advantages with low energy buildings from a financial point of view (lower energy costs and improved building quality).

The interviews mentioned above were carried out late autumn 2008, during the international bank crisis, a fact that may have influenced their hesitating response.

Subsidy

The County Administrative Board deal out subsidies for both solar electricity and solar heating. Maximal subsidy for solar cells is 60 % of the investment cost or 2 million SEK (approx. 200 000 euro). Subsidy for solar heating is based on calculated exchange of heat. Maximal subsidy for solar heating is 7 500 SEK (approx. 750 euro) per apartment or 3 million SEK (approx. 300 000 euro) per project.

There are also subsidies for replacing old oil-fired burners or direct electricity in one family houses with more energy efficient heating systems. For one family houses it is also possible to get tax deduction for work performed in improving the building status (including energy efficient measures).

The Swedish Energy Agency gives subsidy for the demonstration part in a few demonstration projects. During the last five years 8 demonstration projects have been performed and until 2014 eight more demonstration projects are planned.

Iceland

Assessment Methods Stipulating Energy Performance Requirements

There is no label or assessment method for buildings in Iceland that specifically evaluates energy performance of buildings. The special situation of having more than 99% of the energy consumption in Icelandic buildings deriving from renewable energy, as well as an exclusion of the EPBD in Iceland, the incentive for an Icelandic assessment method for energy consumption for buildings has been fairly low.

On the other hand the need for a broader environmental or sustainable assessment method for buildings in Iceland has appeared after the Cultural Policy in the Field of Construction was issued by the Ministry of Education in April 2007. The policy addresses issues like:

- cohabitation of man and nature
- decisions made in the planning stage should be based on life cycle costs
- the state should lead the way regarding sustainability and environmental perspectives and set ambitious goals.

The policy does not address specific issues on energy performance of buildings but it can be seen as one of the issues that would be included in the inclusion of life cycle costs of buildings.

The release of this policy, and the fact that the state should lead the way regarding sustainability and environmental perspectives, has increased the requirements set by the Governmental construction contracting agency in at least 3 projects in Iceland. The Governmental construction contracting agency has chosen to test the BREEAM method in procurement and construction of 3 public buildings in Iceland. Currently, one of the building is in the final phases of the construction phase, one building has finalised the design phase and one building is in the design phase. One more building (built in public private partnership) was evaluated by the LEED method during the design stage (but not certified); this building is now being built. A Green Building Council was established in Iceland in February 2010.

Environmental Assessment Methods

BREEAM (The United Kingdom)



General description

BREEAM (BRE's Environmental Assessment Method) is a system that was developed in the early 1990s as a voluntary system for the environmental assessment of buildings by BRE (Building Research Establishment), which at the time was state owned but is now a private company (www.bre.co.uk). The method was initially used only for offices, but has since then been developed for other types of buildings as well. The system encompasses many areas with different numbers of assessment questions and associated criteria. Many different types of buildings are included, and there are versions for the planning and design phases and for operation and maintenance.

Users and uses

The assessment is carried out according to standard procedures that were developed by BRE. A consultant is used, who is called an Operating Contractor, and under this person consultants are employed who have taken a course to be assessors. A preliminary final rating is based on the system documents at the completion of construction. An inspection is made after the occupants have moved in, which confirms the final rating. A final report is written, which is checked by BRE, which issues a certificate. This is valid for an indefinite period.

Areas of use: energy, resources and indoor environment. The method is used for determining the classification, choice of system and environmental targets for the building in its entirety. BREEAM is available in versions for new and existing offices, schools, ecohomes and retail stores and in a so-called bespoke version (for other buildings, such as churches and industrial buildings).

Input data

Assessment of criteria according to standard procedures.

Method

The system entails receiving a score (an EPI, Probable Environmental Performance Index Score) in every criterion. The scores are added together to a total, which determines the rating.

Results

A summary assessment is given in the form of one of the following final ratings: pass, good, very good or excellent.

SBTool (Canada)



General description

SBTool (Sustainable Building Tool) is a computer program for the Green Building Challenge (GBC), an environmental assessment method that has been developed in international collaboration since 1996. The initiative came

from Ray Cole and Nils Larsson in Canada (www.greenbuilding.ca). The idea behind it was to come to an agreement on a common framework that could be used in different countries in the environmental assessment of buildings. The method was to be able to be adapted to local building and climate conditions. Today, the system is administered by Nils Larsson via the organisation IISBE (International Initiative for a Sustainable Built Environment).

The method considers seven areas: A) Site Selection, B) Energy and resource consumption, C) Environmental loadings, D) Indoor environment, E) Control of functionality and use, F) Performance over time and G) Social and economic aspects. There are three versions of the method, one for each of the following phases: design, construction and use.

Users and uses

The method can be said to have been developed principally for project developers, but purchasers and users could conceivably also be interested in the results.

Input data

A large amount of input data is required for a complete assessment. This data is divided into the following groups: A) Site-related information (distance to services, ground area, ground surface cover, etc), B) Construction data and costs, C) Information about structures predating the development, D) Areas and numbers of stories, E) Ventilation and use, F) Surface water and waste water, G) Energy use, H) Electricity use and local energy production, I) Emissions during the phase of use (indoor and outdoor environment), J) Recycled materials, K) Daylight and L) Technical systems.

Method

The method comprises a hierarchical system of criteria.

Results

The weighted results are presented as bar charts.

CABSEE (Japan)



General description

CASBEE is a state-supported environmental assessment system in Japan (www.ibec.or.jp/CASBEE/english). Its development began in 2001 to meet political and market demands for sustainable construction. Certification is carried out by IBEC (the Institute for Built Environment & Energy Conservation).

There are many different tools in the same system: the Design phase, New constructions, Existing buildings, Renovations, Detached houses, Areas and Areas + buildings. The method uses Japanese norms and calculation methods, such as for energy. The system is based on giving credits for greater than normal user quality and less than normal environmental impact. The normal values are established according to criteria.

CASBEE is in essence a criterion-based system with pre-determined weightings. In addition, a smaller number of quantitative values are estimated, in which LCA-methodology is used. Data has been compiled for the method on the lifespan of the construction materials and on the embodied energy of the materials. The system considers the categories: Indoor environment (Q1),

Quality of service (Q2), Outdoor environment on site (Q3), Energy use (L1), Resources and materials (L2) and Off-site environment (L3).

Users and uses

Some municipalities have introduced a requirement for CASBEE estimations to obtain planning permission. Accreditation as a CASBEE assessor can be obtained following an education.

Energy, resources, the indoor environment and the outdoor environment are included. A large number of buildings have been assessed.

Input data

Depending on the stage, different calculated or measured values are used.

Method

The ratings system from 1 to 5 largely agrees with that of GBTool. The weightings have been set by an expert group.

Results

The results are presented in four different ways: 1) as rose diagrams with weighted values for every area, 2) as bar charts with weighted impact values for every category, 3) as a diagram of eco-efficiency (quality/impact) and 4) as certain quantified indicators.

GREEN STAR (Australia)



General description

Green Star is developed and administered by the organisation Green Building Council Australia (GBCA) (www.gbca.org.au). It is an equivalent organisation to that which develops LEED in the US. The organisation has technology committees that cooperate with professionals in the areas of construction and the environment to develop criteria.

Users and uses

The method is intended to be used by property owners, consultants, quantity surveyors and project managers, among others. There are versions for the design phase, for newly completed buildings and for existing buildings.

Input data

A range of Excel programs provide support in carrying out the assessment. A classification can be given by a comprehensive program, but this contains a range of support programs with which values for consumption, transport and the like can be calculated.

Method

There are the following nine classification categories: Management, Indoor Environment Quality, Energy, Transport, Water, Materials, Land Use & Ecology, Emissions and Innovations. For every assessment area there are a number of different assessment questions.

Results

The following ratings, based on the overall score and in accordance with the above values, are issued.

Ranking: <45 points: no rating, 45-59 points; best practice, 60-74 points: Australian excellence, 75-100 points: world leader.

LEED (the USA)



General description

The LEED™ Green Building Rating System is developed and administered by the U.S. Green Building Council, which is a non-profit association with members across the country (www.usgbc.org). The first version was brought out in 1999. LEED standards exist, or are under development, for:

- New commercial buildings and major renovations (LEED-NC)
- The operation of existing buildings (LEED-EB)
- Interiors in commercial projects (LEED-CI)
- Core, shell and installations (LEED-CS) (commercial buildings)
- Homes (LEED-H)
- Neighbourhoods (LEED-ND)
- Schools
- Healthcare buildings
- Retail stores

LEED was created to:

- define a "green building" by developing a common assessment standard
- promote a whole-building approach
- give attention to sustainable leadership in the construction sector
- stimulate competition within sustainable construction
- increase consumer awareness of the advantages of "green buildings"
- change the construction market

The documents are updated from time to time. The target is to reach 25 percent of the best buildings. The system comprises six categories: Sustainable sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality and Innovation and Design Process. There are a number of criteria inside of every area that each can give one or more credits.

Users and uses

LEED is used by buildings and project developers, particularly for commercial buildings, as a guide for sustainable design.

Input data

Supporting material for assessing whether the selected criteria are fulfilled.

Method

The system entails gaining credits for every criterion that is fulfilled. The credits are added to a total, which determines the score. For new buildings, for example, the highest possible score is 69.

Ranking: 26-32 points: certified, 33-38 points: silver, 39-51 points: gold, 52-69 points: platinum

Results

Classification takes place according to a certification procedure, which places demands on, among other matters, documentation and the involvement

of a certified assessor. An emblem may be displayed in a building that has been classified.

DGBN (Germany)



www.dgnb.de

General description

The German Sustainable Building Certification was developed by the German Sustainable Building Council (DGNB) together with the Federal Ministry of Transport, Building, and Urban Affairs (BMVBS) to be used as a tool for the planning and evaluation of buildings in this comprehensive perspective on quality.

The certificate is based on the concept of integral planning that defines, at an early stage, the aims of sustainable construction. In this way, sustainable buildings can be designed based on the current state of technology, – and they can communicate their quality with this new certificate.

Method

The German Sustainable Building Certification is a tool for planning and evaluation of buildings that covers relevant topics of sustainable construction. Six subjects affect the evaluation: ecology, economy, social-cultural and functional topics, techniques, processes, and location.

Results

The results are expressed in Building Certification with the categories bronze, silver, and gold.

Miljöklassad byggnad (Sweden)



General description

This is an environmental assessment method that includes energy performance (www.byggabodialogen.se). The full name of the method is *Environmental classification of buildings for a sustainable built environment*. The environmental classification system is a tool to help save energy and to safeguard human health and the environment. The purpose of the environmental classification method is to provide an overall picture of how the building works.

Users and uses

The method can be used by building owners (existing buildings) but it can also be used in the planning phase.

Method

The environmental classification covers energy, the indoor environment, and chemical substances in the building. It provides an overall picture, which can be used as a solid basis when taking decisions on improvements. The classification can also establish a foundation for reducing costs, for example lower running costs and insurance premiums or better financial terms. The environmental classification is a voluntary activity that can either be free-standing or combined with the statutory energy performance certificate.

Three categories are classified: Energy, Indoor environment and Chemical substances. A fourth category – Special environmental requirements – is only relevant for buildings with their own water supply and sewage systems. Each category contains a number of environmental aspects. These aspects were selected as the most important in terms of the potential effects of the building on people and the environment.

Input data

The environmental aspects can be represented in measurable factors or so-called indicators. The system awards marks to these indicators, to produce an assessment of each category first, and finally the building as a whole. The marks range from A to D, with A the highest class – C is enough to meet building regulations for new buildings but D is not. The classification system is designed with four levels: categories, aspects, indicators and classification criteria. Some developments and adjustments are currently being carried out to meet the wishes of the market, but environmental classification is now up and running.

These are the four classified categories mentioned above:

- Energy

There are three energy aspects with a total of four indicators, most of them covered by the energy performance certificate. The aspects are:

- o Energy consumption based on purchased energy
- o Energy requirement based on the physical characteristics of the building and heat recovery
- o Energy type based on the proportions of energy types used.
- o The Indoor environment category

- Indoor environment

Indoor environment category identifies the principal health problems that may be related to the indoor environment of the building. Five different aspects are assessed:

- o Noise conditions based on assessment or sound class
- o Air quality based on radon content, ventilation and nitrogen dioxide in the indoor air
- o Thermal climate and daylight based on the transmission factor, solar heat gain factor and daylight
- o Moisture based on the presence or risk of damage
- o Risk of development of Legionella in water, based on the domestic hot water temperature.

- Chemical substances category

Three aspects are considered, relating to the occurrence of chemical substances used in the building and its building materials:

- o Occurrence of particularly harmful substances based on an inventory
- o Documentation of building products and chemical substances using logbooks, databases, etc.
- o Phase-out of particularly dangerous substances, based on documentation.

- Special environmental requirements category

Two aspects that are only relevant for buildings with their own water supply and sewage systems:

- o Small sewage systems with high reduction of eutrophied substances
- o Good drinking water quality based on the analysis of tap water from the property's source.

Results

Weighted results for each aspects are given, there is no general result for all aspects weighted together.

Nordic Ecolabelling of small houses, apartment buildings and pre-school buildings



www.svanen.nu

Small houses, apartment buildings and pre-school buildings can be awarded the Nordic Ecolabel (Nordic Swan). Nordic Ecolabelling requirements cover the construction process, materials and energy consumption. Consideration is paid to all environmental aspects, from the raw materials to the finished building. In addition to low environmental and climatic impact, the building must offer a good indoor environment. This is guaranteed by:

- the constituent materials.
- good ventilation.
- the construction process.
- material and quality controls to prohibit built-in damp damage.

To minimise environmental impact, Nordic Ecolabelling also requires:

- the limitation of substances in construction materials that are hazardous to health and the environment.
- that the building is energy efficient.
- the environmentally suitable disposal of construction waste.
- an operation and maintenance plan for the building.

Energy Assessment Methods

MINERGIE (Switzerland)



General description

Minergie was established in 1998 as a voluntary system for the quality labeling of new, renovated and converted buildings (www.minergie.ch). As the name of the method suggests, the emphasis is on low energy use, with extended versions available for, for example, environmental impact. The system is administered by a non-profit organization and is mostly financed by, among other means, certification and membership fees.

Minergie is available in the following different versions:

- Minergie (since 1998)
- Minergie-P (since 2002) – Passive buildings
- Minergie-Eco (since 2006)
- Minergie-P-Eco (since 2006) – Passive buildings with “eco-demands”
- Minergie-Modul (since 1998) – for building components

Some banks offer reduced interest for Minergie buildings. The energy demands are based on weighted primary energy (production and transport losses included). Minergie does not include specific requirements regarding the indoor climate.

Local certification offices issue the certificates, which are valid for five years.

Users and uses

The organization has members and authorised members, that is, companies that are associated and that can carry out a certification. In Switzerland, about 12 percent of the newly built dwellings and 15 percent of the newly built offices are Minergie certified.

Input data

The input data for calculations are in accordance with the standards of SIA and Minergie.

Method

Minergie sets limits for energy use.

Results

A certificate showing that the building fulfils the requirements of Minergie is issued and is valid for five years for operations that are maintained as they are for this period.

Passivhaus Standard (Germany)



General description

The term passive house (Passivhaus in German) refers to the rigorous, voluntary, Passivhaus standard for energy efficiency in buildings (www.passiv.de). Passivhaus Institut in Germany is the responsible organi-

zation. It results in buildings that require little energy for space heating or cooling. The energy requirement for heating is lower than 10-20 kWh/m² annually (depending on climate). The maximum heating power requirement is 10 W/m².

Users and uses

The Passivhaus standard is used by buildings and project developers, particularly for residential buildings, as a guide for sustainable design. However, the standard is not confined only to residential buildings; several office buildings, schools, kindergartens and a supermarket have also been built according to the standard. Although the standard is mostly applied to new buildings, it has also been used for refurbishments.

The first Passivhaus buildings were built in Darmstadt, Germany, in 1990.

Input data

Energy and power performance is calculated with a software tool called PassivHaus Planning Package.

Method

The Passivhaus standard for central Europe requires that the building fulfills the following requirements:

- The building must be designed to have an annual heating demand as calculated with the Passivhaus Planning Package of not more than 15 kWh/m² per year in heating and 15 kWh/m² per year cooling energy or to be designed with a peak heat load of 10W/m²
- Total primary energy (source energy for electricity and etc.) use (primary energy for heating, hot water and electricity) must not be more than 120 kWh/m² annually.
- The building must not leak more air than 0.6 times the house volume per hour ($N_{50} \leq 0.6$ / hour) when the building is pressurised at 50 Pa.

Results

A certificate showing that the building fulfils the requirements of Passivhaus.

FEBY passive house (Sweden)



FEBY (Forum för energieffektiva byggnader),

<http://www.energieffektivabyggnader.se>

General description

This is an energy assessment method developed by FEBY (Forum för energieffektiva byggnader) ordered by the Swedish Energy Agency (www.energieffektivabyggnader.se). The German passivhaus standard (see below) forms the basis for the Swedish ditto. The Swedish passive house standard is however not a *standard* in the strict sense of the word, but a list of requirements.

For a building to be described as a passive house, it must meet a number of fundamental requirements for this type of building. This quality-assures the meaning of this construction concept in marketing and communication within the construction and management process.

A building that meets the requirements specified here, and where the specified certifications have been carried out for each individual project, can be

classified as a passive house, and the term can be used in communication and marketing to describe the performance of the building in question.

To avoid misunderstanding, it is important to specify which definition of passive house is being referred to.

Users and use

Used by buildings and project developers.

Method

There are two calculation methodologies, an international and a Swedish adapted to Swedish conditions and building regulations.

As mentioned above, the Swedish version of the passive house concept is based on the German passivhaus standard, with national adaption to Swedish conditions. Here are some of the requirements:

- Heat power, residential and commercial buildings
 - o South Sweden: $P_{max} = 10 \text{ W/m}^2$
 - o Middle Sweden: $P_{max} = 11 \text{ W/m}^2$
 - o North Sweden: $P_{max} = 12 \text{ W/m}^2$
- Heat power, small detached houses $< 200 \text{ m}^2$
 - o South Sweden: $P_{max} = 12 \text{ W/m}^2$
 - o Middle Sweden: $P_{max} = 13 \text{ W/m}^2$
 - o North Sweden: $P_{max} = 14 \text{ W/m}^2$
- Air tightness. Maximum air leakage through building is $0,30 \text{ l/s m}^2$ at the pressure difference 50 Pa
- Insulated windows. Maximum U-values is $0,90 \text{ W/m}^2 \text{ K}$

In addition to the requirements above, there are recommendations that *should* be fulfilled. There are recommendations regarding:

- Domestic hot water technique and payment concepts
- Fan power
- Domestic electricity
- Energy performance

The last mentioned recommendations are as follows (non-weighted energy for heating, cooling, domestic hot water and building operation):

- South Sweden: 50 kWh/m^2 buildings not heated with electricity
- South Sweden: 30 kWh/m^2 buildings heated with electricity
- Middle Sweden: 54 kWh/m^2 buildings not heated with electricity
- Middle Sweden: 32 kWh/m^2 buildings heated with electricity
- North Sweden: 58 kWh/m^2 buildings not heated with electricity
- North Sweden: 34 kWh/m^2 buildings heated with electricity

Input data

Input data are specified in a list of requirements from FEBY.

Results

There are two “levels” of fulfillment

1. *Designed* as passive house according to FEBY
2. *Verified* as passive house according to FEBY

The last mentioned level requires supporting measurements. Directions for verifications are given in a separate report.

GreenBuilding (Europe)



General description

This is an energy assessment method. In 2005 the European Commission launched the GreenBuilding Programme (GBP). GreenBuilding is a voluntary programme aiming at improving the energy efficiency of non-residential buildings in Europe on voluntary basis. The programme addresses owners of non-residential buildings to realise cost-effective measures which enhance the energy efficiency of their buildings in one or more technical services.

Users and use

The programme addresses owners of non-residential buildings to realise cost-effective measures which enhance the energy efficiency of their buildings in one or more technical disciplines.

Method

New Buildings should have an energy performance that is 25% less of the requirements in present building code.

Existing Buildings should improve its energy performance with at least 25%, after refurbishment compared to before the refurbishment.

GreenBuilding Partner and Endorser

By becoming a GreenBuilding Partner, your company can present itself as an innovative player regarding sustainability and energy efficiency in non-residential buildings. Your company's commitment will be recognized by the awarding of the GreenBuilding plaque, by letting you use the GreenBuilding logo and in the context of various dissemination activities of GreenBuilding.

The GreenBuilding Endorser Programme has been established to promote GreenBuilding to potential participants and to support already registered GreenBuilding participants in their efforts to reduce the energy consumption in their non-residential buildings. The GreenBuilding Endorser Programme is open to almost all interested parties from the building sector. For example equipment manufacturers, building contractors, energy management and system design companies, electric utilities and energy service companies, energy equipment importers, distributors and vendors, national professional and trade associations.

To become a GreenBuilding Endorser, an organisation must have assisted at least one building owner in becoming a GreenBuilding Partner. Furthermore, it is expected that a GreenBuilding Endorser will undertake specific actions to support GreenBuilding.

Input data

A full description of the expected energy performance of the building together with the technologies used is required.

Results

GreenBuilding certificate for buildings, partners or endorser.

Low Energy Building M-50 and Passive House P-25 (Finland)

There are two Finnish energy assessment methods: Low energy buildings and Passive energy building. Both of them refer to the national building code C3-2010. They contain requirements on U-values ($\text{W/m}^2\text{K}$), envelope air tightness ($1/\text{h}$), heat recovery factor (%), specific fan power efficiency ($\text{kW/m}^3/\text{s}$), primary energy (kWh/m^2), space heat (kWh/m^2) and peak load energy performance (kWh/m^2).

Table 3.1 below shows an example of reference values according to RIL 249-2009

Table 3.1 Apartment building reference values for Norm RakMk (C3, 2010), Low Energy Building (M-50) and Passive House (P-25)

Technical factor	Norm RakMk C3, 2010	Low Energy Building M-50	Passive House P-25
U-values, $\text{W/m}^2\text{K}$			
- building element between the inside of the building and the ground	0.16	0.12	0.10
- floor that is between the inside of the building and the subfloor space	0.17	0.10	0.10
- inside of the building and the outside	0.09	0.09	0.09
- wall	0.17	0.14	0.12
- roof	0.09	0.08	0.08
- window	1.0	0.9	0.8
- door	1.0	0.6	0.5
Envelope air tightness (n_{50}), h^{-1}	<2.0	<0.8	<0.6
Yearly efficiency of the heat recovery in the mechanical ventilation system %	>45	>65	>75
Air ventilation specific electricity consumption, $\text{kW/m}^3/\text{s}$	<2.5	<2.0	<1.5
Primary energy demand, $\text{kWh/m}^2\text{a}$	-	<180	<135
Space heat demand, $\text{kWh/m}^2\text{a}$			
- ordinary winter use	30	15-20	10-15
- design situation peak load	50	30	20

The definition of passive house differs depending on geographical location.

There are three categories for heating and cooling energy demand:

- o South Finland $20 \text{ kWh}/(\text{m}^2\text{a})$
- o Middle Finland $25 \text{ kWh}/(\text{m}^2\text{a})$
- o Lapland $30 \text{ kWh}/(\text{m}^2\text{a})$

The three categories for primary energy demand are:

- o South Finland $<130 \text{ kWh}/(\text{m}^2\text{a})$
- o Middle Finland $<135 \text{ kWh}/(\text{m}^2\text{a})$
- o Lapland $<140 \text{ kWh}/(\text{m}^2\text{a})$

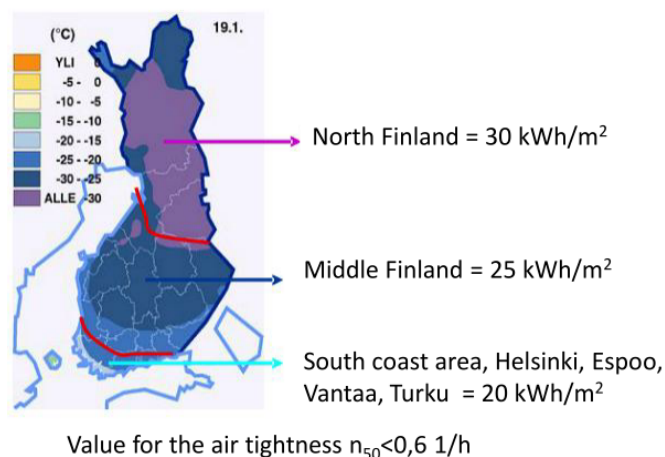


Figure 3.1 The three categories for heating and cooling energy demand.

Primary energy weighing factors are as follows:

Oil and gas:	1.1
District heating:	0.4
Wood based	0.2

Energy Labelling Systems

Energy Labelling of buildings in Denmark



General description

This is an assessment method focusing only on energy performance. The primary purpose of the method is to promote energy savings and energy efficiency in both new and existing buildings. This is achieved through the energy labeling method by:

- Informing potential buyers or tenants about the building's energy status and the expected energy cost of normal use.
- Informing the building's owner, administrator or users on opportunities to implement energy saving measures or improve the energy efficiency of the building.

Users and uses

The energy consultant for small houses must be an architect, engineer, construction designer or the like and must have at least 2 years documented, relevant experience of building technology and energy consultancy during the last 6 years. The qualifications for energy consultants for public buildings, the trade/service sector etc. must be a trained engineer or the like.

The method is used for energy labeling both new and existing buildings in Denmark.

Method

In the Danish energy labeling scheme, buildings require an energy label:

- When they are newly constructed or undergo a major renovation
- When they are sold
- If they are rented out.

In the case of new buildings, the building needs to have a satisfactory energy label (B) to fulfill the energy requirements in the building regulations to be granted a permit for use.

The energy labeling of new buildings is based on a building inspection supplemented with material data from the building plan and building permit application. The energy consultant ensures that the energy requirements of the building regulations have been met by:

- Verifying that required insulation of the technical installations are in order
- Verifying that buildings, installations and products have the energy efficiency assumed when building permits were applied for.

In the case of existing buildings being sold or rented out, the buildings must have an energy label not more than 5 years old. This also applies to blocks of flats, where individual flats are rented out or sold. In blocks of flats, the labeling is done on the building, but with an individual sub label for each flat stating its heating demand.

The daily operation of the labeling scheme is delegated to a secretariat also operating the other schemes related to the EPBD.

The specific rules for labeling to be used by the energy consultants are in the Handbook for Energy Consultants. The handbook is available to the public on www.femsek.dk (in Danish). The handbook also includes tabular data for typical constructions and installation in buildings to facilitate the uniformity of the labels being given by different consultants.

Input data

Calculations and self-supervision (the individual energy consultant's quality control) must be carried out by the certified consultant personally. The consultant is personally responsible that keyed in information is correct. Deviation from this may result in withdrawal of the certification. The energy consultant is free to choose the method of registering the building as long as the registration is correct. The individual consultants are also under surveillance of the Danish Energy Agency. All certificates are collected in a central database at the Danish Energy Agency.

Results

There are 7 classes on the labeling scale from A to G, where A is the highest. New buildings must at least be labeled as class B to get the permit for use. Class A is for low energy buildings class 1 and 2.

The energy consultant identifies two types of energy saving measures:

- Immediately feasible energy saving measures and
- Measures that are only feasible if carried out as a supplement to ongoing renovation.

Energy labeling of existing buildings must conform to the new standards from September 1, 2006.

A4 Market Share

Denmark

Classification of LEB Relative to National Building Regulations

The term Low Energy Building is well-known in Denmark and has been so since the mid seventies. The term was used and defined in the provisions of the Danish Building Regulations BR-S85 of 1 March 1985. Also the Passive House Concept is fairly well-known, however not as part of the Danish Building Regulations.

As described in the previous chapter the current Danish Building Regulations, BR 08, specify a limit for the total primary energy demand of the building for supplied energy for heating, ventilation, cooling, domestic hot water and, where appropriate, lighting. Also, since 1 April 2006, the Danish Building Regulations define two low energy performance levels termed Low Energy Class 2 and Low Energy Class 1. Low Energy Class 2 is defined as having a calculated energy performance that is 25 % better than the minimum energy performance for new buildings and Low Energy Class 1 is defined as having a calculated energy performance that is 50 % better. Consequently, the market share of Low Energy Buildings in Denmark is described in the light of these definitions.

Together with the implementation in Denmark of the Energy Performance Building Directive (EPBD) in 2006 the existing energy certification scheme was adjusted and the accompanying database containing the energy certificates issued was updated. The database, established in accordance with Article 7 of the EPBD, facilitate procurement of an overview of LEB in Denmark. However, due to inequalities when compared to data from Statistics Denmark on the overall building activity, the recordings in the database have been adjusted proportionally.

Market Trends

A large number of LEB projects have been conducted over the years. Two projects are mentioned here: *Fremtidens Parcelhuse* and *Komfort Husene*.

Fremtidens Parcelhuse (~ Detached houses of the future) is a new urban area of detached houses in Herfølge, south of Køge. All houses are being built with strict requirements regarding energy efficiency and environmental impact. At present about 50 building sites out of a total of 86 have been developed. The ongoing project will demonstrate, that it is possible to build and live energy- and environmentally friendly in an urban area of detached houses - without being a do-it-yourself builder and without reducing the comfort of traditional accommodation or the quality of the construction. More information can be found at <http://eng.fremtidensparcelhuse.dk/>.

Komfort Husene (The comfort houses) is a project comprising 10 houses in Skibet, west of Vejle. The project is Denmark's largest development project to date of single family houses with no heating systems. The aim of the ongoing project is to spread knowledge about buildings with passive heating and to set the agenda both for future construction and for the energy policy debate. More information at: <http://www.komforthusene.dk/passivhuse+-+hvordan-c7-/articles+and+brochures+in+english>.

Below tables and figures illustrate the status of LEB in Denmark. Table 4.1 shows floor area completed 2007-09 divided into building categories while table 4.2 shows floor area divided into energy performance levels. Some building categories have been excluded in order to be able to relate to the Energy Certificate Database. Succeeding figure 4.1 gives the distribution of energy certificates issued with respect to building category and energy performance level. The number of single family houses and terraced houses completed 2007-09 is given in table 4.3 divided into energy performance levels and finally figure 4.2 gives the relative distribution of houses completed (~ energy certificates issued) divided into year of construction and energy performance level. For apartment blocks energy certificates are issued based on certifying one or more selected apartments in the block. Therefore, neither the number of certified apartment blocks nor the number of certified apartments can be established within reasonable accuracy. For residential buildings Statistics Denmark provide statistical data on both completed floor area and number of buildings completed, but for other buildings the completed floor area alone is registered. Consequently, table 4.3 concerns only single family houses and terraced houses.

It should be noted that although the concept of Low Energy Buildings typically and intuitively is related to new buildings, the Danish Building Regulations - with reference to EPBD - also consider LEB in connection with renovation.

Table 4.1. Floor area completed 2007-2009. In order to make it possible to relate to the Energy Certificate Database some building categories have been excluded. Source: Statistics Denmark.

Denmark	Completed floor area [m ²]			
	2007	2008	2009	Total
Single family houses	2,123,224	2,092,603	1,506,462	5,722,289
Terraced houses	746,198	724,077	367,615	1,837,890
Apartment blocks	1,047,764	678,730	435,351	2,161,845
Other residential buildings	262,154	280,354	286,970	829,478
Office buildings	1,329,128	1,745,803	1,407,794	4,482,725
Educational buildings	152,483	224,624	207,533	584,640
Other types of buildings	178,529	241,005	282,421	701,955

Table 4.2. Completed floor area 2007-2009 divided into energy performance levels based on combining the Energy Certificate Database and Statistics Denmark. For each building category the numbers in parenthesis indicate the percentage of the total completed floor area, i.e. the rightmost column.

Denmark	Completed floor area [m²]					
	Standard	LEB Class 2		LEB Class 1		Total
Single family houses	5,126,604	532,562	(9.3 %)	63,123	(1.1 %)	5,722,289
Terraced houses	1,650,343	186,612	(10.2 %)	935	(0.1 %)	1,837,890
Apartment blocks	2,104,460	57,385	(2.7 %)	0	(0.0 %)	2,161,845
Other residential buildings	747,342	78,046	(9.4 %)	4,090	(0.5 %)	829,478
Office buildings	4,199,561	264,226	(5.9 %)	18,938	(0.4 %)	4,482,725
Educational buildings	537,730	28,960	(5.0 %)	17,950	(3.1 %)	584,640
Other types of buildings	683,363	18,592	(2.6 %)	0	(0.0 %)	701,955

Table 4.3. Number of houses completed 2007-2009 (~ number of energy certificates issued) divided into energy performance levels based on combining data from the Energy Certificate Database and Statistics Denmark. For each building category the numbers in parenthesis indicate the percentage of the total number of houses completed, i.e. the rightmost column.

Total number of houses completed, i.e. the rightmost column.						
Denmark	Number of houses					
	Standard	LEB Class 2		LEB Class 1		Total
Single family houses	21,583	2,004	(8.4 %)	227	(1.0 %)	23,814
Terraced houses	14,769	1,929	(11.5 %)	17	(0.1 %)	16,715

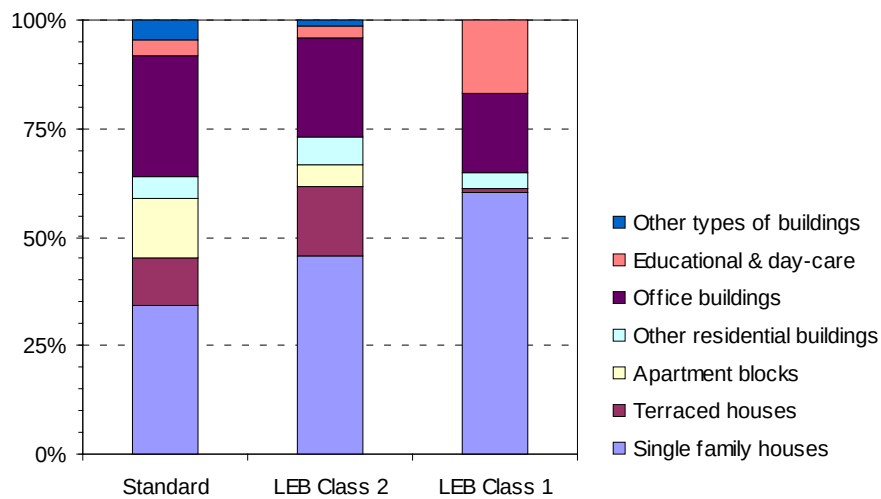


Figure 4.1. Distribution of energy certificates issued 2007-2009 based on the heated area as reported in the Energy Certificate Database.

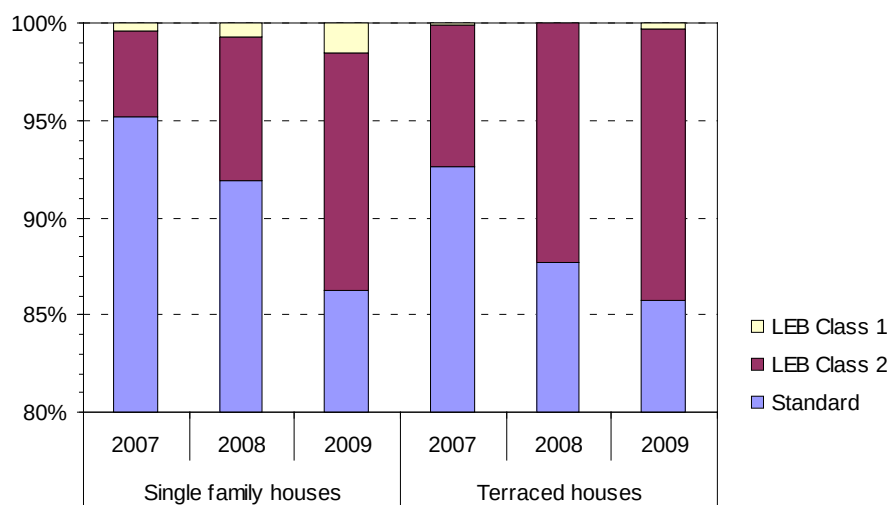


Figure 4.2. Relative distribution of houses completed 2007-2009 (~ number of energy certificates issued) divided into year of construction and energy performance level. The figure is based on combining data from the Energy Certificate Database and Statistics Denmark.

Norway

Classification of LEB Relative to National Building Regulations

Figure 4.3 below shows a comparison of the delivered energy use for a detached house built according to national average, according to the current building code, according to the low energy standard, and according to the passive house standard.

Currently, the low energy and passive house levels are officially defined for dwellings only (NS 3700). However, the energy labeling system include requirement for calculated delivered energy for 13 different building categories. Quality level C corresponds to the requirement in the building code, but is based on calculated delivered energy, while the code requirement is based on net energy demand. The calculation is based on NS 3031, as for the building code. Quality levels A, and B correspond to 50 % and 25 % reduction of delivered energy relative to level C. Energy label B corresponds approximately to the low energy level, while label A corresponds approximately to the passive house level.

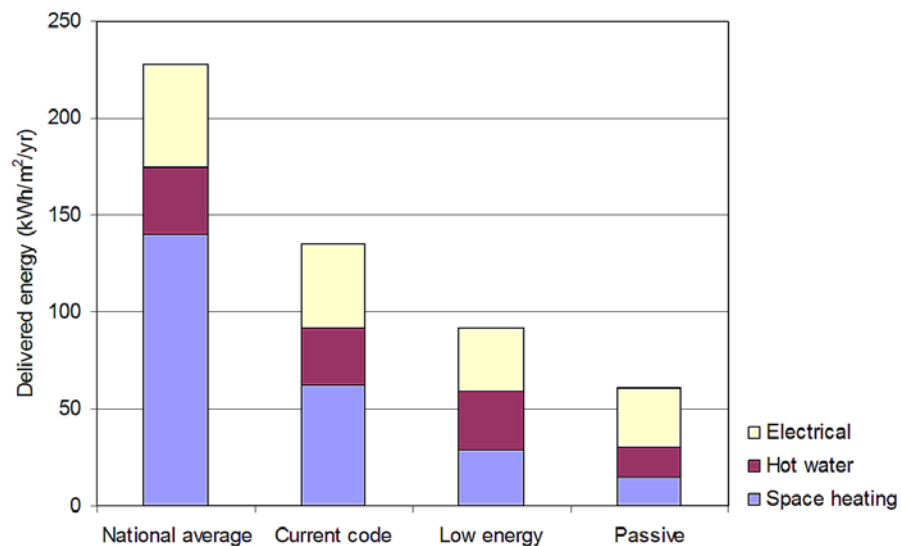


Figure 4.3. Comparison of the delivered energy use for a detached house built according to national average, current building code, low energy standard, and passive house standard.⁴

Market Trends

Currently, there is quite a large interest in low energy and passive houses, and several hundred projects are in the planning phase. Several hundred low energy buildings have been built, cf. table 4.4, but only a few passive houses. However, virtually none of the projects have undertaken a measurement and verification program to document the energy and environmental performance. Hence it is not known to what extent they live up to their expectations.

Up to now, the focus has been mainly on new construction, but renovation to low energy and passive house levels is starting to gain interest, and a few projects are under planning and construction. No zero or plus energy buildings have been built, but 1-2 pilot project will probably be initiated during 2010.

The main focus in Norway has been on dwellings and new construction, partly due to financial incentives and information programs from the Norwegian State Housing Bank (Husbanken) and the Norwegian state energy agency (Enova). The Norwegian association of dwelling producers (Bolig-

⁴ Note that the building code refers to net energy demand and not delivered energy.

produsentene), have had a large 5-year program to develop and implement low energy solutions in their portfolios. The project, which was supported by Enova, focused mainly on envelope solutions (air-tightness, etc.), but did also include other aspects such as water based heating systems and BIM⁵.

Some major market players have ambitious targets for low energy buildings. For example, the City of Oslo has decided that all their new buildings should be at passive house level from 2014. Another example is the large building manager Entra (www.entra.no), who has an aim that all their projects should satisfy at least energy label B.

There is currently no national registration of low energy and passive buildings. From July 1, 2010, all new buildings and buildings that are being sold will have to be energy labeled, and there will be a national register administered by NVE. Thus for now, it is not possible to make an accurate estimate of the number of low energy buildings. The numbers in table 4.4 are estimated based on the databases of the Norwegian Association of Architects (www.ecobox.no), Enova's reference projects (<http://naring.enova.no>), statistics from the Norwegian State Housing Bank (www.husbanken.no/Statistikk) and surveys made by the Norwegian Association of Dwelling Producers (www.boligprodusentene.no).

Table 4.4. Buildings built in Norway between 2005 and 2010 divided into building category and energy performance level, in m2 floor area. For each building category the numbers in parenthesis indicate the percentage of the total number of buildings built, i.e. the rightmost column. Please note that significant uncertainties are associated with the number of low energy buildings.

Norway	Standard	Low Energy	Passive	Zero Energy	Plus Energy	Total
Single family houses	9,346,419	1,038,802 (10.0 %)	2,800	0	0	10,388,021
Apartment blocks	5,381,544	598,208 (10.0 %)	2,324	0	0	5,982,076
Office buildings	1,533,144	128,212 (7.7 %)	0	0	0	1,661,356
Educational buildings	1,947,797	6,600 (0.3 %)	6,230	0	0	1,960,627
Other types of build.	17,875,393	23,451 (0.1 %)	15,129	0	0	17,913,973

⁵ Boligprodusentenes forening. Prosjekt 04/657 "Boligprodusenter i nettverk for økt energistandard i boliger", Sluttrapport 2005-2009.

Sweden

Classification of LEB Relative to National Building Regulations

In figure 4.4 comparisons of the delivered energy use for apartment blocks and premises are made for national average, current code, green building classification, class A according to a coming Swedish standard and passive house classification. Delivered energy includes energy for space heating, comfort cooling, tap water heating and operational electricity in accordance with the current building code. Green building classification is only for premises so far. The figures for passive house classification for premises are so far only for kindergartens and schools.

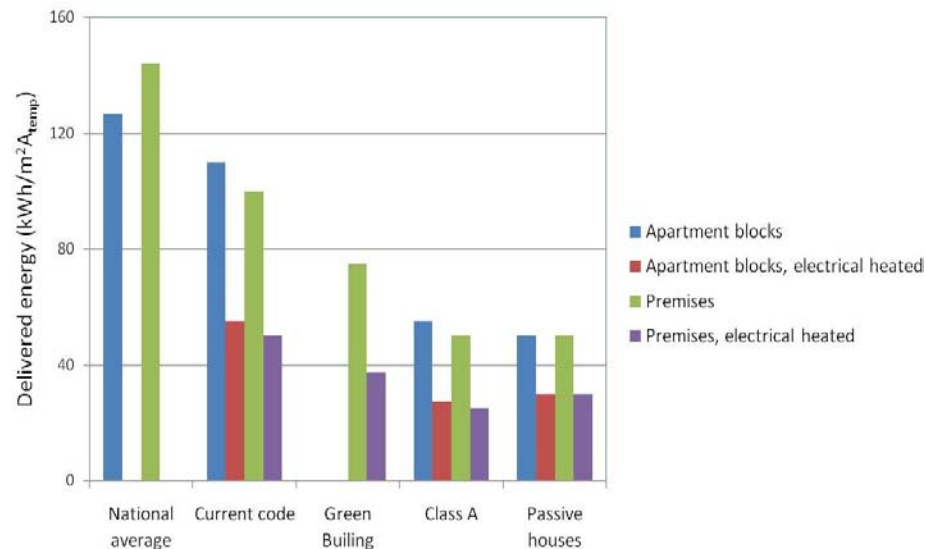


Figure 4.4. Comparison of delivered energy for space heating, comfort cooling, tap water heating and operational electricity for apartment blocks and premises in climate zone

Market Trends

The first good examples of energy efficient apartment buildings was realised in 2000 in Gårdsten, Gothenburg, Sweden. The apartment blocks from early seventies were successfully refurbished and attracted international attention.

Another good example of energy efficient apartment buildings is a new and energy efficient apartment block called Jöns Ols built in 2000 in Lund.

The European housing exhibition Bo01 in Malmö 2001 and later Hammarby Sjöstad in Stockholm were both meant to be good examples in many aspects but did not quite live up to expectations regarding energy use.

It was not until 2006 that three new areas with energy efficient apartment blocks were completed (12 apartments in Frillesås (Kungsbacka), 40 apartments in Oxtorget (Värnamo) and 12 apartments in Hertigs Gård (Falkenberg). All of them are defined as examples of passive house techniques. Sweden got more good examples in 2008 when Hamnhuset, a new building with 116 apartments in Gothenburg was built. Moreover, a large refurbishment project is in progress in Brogården, Alingsås. In 2008 18 apartments from the seventies were refurbished according to the passive house technique, but another 282 apartments will be refurbished in the near future.

One may say that the Swedish market eventually has started for apartment blocks, even though most buildings still are built according to the national building code, which has no high requirements on building energy performance.

The first 20 passive houses were built as terraced houses in Lindås 2001. Thereafter it was a slow business. It was not until 2004 36 new terraced houses were ready in Glumslöv. In 2008 the first kindergarten built after the passive house principal was ready in Alingsås and a school in Storfors and a separate one family house in Lidköping. A few projects for energy efficient offices are ongoing in Stockholm. In Borås there is a very energy efficient hospital but otherwise the good examples of premises are few.

The market introduction of low energy houses and passive houses has been very slow in Sweden. During the last years the introduction of passive house technique has been demonstrated on dwellings, mostly in west and south-west of Sweden (Västra Götalandsregionen, Halland and Skåne). There have not been clear definitions or certification schemes for neither passive houses nor low energy houses in Sweden. Therefore, it is very difficult to exactly define the buildings between them. During the last year the first buildings have got a certificate for managing passive house requirements and a classification standard is planned to be published within a few months. Most of the good examples only account for designed energy performance and only a few of them have had a real follow up program. The new building code requirement where energy performance should be measured within 24 months after building completion will, during this year, give the first results of measured energy performance.

The passive house technique for dwellings has started to settle in west and southwest of Sweden and different actors are planning to do demonstration projects within their organizations. Other areas in Sweden have begun to adapt the technique and are in the planning stage to carry out their own demonstrations projects. Even though the construction and building sector has started to try the technique there is a need for incentives for using the technique in more than demonstration projects.

Interest has also been reached for demonstration of passive house technique for kindergartens and small schools in several places in Sweden. The passive house technique has been discussed a lot in Swedish media lately and is now well known within the construction and building sector.

For the market of premises the discussions is more about low energy houses rather than passive house technique. Many within the branch talk about benefits with heat pump techniques that can be used for both heating and cooling. The interest for different techniques to build low energy houses is increasing but it will probably take a few more years before actual projects may be in operation. With experiences of the very slow market introduction of passive house technique in Sweden there is a need for clear incentives if the market introduction will be realized within this decade.

Besides low energy houses and passive houses a renovation concept has started to be established in Sweden. The renovation concept is called "the total concept" and has been developed within the BELOK program (clients group for premises), www.belok.se, and is now also practised within the program BeBo (clients group for apartment blocks), www.bebostad.se. The "total concept" is a financial model to show for the decision takers. The financial model includes all energy efficient measures in order to reach 50 % reduction of energy use. This means that also measures that are not cost effective on its own will be cost effective within the package. In this way energy efficient measures will be performed during the renovation that otherwise would be discussed for ages during the next renovation maybe 20 - 40 years ahead.

There is currently no national registration of low energy and passive buildings. Therefore, the figures in the tables below have been collected from a number of sources, e.g. www.fastighetsagarna.se/web/GreenBuilding.aspx, www.byggtermometern.se/Hela_riket.asp and www.passivhuscentrum.se/.

Table 4.5. Number of buildings/apartments built in Sweden between 2005 and 2010 divided into building category and energy performance level. Numbers in parenthesis indicate the percentage of the total number of buildings built.

Sweden	Standard	Passive House technique	Plusenergi	Green Building (75% of building code)
Single family houses and terraced house	55,000	320 (0.6%)	2 (0%)	
Apartment blocks (apartments)	90,000	750 (0.8%)		
Office buildings	15,000 – 20,000			About 30 (~ 0%)
Educational buildings		4 (~ 0%)		
Other types of buildings				

Table 4.6. Number of buildings/apartments renovated in Sweden between 2005 and 2010 divided into building category and energy performance level. Numbers in parenthesis indicate the percentage of the total number of buildings built.

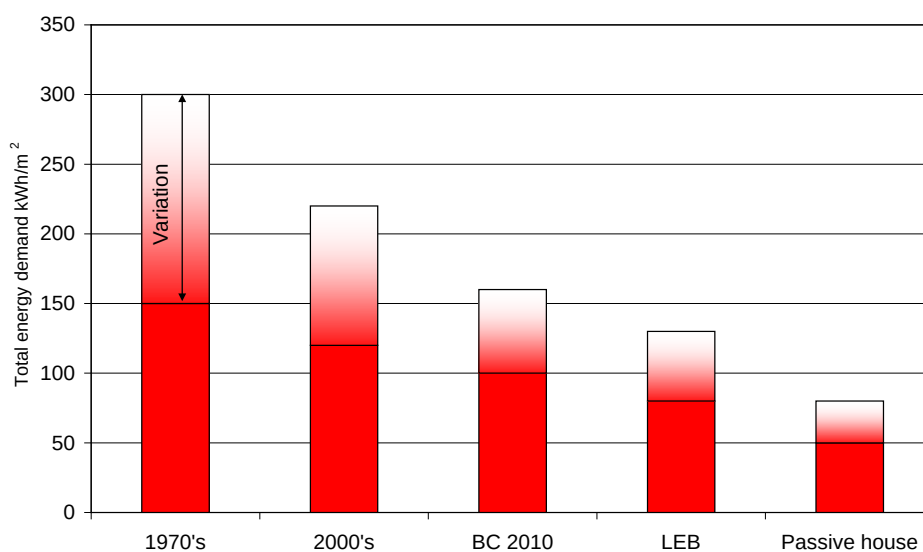
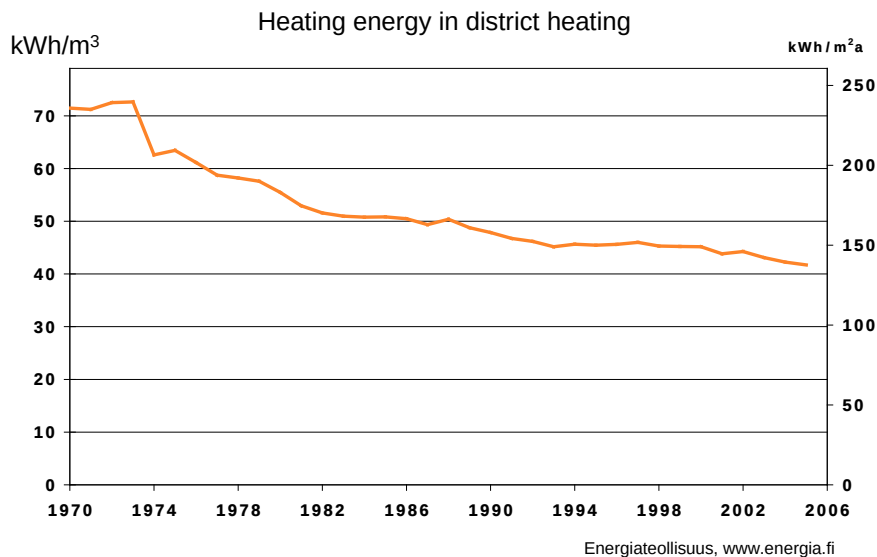
Sweden	Standard	LEB	50% reduction compared to before renovation	Green Building, 25% reduction compared to before renovation
Apartment blocks (apartments)	141,000	320 (0.2%)	250 (0.2%)	
Office buildings			5	About 110
Educational buildings			3	
Other types of buildings			20	

Finland

Classification of LEB Relative to National Building Regulations

A Low Energy Building was first defined by VTT within the national research programme Energy-Efficient Buildings and Building Components 1990 - 1994. Low energy buildings were promoted, e.g., by competition organised by Motiva, an affiliated Government agency for energy-efficiency. Energy-efficiency in general gained interest, but the development has been slow. VTT made a markets study on low energy housing in 2004. According to a questionnaire study for 300 families who have a plot but no building permission, roughly 50% were very interested in building a low energy house, but in reality only 10% of the families implemented energy efficiency measures in their houses.

Figures below show the development energy demand in the Finnish building stock. The specific energy demand has decreased quite steadily. Apartment buildings of the 1960's and 1970's have the highest energy consumption, and the number of these buildings is large (roughly 560 000).



Market trends

All major construction companies have developed very low energy concepts. The market leader in energy-efficient apartment buildings, however, is a SME construction company RKL Reponen Oy who announced already a few

years ago that they will build only passive or very low energy buildings. The company produces roughly 100 apartments a year.

Producers of prefabricated detached houses have also developed their own concepts. Finndomo Oy published their future aim of zero energy house 2020 in 2008. Low energy buildings seems to be the major trend in single-family houses.

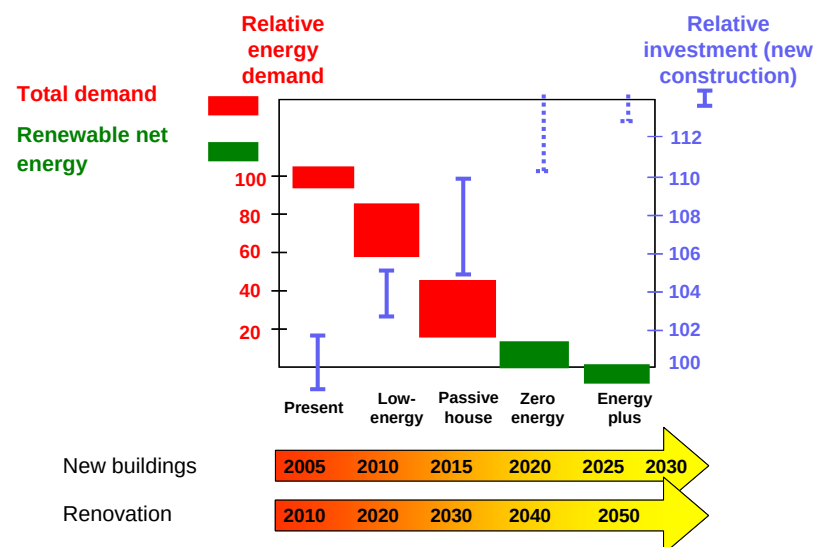
Some cities such as Oulu has promoted low energy construction by guidance and help to builders. As a result, the average heating energy demand in new houses in Oulu was about 30 - 40 % lower than typically in other cities. The City of Helsinki ordered that where the site locates on land owned by the city, all buildings must fulfil at least the requirements of energy label class A.

The major problem with low energy buildings is the quality of design and construction. Although the land use and building act from 2000 gives tools for builders to largely secure the construction quality by means of site supervision, private builders do not understand the importance of the supervision.

Superinsulated building structures have gained a lot of resistance due to distrust in hygrothermal performance of thick insulation layers. There has been a lot of public discussion on the performance issues, however, the argumentation has based on skipping the basic requirement of energy-efficiency - quality of design and construction.

Despite of the negative argumentation against the low energy construction the actions on promotion of energy efficiency have been very successful. Low energy buildings gain more market share all the time.

There are no technological barriers for the wide adoption of very low energy or passive buildings. The figure below estimates the market penetration of various very low energy building concepts in new construction and renovation.



Source: Construction sector's energy efficiency strategy. VTT 2008

Iceland

As described in the previous chapter there are no limitations for the total primary energy demand in buildings in Iceland and therefore no registration of low energy buildings in Iceland exists. Iceland statistics publishes statistics of the residential buildings built in Iceland (in m³). Table 4.7 shows the estimated total floor area of residential buildings completed 2005-09 assuming an average height of 2.4 m.

Table 4.7. Completed floor area 2005-2009 in Iceland. Source: Statistics Iceland*.

Iceland	Completed floor area [m ²]					
	2005	2006	2007	2008	2009	Total
Residential buildings	602,917	640,417	656,250	586,667	179,583	2,665,833

* In Iceland completed buildings are registered in m³. In this table the volumes have been divided by the average height of 2.4 m in order to estimate the completed floor area.

Low Energy Buildings in Europe

Low energy buildings are known under different names across Europe. A survey carried out in 2008 by the Concerted Action supporting EPBD identified 17 different terms in use to describe such buildings e.g. *low energy house*, *high-performance house*, *passive house/Passivhaus*, *zero carbon house*, *zero energy house*, *energy savings house*, *energy positive house*, *3-litre house* etc. In the relevant literature additional terms such as *ultra-low energy house* can be found. Finally, concepts that take into account more parameters than energy demand again use special terms such as *eco-building* or *green building*.

Furthermore, what energy use is included in the definition varies from country to country. It may be argued, that the minimum performance requirements should take into account all types of energy use that is demand for space heating (cooling), water heating, air conditioning as well as consumption of electricity. This is often not the case. On the contrary, the definition may cover only space heating ignoring all electricity demand that may cover most heating needs for instance in office buildings. This is, however, inconsistent with the EPBD.

The definitions for passive houses and equivalent concepts are even more heterogeneous. What is understood by the term differs from Central/ Northern Europe (Germany, Austria, Sweden etc.) to southern Europe (e.g. Spain, Italy, Portugal, Greece). Particularly in central Europe, the term Passive House refers to a certain standardised type of low energy building as developed in Germany. The annual demand for space heating is limited to 15 kWh/m² per year which means that such a house roughly use 85 % less overall energy with the limit for total primary energy use being 120 kWh/m² per year. In Switzerland a similar standard, MINERGIE®-P is used. The application of the standard Passive House concept has some limitations for southern climates where the problem of household energy use is one not only of providing warm houses in winter, but also, and in some cases more importantly, of providing cool houses in summer.

According to the Commission's Info-Note on "Low Energy Buildings" of Sep. 2009 (http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm) at present more than 12,000 such houses have been built in Europe, however mostly located in Germany, Austria and Scandinavia.

Germany and Austria

In Germany there are two definitions regarding LEB: Residential Low Energy Building and Passive House. The maximum energy consumption for a Low Energy Building is 60 kWh/m² per year or 40 kWh/m² per year; whereas the requirement for a Passive House is an annual heat demand lower than 15 kWh/m² and total energy consumption lower than 120 kWh/m² per year.

In Austria the LEB-definitions are similar to the German ones. For a Low Energy Building the annual energy consumption for heating must be below 40-60 kWh/m². The definition for a Passive Building corresponds to the German Passive House.

In order to support planners and building owners in realizing their project, the Passivhaus Institut (PHI) in Germany has defined quality criteria for the Passive House standard. Projects living up to the quality criteria may be certified. Certification is carried out by the PHI or through a person authorized by the PHI.

The document "European Embedding of Passive Houses", (http://erg.ucd.ie/pep/pdf/European_Embedding_of_Passive_Houses.pdf), elaborated as part of the project *Promotion of European Passive Houses* partially supported under the Intelligent Energy Europe Programme reports about 8,000 passive house dwellings have been built in Germany until now (May 08). This equals a market share of about 1 %.

Even if the dwellings actually have been built according to Passive House standard it may be assumed, that a greater number of the dwellings have not been officially certified according to the PHI criteria. The database at www.passivehausprojekte.de lists about 1,300 passive house projects in Germany. Out of these projects only 223 have been certified.

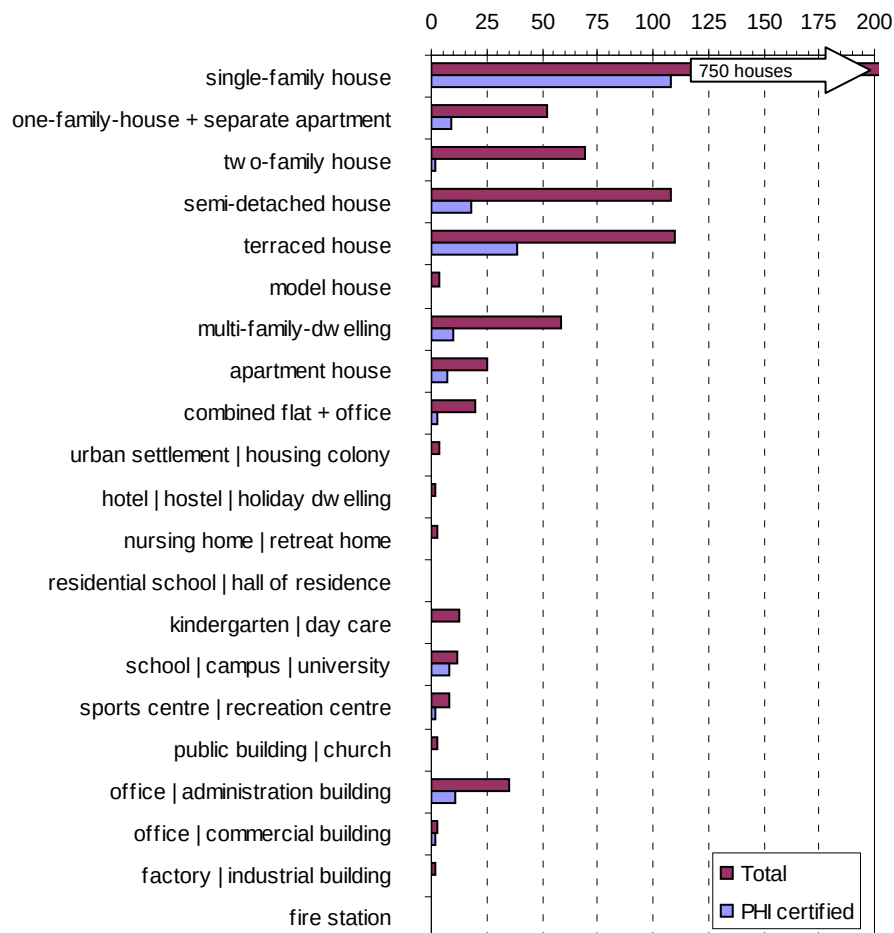


Figure 4.5. LEB/PH in Germany according to the database at passivhausprojekte.de. Note the scale; the database reports 750 single family houses in total. Source: www.passivhausprojekte.de.

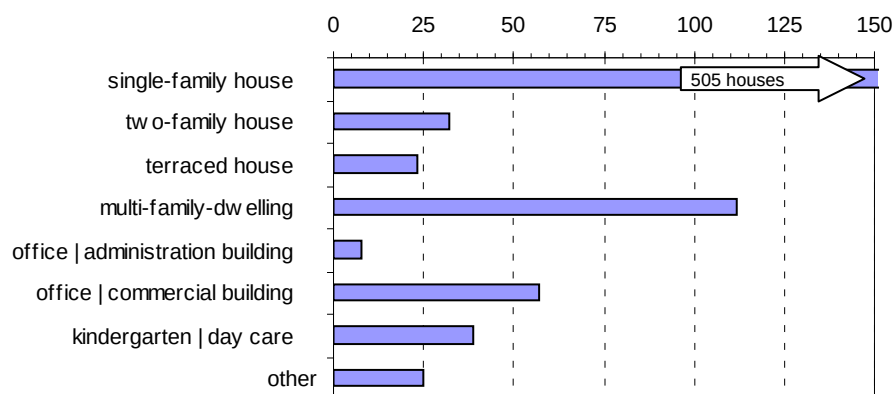


Figure 4.6. LEB/PH projects in Austria according to the database at igpassivhaus.at. Note the scale; the database reports 505 single family houses in total. Source: www.igpassivhaus.at.

Similarly, regarding LEB in Austria, the document from the PEP-project mentioned above reports implementation of just under 2,000 passive houses in

Austria. The very extensive database at www.igpassivhaus.at lists about 800 projects of which 335 live up to the PHI requirement of a heat demand lower than 15 kWh/m² per year. The database is established by the syndicate of passive houses in Austria (IG Passivhaus Österreich).

As part of the project PASS-NET a European-wide database is in the process of being established. The database will describe and promote pilot passive house projects. Figure 4.7 shows, as registered by the project, the number of documented and built passive houses throughout Europe.

Regarding low energy buildings other than passive houses there is no national registration of such buildings in general, hence exact figures cannot be provided. Estimates are that the market share of new LEB in Germany and Austria relative to the total amount of new buildings is in the same order of magnitude or slightly higher as for Denmark and Norway.

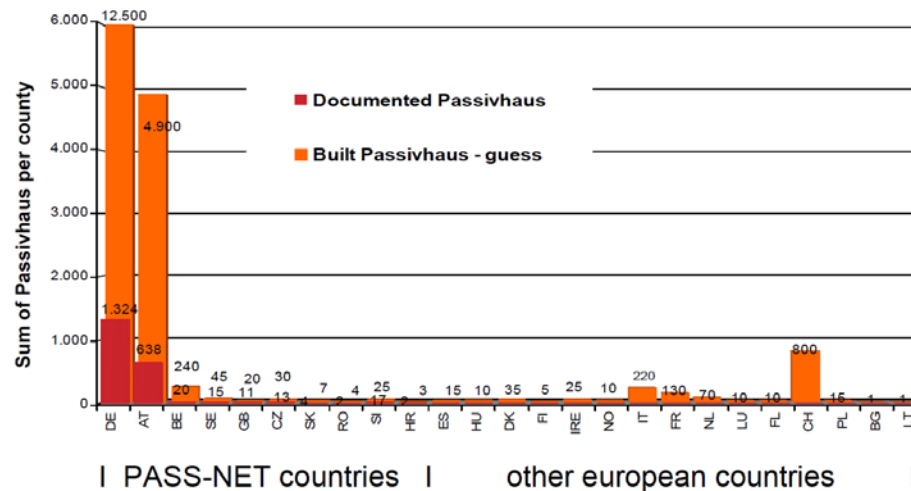


Figure 4.7. Documented and built – guess – passive houses in Europe. Source: International Passivhaus Database, Establishment of a Co-operation Network of Passive House Promoters (PASS-NET), 1. Period of documentation 2007 – 2009, <http://www.pass-net.net/index.htm>.

Switzerland

Minergie is a private organization and a registered trademark owned by the nonprofit Minergie Association. The Minergie base standard was introduced in 1998, with the more stringent Minergie-P and Minergie-P-ECO standards appearing later. Minergie-Eco (and Minergie-P-Eco) pays attention to selection of building material more comprehensively than Minergie, Minergie-P and the national building code.

The Minergie Association counts approximately 400 supporting members, including many architectural firms, construction and manufacturing companies, and banks. With 14,000 certified buildings, the Minergie standard has become a major factor in the Swiss energy policy. All 26 cantons are members of the Minergie Association and they are integrated in the certification process. The large majority of cantons offer special subsidies to Minergie homeowners. The average subsidy for Minergie-P is equivalent to approximately 9,000 euro per new single-family house.

A Minergie building consumes about 60 % less energy compared to the conventional Swiss building, built according to the Swiss building code, SIA.

Belgium

Next after Germany, Austria, and Switzerland, Belgium has established itself as a lead country with respect to the introduction of passive houses. This is quite impressive, considering the fact that Belgium had virtually no tradition

in low energy building. In 2002, a non-profit passive house centre (www.passiefhuisplatform.be) was established to introduce the passive house concept in the Flanders Region. Four years later, demonstration projects and novel technologies were available for the Benelux market, which swung the local market development by a factor four.

Figure 4.8 below shows a comparison of the delivered energy use for a detached house built according to national average, according to the current building code, according to the low energy standard, and according to the passive house standard. The total energy demand is about 75 % lower than for a house built according to the local building code.

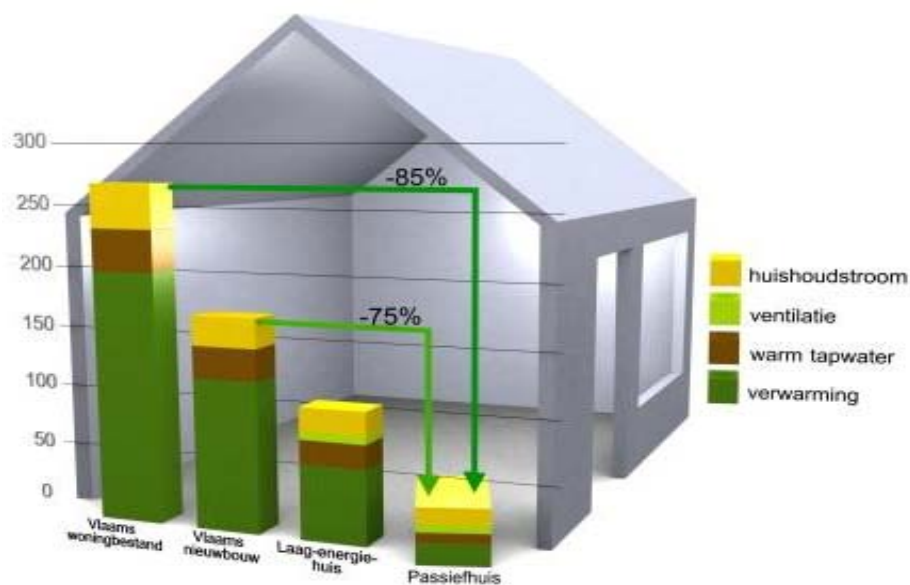


Figure 4.8. Comparison of the delivered energy use for a detached house built according to the average in the Flanders region, according to current building code, for the low energy standard, and for the passive house standard. Source: www.passiefhuisplatform.be.

Table 4.8. The number of passive houses built in Belgium between 2005 and 2010, compared to the total number of buildings erected. Source: www.bepassive.be, # 1, nov 2009.

	2005	2006	2007	2008	2009
Passive houses	16	27	48	76	171
Total houses	59,378	61,155	53,854	52,486	47,238
Percentage	0.03 %	0.04 %	0.09 %	0.14 %	0.36 %

A5 LEB technologies, solutions and R&D activities

Denmark

Technologies, solutions, and R&D Topics for LEB

In the following paragraphs, a description is given on the present focus areas with respect to technologies, solutions, and R&D activities concerning low/zero energy buildings in Denmark. The description covers the most important areas; areas in which there are challenges, further potential energy savings and necessary advances for the future.

The following is a list of references used for the description of the present status, potential, shortcomings and so forth:

- Strategy document of the nationally funded project LavEByg (abbreviation of Low Energy Buildings), which is an innovative network for integrated low energy solutions
[http://www.lavebyg.dk/upload/centre/lave/strategiplan%20nye%20bygninger/strategivers2_final_\(28-05-09\).pdf](http://www.lavebyg.dk/upload/centre/lave/strategiplan%20nye%20bygninger/strategivers2_final_(28-05-09).pdf)
- Strategy document from the Danish Government concerning the reduction of energy use in buildings
http://www.energivinduer.dk/Strategi_reduktion_energiforbruget.pdf
- The market for energy savings in buildings from Dansk Byggeri
http://www.danskbyggeri.dk/files/Filbibliotek/Nyheder%20og%20presse/Barometer/Analyser/2006/Nr.%201/23763.markedet%20for%20energibesparelser%20i%20bygninger_ny.pdf
- Recommendations on how to exploit the potential of renewable energy sources and energy efficient solutions from Danmarks Vækstråd,
<http://www.danmarksvaekstraad.dk/file/9149/rapportDetgroenneguld.pdf>
- Barriers and solutions for market introduction of alternative energy systems, report from EU-project SENTRO
http://www.sentro.eu/documents/APPENDIX5WP3FINAL_D2.PDF
- Market survey for demand controlled hybrid ventilation in residential buildings from the IEA-project RESHYVENT, [RESHYVENT report No: RESHWP2-D2.1 2005-02-25](#)

Projects involving development and demonstration of new technologies and solutions for low/zero energy buildings in Denmark have typically been carried out as research projects where national research institutes or universities cooperate with different actors from the building industry. The building industry has typically been represented by architects, consulting companies, construction companies, developers and producers of building materials or components, e.g. insulation materials, window and glazing materials, ventilation systems, heat pumps and other heating systems etc. Financing for these projects have typically been combinations of state institution grants and a degree the building industry's own financial contribution. The main R&D topics include:

- Building envelope: increase thermal insulation, reduce thermal bridges, increase air-tightness, avoid moisture problems.

- Windows and glazing systems: increase of glass/frame ratio, reduce thermal bridge of spacer-profile, reduce thermal transmission of frame, different coatings.
- Lighting, shading and daylighting: reduce electricity use for lighting through optimised use of daylighting or alternative sources (LED).
- Ventilation systems: high efficiency heat exchangers, reduce electricity use through optimised fan design and ductwork, demand control ventilation.
- Heating systems: optimised boilers (both oil and gas).
- Heat storage: active thermal mass, phase change material.
- Solar systems: optimised both thermal solar and PV
- Heat pumps: ground source, CO₂ as refrigerant.
- Electricity consumption: minimizing electricity consumption for pumps, ventilators and household appliances.

Below is a description of areas in which Denmark has had special focus within the last few years, however, some of them still needs further development in order to qualify for future low/zero energy buildings:

Air tightness of the building envelope

Air tightness of the building envelope has been a focus area for quite a few years in Denmark. Specific demands to air tightness were first introduced in the 2006 revisions of the Building Regulations. The present minimum requirement is an air change rate of less than 1.5 l/s per m² at 50 Pa pressure. In the 2010 revision of the Building Regulations, the minimum demand will remain at 1.5 l/s per m², however, for low energy buildings the demand will be 1.0 l/s per m². The Building Regulations require that municipalities test a minimum of 5% of all new buildings for air tightness.

Investigations on air tightness for Danish low energy houses have shown that in general there is a high level of air tightness, and especially in houses where particular focus has been on the issue.

Balanced mechanical ventilation with heat recovery

Balanced mechanical ventilation with heat recovery efficiently reduces ventilation heat losses and secures a good indoor climate. Over the past decades these systems have undergone a dramatic evolution especially concerning electricity consumption and heat recovery efficiency; however, there are still potential developments that would make these systems even more suitable for future zero/low energy buildings.

Ground source heat pumps

Ground source heat pump systems have become increasingly popular in Denmark over the last few years. The system consists of a long pipe buried in the upper layers of the ground and a heat pump. The heat pump converts the heat derived from the soil via electricity to heating power in the house. Each kWh of electricity used is converted into approximately 3-4 kWh of heat (space heating and domestic hot water).

Ground source heat pump systems are relatively expensive to install and they require a lot of space (for ground heat pipes). The systems are fairly low maintenance, i.e. exchanging a filter once a year in the pump, however the expected lifetime of the heat pump is usually only around 15 years and the ground pipes life expectancy is more than 50 years.

Insulation materials and thermal bridges

Since the mid-nineties a lot of energy has been put into developing principles for highly insulated building envelope constructions with reduced thermal bridges in Denmark. The development was achieved in collaboration

with the building industry, focusing especially on the exterior walls for future construction and with the overall aim to stimulate development of low energy solutions. The principles have been tested in a series of experimental buildings. This process has created a good basis for low energy buildings in Denmark, and the principles can be used in the future to further lower the energy consumption in new buildings.

Passive house windows

Typical Danish windows have an annual energy balance of approximately minus 40-50 kWh/m² (i.e. for a standardised orientation and size where solar gains count positive and transmission heat loss negative). There are a few Danish windows that have an energy balance up to minus 25. Typical passive house windows have energy balance up to minus 10, and the best foreign windows produce an energy balance of plus 10. These facts show great potential for further development of Danish windows.

The energy performance of windows depends on materials, construction and area-ratio between frame and glass. Also important are window orientation and shading conditions.

Alternative energy sources

In Denmark, heating of buildings and provision of hot water are primarily based on the use of district heating incl. use of renewable energy systems (app. 60%), oil (app. 20%) and natural gas (app. 15%). Secondly also electricity, solid fuel incl. biomass and heat pumps are used to some extent, while solar energy systems are only used to a minor extent. Therefore, a further market introduction of alternative energy systems in Denmark should focus on solar systems and heat pumps.

In Denmark district heating is to a very high extent based on the use of CHP, only a minor part of the production facilities only produce heat. The heat production is primarily based on the use of natural gas, biomass and coal, but also to some extent waste heat from industries. Due to an increase in the use of CHP and biomass, the CO₂ emission for district heating has gone down from 87 kg/GJ in 1980 to 34 kg/GJ in 2005. Further reductions are expected, both because of a stronger integrations of the major energy systems, and because the district heating facilities are expected to include solar energy, geothermal energy, heat pumps, increased use of biomass and low temperature district heating.

Examples of pilot building projects

New building project



Green Lighthouse. Year of construction: 2008-2009.
Approx. price : 37 mill DKK corresponding to 5 million €.

The Green Lighthouse (<http://greenlighthouse.ku.dk/english>) is placed at the Faculty of Science, Copenhagen University and contains service functions for students, meeting facilities and a faculty club for researchers.

The partners in this public and private consortium are Copenhagen Municipality, VELUX⁶, VELFAC, the University of Copenhagen and the Danish University and Property Agency. The building process is a close cooperation between all involved partners. The Danish University and Property Agency is building owner. A consortium consisting of Hellerup Byg, Christensen & Co. Arkitekter and COWI, which has developed the architecture and energy concept and has constructed this new climate landmark, has built the Green Lighthouse.

The energy concept contains solar thermal and PV collectors, solar cooling, seasonal heat storage, a heat pump and a connection to the district heating net, as well as optimized use of daylight, LED lighting and natural ventilation. This means that daylight is evident in all rooms. Due to the construction of the automatic window shades, sunlight is reflected deeply into the building.

The house has its own energy supply consisting of an unprecedented combination of thermal solar heat, heat pumps, seasonal storage, PV solar cells and district heating. The house is filled with plenty of fresh air deriving from natural ventilation, which ensures a healthy indoor climate. By means of the building's energy design, the building has cut down $\frac{3}{4}$ of its energy consumption in relation to Danish building standards. This means that the building is better than other buildings in Low Energy Class 1 under the EU standards applicable since 2006, using 30 kWh/m² per year for primary energy.

The purpose of the energy concept in Green Lighthouse is to make the house CO₂ neutral. The Green Lighthouse is a completely new experiment with an energy concept that consists of a combination of district heating, solar cells, solar heating and cooling, and seasonal storage. This energy concept, which is developed by COWI, consists of a new type of solution; district heating is used to power a heat pump. By using district heating instead of electricity, less CO₂ is produced. Furthermore, district heating leads to a far more efficient utilization of energy.

The sun constitutes the central point and primary energy source of Green Lighthouse. The house is 950 m² and is built in accordance with the "active house" principle, which means that it generates energy. A combination of the following energy sources supply heating for Green Lighthouse:

- 35% solar energy from solar collectors on the roof and the storage of solar heat in the ground via a heat pump
- 65% eco-friendly district heating with a share of renewable energy of approx. 35%
- The heat pump increases the utilization of the district heating by approx. 30%

The 76 m² solar cells on the roof will be a major source of electricity in Green Lighthouse for lighting, ventilation and pumps. The annual cost of district heating is approx. 1,500 € according to current exchange rates. The energy concept will be a real experiment and it is first time it is applied in Denmark. In the long term, this solution can be used in construction of offices and industrial buildings in most parts of Europe. The energy concept will undoubtedly be used when planning energy supply with focus on CO₂ neutral construction in the future.

Partners delivering the products are Window Master A/S, Rockwool A/S, Fa-ber Group, Knauf Danogips and Veksø. Furnitures are delivered by Montana and Frits Hansen.

⁶ http://www.velux.com/Sustainable_living/Model_Home_2020/The_experiments/Green_Lighthouse/default.aspx

The energy concept secures the best possible utilisation of renewable sources of energy. This interaction means that the energy concept utilises the sun not only for cooling during summer, but also in order to improve the efficiency of the heat pump during winter. Solar heat energy is generated by directing solar heat through south facing windows. It is used for floor heating or, when not required, stored in the ground. A heat pump circulates solar heat, geothermal heat and cooling in the building. This ensures optimal utilisation of district heating, as it will only be used if solar heat is out of stock.

Renovation project



In "*Energy Project Villa*" the cost saving effect of renovating a typical existing villa built before 1950 has been documented⁷. The partners were Rockwool International, Rockwool A/S, Danfoss and DTU Byg. The project was carried through in the winter 2004-2005.

The work was carried out by professional contractors and the total cost was DKK 157,000. Assuming a conservative energy price and a conservative way of financing the house owner will obtain a net saving the first year of DKK 7,500. First year's cost of financing the building work equals DKK 8,500 and the energy saving equals DKK 16,000. Seen over a 30-year period the total savings in NPV (net present value) will be DKK 396,600.

The goal of the project has been to demonstrate the energy savings obtained by renovating a typical villa built before 1950. The total economy should be documented and the optimal result would be a saving from day 1 - even without taking into account the higher market value such measures might add to the house. The purpose of the project is to get more attention and, via a marketing effort, to try to motivate and influence people to activate the energy saving potential in existing houses, using well known existing solutions.

The Villa is an old typical Danish master builder house of 161 m² with a C5 classification⁸ for heating before the energy renovation. It has a full basement (not heated), a ground floor and a first floor, and is occupied by four people. Of all the houses that have been certified in Denmark, built between 1910 - 1950, 25% have a C5 classification for heating, corresponding to a G house today.

The energy saving measures carried out in the project are "easy to carry out" measures. The package of measures carried out consisted of: Improvement of the insulation level of the building envelope, amendments to the heating system and applying storm windows.

The Villa from 1927 had a monitored gross energy consumption of 53,400 kWh per year (332 kWh/m² per year) at an indoor temperature of 20°C prior to energy renovation. The energy consumption and the indoor environment of a building are closely related. Declaration of a building's energy consumption without stating the related indoor environment is of no use. It has been important for the project partners to see that the energy savings in the Villa are obtained without increased risk of thermal discomfort, mould growth, and other health risks.

⁷<http://www.byg.dtu.dk/upload/institutter/byg/publications/rapporter/byg-r102.pdf>

⁸ According to the old Danish energy classification system for heating, ranging from A1 to C5

The project has shown that with the energy renovation it has been possible to reduce the gross energy consumption to 28,100 kWh per year (175 kWh/m²) at an indoor temperature of 20°C. This equals a reduction of 2500 litre of fuel oil per year corresponding to almost 50 % of the original energy consumption. The indoor environment is also improved by the energy renovation.

Future Needs and Trends

In order to move forward and reach the Danish national goals concerning energy efficiency of future low/zero energy and passive houses, it is necessary to focus on a wide range of developments. Several new projects concerning this development have already been launched in Denmark (i.e. BUILD.AAU, LavEByg, Videntcenter for energibesparelser, Center for energibesparelser, ZEB.aau.dk, Boligplus.org), and participations encompasses all major Danish research institutes, universities along with a strong representation of the entire building industry. The overall aim of these projects lies in the development of energy efficient solutions for both existing and new buildings that will ensure that the goals put forth by the Danish Government are met, making Denmark independent of fossil fuels by 2050. Below is a list of the most important R&D topics:

- Air tightness around installations and air tightness in buildings made from prefabricated constructions assembled at the building site.
- Ventilation systems: energy consumption for air transport, i.e. reducing pressure drop in recovery unit and duct system and developing flow optimised components. Exploitation of natural driving forces, i.e. hybrid ventilation solutions. Energy efficiency of fans, i.e. fan geometry and design, along with optimisation of the engine itself and the electronic control of the engine speed. Research solutions for rotary and counter flow heat exchangers.
- Heat pumps and geothermal energy: issues concerning dimensioning of systems needs to be resolved. Further development of systems and controls. Developing systems that can produce heat at higher temperatures without decreasing the efficiency of the heat pump. Combining systems with long term heat storage systems, including intelligent electricity meters, i.e. running heat pump only on the times of day when power prices are low, i.e. typically at night. Combining systems with other forms of renewable energy, i.e. solar panels and the implementation of demand control strategies.
- Building envelope components: constructions with more insulation and a minimum of thermal bridges. Foundations below windows and doors suitable for low energy housing need further development.
- Windows: reducing the thermal transmittance and area of frame, i.e. reducing thermal transmittance and increasing solar gains. Concerning glazing focus should be on gas filling, low emission coatings, low iron content in glass, anti reflex coatings, spacer profile and glass layers.
- Energy efficient lighting: effort will focus on developing, analysing and guidance on energy efficient dynamic facade solutions with increased focus on daylighting influence on users well being and health.
- Energy supply systems: integration of energy production in the building, e.g. by PV panels or fuel cells.
- Research concerning dwellings, offices, educational facilities and institutions will for both new buildings and existing buildings be concentrated on achieving a total energy and environmental optimisation of buildings and installations.

Norway

Technologies, solutions, and R&D Topics for LEB

No all-encompassing market surveys of Norwegian technologies, solutions and R&D projects with respect to low energy building were found. The following description is made based on the following sources:

- Database of the Norwegian Association of Architects, www.ecobox.no
- Database of Enova's "reference projects" and "energy stories" <http://naring.enova.no/sitepageview.aspx?sitePageID=1151>, <http://www.enova.no/publikasjonsoversikt/publicationlist.aspx?keywoidID=46>
- Project database of the Norwegian Research Council, <http://forskingsraadet.no/servlet/Satellite?c=Page&cid=1226993846917&pagename=renergi%2FHovedsidemal>
- Project database of the Norwegian State Housing Bank, www.lavenergiboliger.no
- Report by the Norwegian Association of Dwelling Producers Boligprodusentenes forening. Prosjekt 04/657 "Boligprodusenter i nettverk for økt energistandard i boliger", Sluttrapport 2005-2009.
- Market survey for demand controlled hybrid ventilation in residential buildings from the IEA-project RESHYVENT, RESHYVENT report No: RESHWP2-D2.1 2005-02-25
- "Tiltak og virkemidler for redusert utslipp av klimagasser fra norske bygninger – et innspill til Klimakur 2020", Rapport 4-2010, Norges vassdrags- og energidirektorat.
- Internal network and databases of NTNU⁹ and SINTEF.

NTNU and SINTEF have been involved in a majority of the projects involving development and demonstration of new technologies and solutions. Other actors are architects, consulting companies, construction companies, developers, and manufacturers of products: insulation, air-tightness solutions, windows and glazing systems, solar shading and daylighting systems, wall/facade systems, roofing systems, ventilation components, heat pumps, and solar systems. The majority of the projects have been national projects financed by the Research Council, The Norwegian State Housing Bank, and Enova. A few projects have been conducted within the framework of the International Energy Agency and the EU. Main R&D topics include:

- Envelope systems: thermal insulation, thermal bridges, vacuum panels, air-tightness, moisture
- Window and glazing systems: passive house windows (frames), switchable glazing
- Shading and daylighting systems
- Ventilation systems: hybrid ventilation systems, high efficiency heat exchangers
- Heating systems: simplified water based systems
- Heat storage: thermal mass, ground heat exchangers
- Solar systems (PV and thermal): architectural integration, building integration, polymer based thermal collectors
- Heat pumps: ground source, CO₂ as working fluid
- Integrated energy design methods
- Operation: continuing commissioning, control systems
- Indoor environment: air quality, thermal comfort, daylight, acoustics
- User cultures and user behaviour
- Standardization and regulations: new passive house standard, revision of energy codes

- Pilot building projects: building projects with passive house standard

These projects have led to the development of several new products, solutions and processes, and significant new knowledge about low energy and passive buildings. The solutions have been implemented in pilot building projects, and some of them have reached quite widespread use in the low energy building market.

Based on the survey, a typical 4 step “pathway to innovation” has been identified:

1. It starts out with collaboration in wide international projects within the IEA or the EU.
2. It then moves on to national knowledge projects, typical financed by the Norwegian Research Council or Husbanken, and a wide range of users from the building industry
3. Then, it moves on to smaller development projects with individual industries, financed mainly by the industry
4. And ends up in pilot building projects, financed by industry, Husbanken and Enova.

There seems to be a step 5 missing: follow-up analyses and further development of implemented technologies and solutions.

It is not easy to make a selection of which projects to highlight, but the following 3 topics and project portfolios were selected to illustrate some major innovations:

Air tightness of the building envelope

Significant development work has been dedicated to finding good solutions to reduce the air infiltration through the building envelope, particularly for residential buildings. Construction details and special products for air-tightness (e.g. special tape products) have been developed, lab tests have been carried out, and pilot building projects have been constructed. Also, simplified equipment for measuring air leakage during construction, have been developed. Buildings with measured air leakage numbers between 0.2 and 0.6 ACH have been demonstrated. Main remaining challenges include developing a larger variety of standardized construction details and testing the longevity of the solutions. Main actors have been producers of dwellings (www.boligprodusentene.no), producers of building envelope products (www.isola.no, www.glava.no), SINTEF Byggforsk, Husbanken and Enova.



Passive house windows

The introduction of the passive house standard in Norway has led to the development of windows with significantly improved thermal insulation. The Norwegian window manufacturer, NorDan (www.nordan.no), was the first to introduce a passive house window to the market in 2007. The window is triple glazed with argon gas filling, 2 low emissivity coatings, foam spacers and insulated frame. The total rated U-value is 0.7 W/(m²K), compared to 1.6 W/(m²K) which is the minimum requirement in the code. In 2009-2010, several other Norwegian window manufacturers are introducing passive house windows.

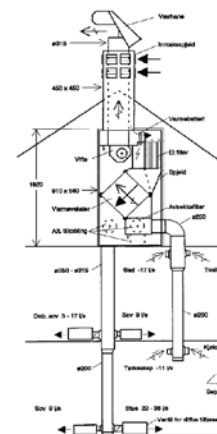


Simplified water based heating systems

In Norway, there has been scepticism related to heating systems based solely on ventilation air heating, mainly due to indoor comfort considerations. Since the passive house concept is depending on minimizing the installation costs of the heating system, simplified water based heating systems were investigated. A system configuration for dwellings was developed, tested in the lab, and installed in a pilot building project (Løvåshagen, described below). Also, general guidelines for designing such systems have been produced. Remaining challenges includes developing simplified systems for different types of buildings and room layouts, further reduction of the installation cost and collection experience with respect to operation and maintenance of the systems. Main actors have been SINTEF Byggforsk, Varmeinfo (www.varmeinfo.no), producers of dwellings (www.boligprodusentene.no), OBOS (www.obos.no), CTC Ferrofil (www.ctc.no), Husbanken and Enova.

Hybrid ventilation

Several projects on hybrid ventilation of buildings have been conducted in Norway since the early 1990's. Hybrid ventilation is a two-mode system which is controlled to minimise energy consumption while maintaining acceptable indoor air quality and thermal comfort. The two modes refer to natural and mechanical driving forces. The focus has mainly been on developing systems and components for retrofitting of residential buildings and schools, as well as on new school buildings. When implementing hybrid ventilation systems, an integrated energy design approach is needed. Several pilot building projects have been carried out, and guidelines have been produced. Remaining challenges include improving the demand control system, increasing the efficiency of the heat recovery, and costs. Main actors have been SINTEF Byggeforskning, producers of ventilation systems and companies and Forskningsrådet.



Example of ventilation system from
RESHYVENT project / Flexit

Examples of pilot building projects

New building project

The *Løvåshagen passive house project* was constructed in Bergen in 2008. This was the first apartment building with passive house standard to be realised in Norway. The project consists of 28 apartments in two 3-storey building blocks. Main actors involved were SINTEF Byggforsk, Bybo (developer), ABO Architects, CTC (heating system), NorDan (passive house consultant). The project involved the following main innovations:



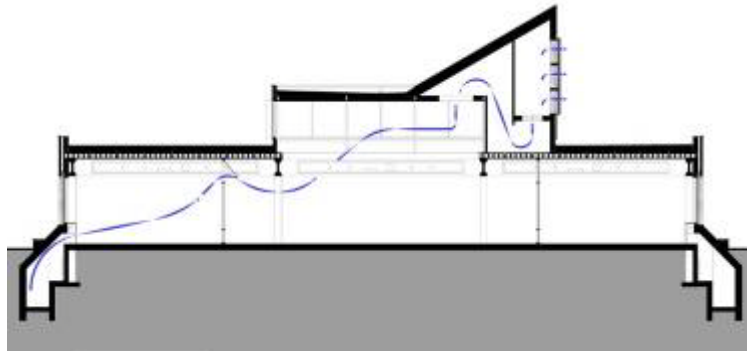
ing system), NorDan (passive house windows). The project demonstrated the following main innovations:

- Integrated energy design
- Air tight envelope solutions, measured air leakage $n_{50} < 0.6$ ACH
- Super insulated envelope solutions, double wood frame construction (walls) and I-beams (roof)
- Passive house windows, total U-value < 0.8 W/(m²K)
- Simplified water based heating system
- User friendly demand control system

The evaluation of the project is not finished, but net total energy demand was calculated to 91 kWh/m²/yr, of which 13 kWh/m²/yr is for space heating. The project received financial support from Husbanken and Enova.

Renovation project

Borgen Community Centre in Asker was an existing school building from 1970 that was retrofitted, enlarged and transformed into a community centre in 2006. An integrated energy design approach was applied, focusing on a well insulated building envelope, daylight utilization, and hybrid ventilation. The purchased energy consumption before retrofitting was 280 kWh/m²a, while the measurement for 2007 (normalised) showed 102 kWh/m²a. Main lessons learned from the project were summarized by the project leader for the municipality: “Borgen Community Centre stands as a very successful project, representing a major contribution to improve environment and indoor climate. I register with pleasure that our goal of reducing energy consumption by at least 50 % has been achieved by a good margin. Our experiences with the technical principles applied to the building represent a good foundation for future buildings in our municipality.” The project received financial support from the EU and the Norwegian Research Council.



Cross-section of the classrooms and common area of Borgen Community Centre, showing the natural ventilation principle.

Future Needs and Trends

Future trends for development of low energy buildings involves monitoring, testing and improving low energy and passive buildings, and moving from passive houses to zero energy buildings. A new large R&D project has just been established, entitled Zero Emission Buildings (ZEB), www.zeb.no. The project is led by NTNU and SINTEF, and involves 20 different participants including architectural and engineering companies, developers, construction companies, producers of materials and products, and governmental institutions. The aim of the project is developing competitive products and solutions for existing and new buildings that will lead to market penetration of buildings that have zero emissions of greenhouse gases related to their production, operation and demolition. The following R&D topics are investigated:

- highly insulating materials and envelope systems with high robustness and low environmental impact
- embodied energy/emissions of building materials and installations
- heating systems for small loads based on renewable energy
- cost-efficient integrated renewable electricity supply systems
- small scale combined heat and power systems
- utility interactive systems
- energy-efficient ventilation systems, high-efficient heat exchangers, and hybrid ventilation systems utilizing thermal storage
- architectural design of ZEB and building integrated energy systems
- user friendly and efficient energy management systems
- improved combined daylighting and shading systems
- building, testing and verifying new building concepts, pilot buildings
- user cultures and attitudes towards ZEB-solutions

Sweden

Technologies, solutions, and R&D Topics for LEB

Two market surveys^{10,11} have been identified, the homepage of Passivhus-Centrum in Alingsås (www.passivhuscentrum.se) and projects performed within the BELOK program (clients group for premises, www.belok.se) and the BeBo program (clients group for apartment blocks, www.bebostad.se).

Based on these three sources the following fields of advancement for Sweden have been selected.

Balanced mechanical ventilation with heat recovery

Ventilation systems including air-to-air heat recovery with high temperature efficiency have been developed during the last years but still needs further developments. A successful technical procurement in 1999, organised by the Swedish Energy Authority, for systems for one-family houses resulted in two winners, out of which one is the market leader. The different demonstration buildings have focused on both centralised and decentralised heat recovery units as well as both rotary and counter flow heat exchangers. Different solutions have for examples been tested in order to avoid over flow from exhaust air to supply air in rotary heat exchangers as well as minimizing freezing risks in counter heat exchangers. There are still development needs for these techniques. Eight air handling units for one-family houses have just been tested by the Swedish Energy Authority (www.energimyndigheten.se/sv/Hushall/Tester/Testresultat/FTX-aggregat-hus-med-130-m-boyta).

For renovation of apartment blocks special focus have been initiated on developing complete system solutions including air tightening of the building envelope, innovative solutions for installation of the duct system and construction of fan rooms.

Heat pumps

Heat pump with heat sources such as outdoor air, exhaust air, and geothermal (ground, water or rock) have for the last decade been very successful primarily for one family houses but have also been used in larger buildings. Already in 1993/94 there was a successful technical procurement of ground source heat pumps for one-family houses. The energy requirement performances for electrically heated building from 2010 have lead to that exhaust air heat pumps for one-family houses now are improved. They are designed for low exit air temperatures. This results in condensing of water vapour on the exhaust air coil.

There are twenty-one manufacturers/importers in the Swedish Heat Pump Association (www.svepinfo.se). Future development challenges are primarily for large systems that can deliver both heating and cooling in premises -and for heat pumps for small loads in LEB.

¹⁰ Marknadsöversikt för passivhus och lågenergihus i Sverige 2008 - Ökande efterfrågan på energieffektivt boende och energieffektiva produkter. Juni, 2009. Forum för Energieffektiva Byggnader – FEBY, Energimyndigheten, Eskilstuna. www.energieffektivabyggnader.se

¹¹ Energianvändning i monteringsfärdiga småhus – en marknadsöversikt. November 2009. Hållbar utveckling Väst, kommunala energi- och klimatrådgivare, Passivhuscentrum, TMF (Trä- och möbelindustriförbundet), Västra Götalandsregionen och Energimyndigheten. www.hallbarutvecklingvast.se/energieffektivahus

For renovation of apartment blocks special focus have been started on developing complete system solutions for exhaust air heat pumps as an alternative for heat recovery with balanced mechanical ventilation.

Bio-fuel boilers and burners

Bio-fuel stoves, all mainly fired with wooden pellets. Currently developments are performed for pellets burners in combination with solar thermal systems aimed for one-family houses (www.pellsam.se).

Passive house windows

The Swedish Energy Authority has performed several technical procurements of windows during the last fifteen years. They have resulted in improved windows and not least in better knowledge by window manufacturers. Since a few years windows are energy rated in Sweden and the results are available on a homepage (www.energifonster.nu).

Windows has been frequently discussed within the demonstration projects but the homepage showed that six of the fourteen window manufactures with energy rated windows in Sweden are owned by Danish (4 by VKR Holding), Norwegian (1) or Finish companies (1). A few companies are dominating the Swedish window market. Further needs for development are low U-values for balcony doors with windows.

Air tightness of the building envelope

Already around 1980 several handbooks were published how to design and construct (manufacture) airtight building envelopes. Based on these the processes were developed early and they have been reviewed and further developed in connection with the construction of passive house the last decade. The building code has no requirement of air tightness but incentive systems as the passive house requirement specification does not only require special air tightness but also require that the air tightness should be measured. This has had the effect that both technique and skills for air tightness processes have been developed. Special skills for airtight building envelopes of wooden frames have been developed during many years.

Thermal bridges

Technical solutions in order to avoid thermal bridges have been developed within the demonstration projects. Special skills have been developed for wooden frame building envelopes without any thermal bridges.

Energy efficient tap water devices

Several demonstration projects have shown that installation of new energy-efficient taps and shower mixers can substantially reduce the use of water and energy for heating the tap water. Development of energy-efficient tap water devices has been ongoing for a decade in Sweden and started with technology procurement in 2001 – 2003. The techniques are focusing on reducing water consumption while still keeping the end users requirements of comfort. In order to further improve the technologies and to guide purchasers to choose the most suitable products, a labelling system to indicate energy efficiency is under development. New standards with test methods for measuring energy efficiency and requirement criteria for classification of energy efficiency has been developed and scheme rules for the energy labelling system are close to be established. First out are tap water devices for basins and kitchen sinks. Further developments are needed for shower mixers and to introduce the energy labelling system into European level.

Concepts for building low energy houses

How to construct a low energy building, which includes construction processes as well as education and motivation of construction workers have

been tested and further developed within the demonstration projects. Primarily the concept for construction of the complete energy solution for dwellings with the passive house technique has so far been very successful. The concept includes the whole energy solution with for example high air tightness, avoiding thermal bridges, adequate thermal insulation, and heat recovery of exhaust air.

The Lindås-project from 2001 is a shining example of how good information from the architect and the other consulting engineers could motivate the construction company and its workers on all levels.

Partnering organisation

Several of the demonstration projects have successfully tested a new way of organisation within the construction. Partnering is a structured cooperation where the client, constructors, consultants and other key actors are solving the assignment together.

Total concept for renovation

The proprietor group for commercial buildings BELOK, under the auspices of the Swedish Energy Authority, has developed a method for “total renovation of existing non-residential buildings. The buildings are owned by BELOK’s members, the 15 largest proprietors, in Sweden. For the moment totally 28 demo projects are ongoing, most in the planning or construction phase. The buildings types are: 5 office buildings, 3 schools, 2 hospital buildings and 18 public and commercial buildings of all types. Since the concept has shown to be effective, it is now also tested in apartment blocks within a project of the BeBo program. The “total concept” is mainly a financial model to show for the decision makers.

Examples of pilot building projects

New apartment blocks – Hamnhuset in Göteborg

Hamnhuset is located in the old Sannegård harbour on the north side of the Göta River in central Göteborg. The proprietor is the city owned company Älvstranden Utveckling AB.



The house has two buildings with four or five floor each. The total number of flats is 115, out of which the majority has two rooms and kitchen. The heated floor area is 11 626 m² Atemp (residential area 7 868 m² BOA and gross area 15 021 m² BTA). The buildings fulfil the Swedish passive house requirements. The heating is carried out by hydronic air heating coils served by district heating.

The planned project cost (incl. land, developer’s costs and VAT) was 202 million SEK. This is SEK 25 670/m² BOA residential floor space or SEK 13 447/m² BTA gross floor space.

The total annual energy consumption for Hamnhuset (including heating, hot water, utility use and other electrical use) was estimated to 60 kWh/m², (gross area). Annual share for heating: 12 kWh/m²; Annual share for hot water: 13 kWh/m²; Annual share for electricity: 35 kWh/m². This compares with

2006 building regulations' requirements for new building of 110 kWh/m² in southern Sweden and 130 kWh/m² in northern Sweden*.

The construction work started in 2007 and the flats were occupied during the spring of 2008. Consequently, the buildings will be energy certified two years after being moved in to, which is in the summer of 2010. Monitoring of the energy use has been carried out since the houses were occupied.

Renovated apartment blocks – Katjas gata in Backa Röd Göteborg

Totally at least a handful of projects concerning renovation of existing apartment blocks have been carried out in Sweden. They range from more or less a well-thought through renovation (Gårdsten, Norrköping, etc.) to the ongoing passive house renovation of around 300 flats in Alingsås.

The project is a renovation of one typical apartment block (point house) from 1971 to a low energy building. The house is located on Katjas gata 119 in Backa Röd on the island of Hisingen in Göteborg. It contains four floors with 16 flats with three rooms and kitchen each.



The heated floor area is 1 357 m² Atemp and the residential area 1 244 m² BOA. The existing energy consumption was 178 kWh/m² Atemp. The goal of the project was to reach an annual energy consumption of 60 kWh/m² Atemp, excl. tenants electricity. This goal was fulfilled through:

- Well insulated building envelope
- Air tight building envelope
- Energy efficient and good ventilation

This means supply and exhaust air via a central air-handling unit in a new mechanical room on the roof. This has air-to-air heat recovery via a rotary wheel and energy efficient fans. In each apartment, there is a kitchen fan with direct exhaust. The existing hydronic radiators are served by district heating which supplies the heating of the building.

The energy part of the building renovation meant an extra cost of 240 000 SEK per flat (3 000 SEK/m² BOA). The renovation results in a decreased energy use of around 6 800 SEK/a and flat.

Preliminary monitoring shows that the radiator heating use is around 22% of the existing reference house next door, just as expected. The domestic hot water use is very varying and comparison with the reference house is not finished yet. The cold water use is about half of the reference house. The electricity for the building services has decreased somewhat compared to the reference house, despite balanced ventilation in the retrofit. This is probably due to efficient ventilation fans and efficient lighting systems.

* Comparable annual total energy consumption for Hamnhuset built without garage and with foundation slab on soil is 49 kWh/m² (gross area). NOTE! The above values also include the laundry rooms. To compare with buildings that have individual laundry and drying facilities in each apartment and for which the tenant pays running costs, subtract a further 10 kWh/m² per year (gross area).

New public buildings – education: Vargbroskolan, Storfors

In Sweden there are only one or two new low energy schools and maybe a handful of low energy pre-schools.

One of the first elementary schools was Vargbroskolan in Storfors. This is a new school with a hybrid ventilation system. The house fulfils the Swedish passive house requirements except for the windows. This is because when the school was built during 2007 the best U-values available was $1.1 \text{ W/m}^2 \text{ K}$. The school has around 300 pupils in grad 4 to 9. The building has two floors as well as a basement for heating/cooling of the supply air. The floor area is around $4\,000 \text{ m}^2$.

The school has 131 m^2 of PV panels and a special educational part the “Green Room” with solar heating and a small wind turbine. This room requires some electric heating which is not included. The total cost for the school was 66 million SEK.



The school was taken into operation in January 2008 and the monitoring report of the first two years has just been published ¹². The results show that the heating energy use is $35 \text{ kWh/m}^2 \text{ Atemp}$. This is only the district heating used for the radiators of the hydronic heating system. Direct electric resistance heaters are used for the service hot water. This eliminates hot water circulation losses, which are calculated to be of the same order as the energy used for service hot water (2.1 kWh/m^2). The building services systems use very little electricity (2.1 kWh/m^2) since they only consist of energy efficient supply air fans and hydronic heating system pumps. The monitored annual energy supplied to the building was 35 kWh/m^2 district heating and 28.4 kWh/m^2 electricity. The last does not include 3.8 kWh/m^2 from the PV panels. The electricity used for running the school, the users' energy, was 19 kWh/m^2 (excluding car motor heaters in the parking lots, external lighting etc. 5.2 kWh/m^2). This number was higher than designed because the lighting control system had a high standby power.

Consequently, the monitored energy performance of the school according to the Swedish Building Code (supplied energy minus the energy from PV panels and users' energy) is 35.4 kWh/m^2 . This is less than one third of the official requirements. The Swedish passive house requirements are maximum 55 kWh/m^2 .

¹² Jens Beiron (2010) *Vargbroskolan i Storfors - Drifterfarenheter från en energieffektiv skola*. Arbetsrapport, Januari 2010. Karlstads universitet, Fakulteten för teknik- och naturvetenskap, Energi-, miljö- och byggt teknik, Karlstad.

Renovated commercial buildings – offices: Getholmen in Skärholmen, Stockholm

As described above the Total concept for renovation from BELOK has so far resulted in 28 demo projects. Of these only a few of the first five office buildings have been monitored and partly evaluated yet.



The first five office buildings, all built during the 1970s, were renovated during 2007/08¹³. The first office building, Getholmen in the suburb Skärholmen of Stockholm, was taken into use in May 2009. Consequently, it has just been monitored for first year. The second office building, Pennfäktaren in the centre of Stockholm, was taken into use in December 2009.

The three schools and the two hospital buildings are currently being renovated. The eighteen other non-residential buildings of all types are currently being selected by the building owners.

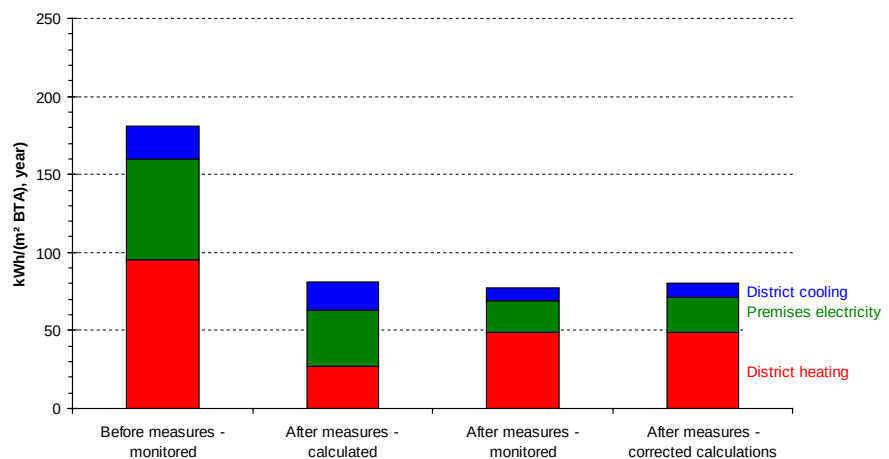
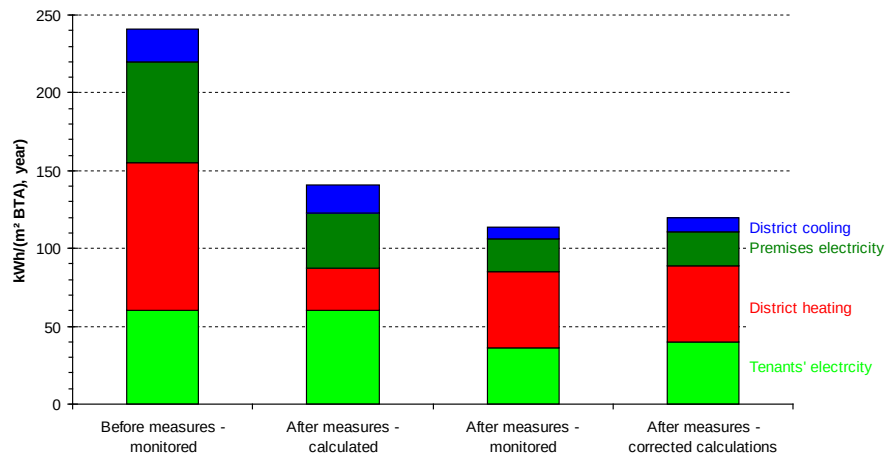
Brostaden, a subsidiary to the large proprietor Castellum, owns Getholmen office building. It was built in 1975 and has three floors. The gross floor area is 8 460 m² BTA. The building is supplied by district heating, district cooling and connected to the electric grid. The building was renovated during 2008 and it was occupied in April 2009. Consequently the building was used for one year in the end of April 2010.

The annual energy use in kWh/(m² BTA year) of the building is summarized in the following table.

Type of energy	Before measures – monitored	After measures – calculated	After measures – monitored	After measures – corrected calculations
District heating:	95	27	48.5	49
Electric energy excl. users' electricity:	65	36	20.8	22
District cooling:	21	18	7.7	9
Estimated tenants' electricity:	60	60	36.5	40

These numbers are also shown in the figures below. The first figure includes the tenants' electricity, whereas this is taken away in the second figure. The last figure corresponds to the energy performance defined according to the Swedish Building Code. Consequently, the energy performance after all measures is 80 kWh/(m² BTA year) where the gross floor area is used. This is less than half of the performance before measures. The energy performance per heated floor area is around 94 kWh/m² Atemp per year, which is around 10% below the requirements for new premises buildings according to the building code.

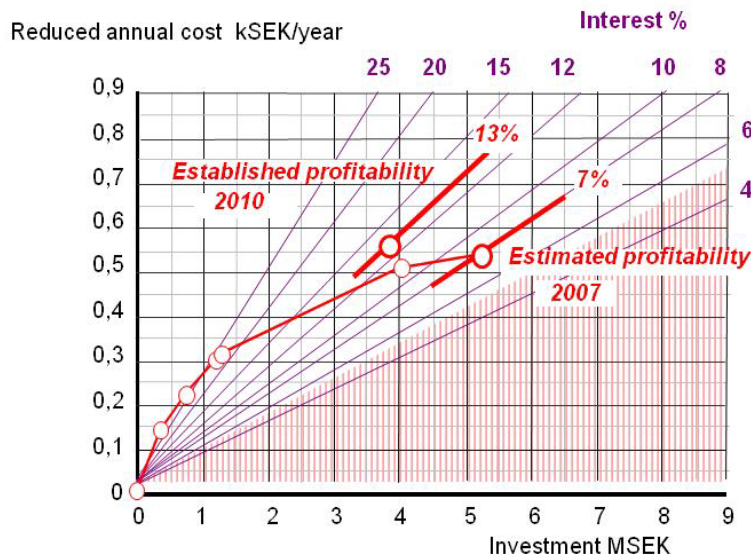
¹³ Enno Abel (2009) Getholmen. Ett genomfört Totalprojekt: Åtgärds paket - Beräknade kostnader och energibesparingar; Ombyggnad - Verkliga kostnader; Energiuppföljning - Verklig energi-besparing. Mars 2010. CIT Energy Management AB, Göteborg.



Energy measures implemented include:

- New windows
- Insulation of the roof
- Renovated ventilation system including new air handling units
- New lighting system (except tenants)
- Reduced heating base load (mainly control measures)
- Night cooling via ventilation
- Quality assurance

The figure below shows the internal rate of return for these measures as a whole package. The proprietor required a minimum of 4 % internal rate of return of the package or reducing the existing energy performance to half. The total renovation package with seven measures had an internal rate of return of 7% based on the calculated energy conservation. However, the monitored energy conservation and the follow up of the costs show that the internal rate of return of the package became 13 %.



Profitability of energy package, pre-calculated and post-calculated based on measurements (Enno Abel 2009).

If the measures had been carried out one by one only the measures that have a line in the diagram with a slope higher than 4% internal rate of return would have been carried out. In this case only the first four measures would have been carried out, which means that the annual energy conservation would be only half of the whole package. Consequently, it is very important to use the profitability for energy conservation packages when renovating non-residential buildings.

Future Needs and Trends

Future trends for development of low energy buildings for dwellings involve primarily renovation concepts for existing buildings down to LEB and for new constructions to move from passive houses to nearly-zero-energy buildings. For premises the primarily need is to get a higher implementation of LEB. A new programme for Low Energy Buildings called LÅGAN has just been established.

LÅGAN, is mainly funded by the Swedish Energy Authority. The program is divided into four areas; communication, cooperation, demonstration and tools for implementation. Within each area support can be given to different projects and actors. The different areas are connected with a national platform which is administrated and coordinated by the Swedish Construction Federation. The specific developments within each focus area has not been defined but will be specified depending on the applications.

Within the preparation of LÅGAN, an interview study with the construction and building owners sector was performed¹⁴. Together with the survey made for the present study the following topics have been identified as future needs of R&D activities in Sweden:

- A more fast and easy process in order to make buildings air tight, pre-fabricated products etc.
- More energy efficient ventilation systems with reduced pressure drops and energy efficient fans. This includes for example development supply air device for high temperature supply air in pas-

¹⁴ Åsa Wahlström (2009). *Förslag till strategisk inriktning på Energimyndighetens program för byggnader med mycket låg energianvändning*. 30 juni 2009. CIT Energy Management AB, Göteborg. www.energy-management.se/publications/42/read

sive houses and more cost effective and easily changeable filters in heat recovery units. Higher performance of heat recovery units both regarding energy efficiency and other technical aspects.

- Complete heat recovery systems for renovation of apartment blocks. Including solutions for air tightening of the building envelope, innovative solutions for installation of the duct system and construction of fan rooms. This includes both solutions with heat exchangers between supply and exhaust air, as well as solutions with exhaust heat pumps.
- Heat pump with technical solutions for premises where both heating and cooling are integrated. Heat pumps for small loads in LEB.
- District heating net techniques for areas with LEB.
- Further development of technique and implementation schemes for energy- efficient tap water devices.
- Combination of different systems as heat pumps or bio fuels systems with solar energy systems for increasing the share of renewable energy.
- Development of photovoltaic systems and small wind turbine systems. This includes technique for connecting, measuring and contracting of connection to the grid.
- Development of doors and balcony doors with better U-values.
- Development of alternative heating distribution systems for low temperature carriers.
- Development of zero energy houses concepts.
- Development of complete concepts for construction and renovation of LEB. Cooperation process within the complete building process. Including education and motivation of all actors as well as tools for convincing decision makers. Quality assurance and energy management schemes. Help tools for integration of building envelope with the building services systems.

Finland

Main R&D Topics

Tekes – the Finnish Funding Agency for Technology and Innovation

Tekes is the most important publicly funded expert organisation for financing research, development and innovation in Finland. Tekes aims at boosting wide-ranging innovation activities in research communities, industry and service sectors. Tekes promotes a broad-based view on innovation: besides funding technological breakthroughs, Tekes emphasises the significance of service-related, design, business, and social innovations.

Every year, Tekes finances some 1,500 business research and development projects, and almost 600 public research projects at universities, research institutes and polytechnics. Research, development and innovation funding is targeted to projects that create in the long-term the greatest benefits for the economy and society. Tekes does not derive any financial profit from its activities, nor claim any intellectual proprietary rights.

Tekes strategy focus areas outline future priorities for R&D and innovation in Finland. The policies will guide research, development and innovation prioritisation and the use of Tekes' and other R&D and innovation funding resources in the coming years. Tekes will implement the strategy focus areas through Tekes programmes and Strategic Centres for Science, Technology and Innovation.

The Tekes activities include the following themes:

- Energy and environment
- Forest and chemicals
- Health and well being
- Information and communication
- Innovation policy
- Machinery, materials and production
- Real estate and construction
- Services

The on-going Tekes programs focusing directly on the R&D in real estate and construction are Sustainable community (2007 - 2012), Build environment (2009 - 2014) and Indoor space (2008 - 2012). Other programs touching real estates and construction are, e.g., Groove - renewable energy (2010 - 2014), Serve - service business (2006 - 2013), and Functional materials (2007 - 2013).

The Strategic Centres for Science, Technology and Innovation

The Strategic Centres for Science, Technology and Innovation established in Finland are new public-private partnerships for speeding up innovation processes. Their main goal is to thoroughly renew industry clusters and to create radical innovations.

Long-term cooperation between industry and the research institutions develop and apply new methods for cooperation, co-creation and interaction. International cooperation also plays a key role in the operation of the Strategic Centres. Testing and piloting environments and ecosystems constitute an essential part of the Strategic Centres' operations.

In Strategic Centres, companies and research units work in close cooperation, carrying out research that has been jointly defined in the strategic re-

search agenda of each Centre. The research aims to meet the needs of Finnish industry and society within a five-to-ten-year period.

Strategic Centre for Built Environment Innovations combines the research strategies of industries and research institutions. The common strategy responds to the research and development needs on construction industries within a time span of 5 - 10 years. The vision is to create world class competences and competitiveness for the whole life-cycle of the build environment

The main goal is user and client driven development of the build environment. Strategic R&D based on applications together with international networks aims high-class know-how, services and products. The Strategic centre also aims at an increase in real estate and construction sector's yearly R&D expenditure from the present 230 million to 500 million € by the year 2020. Build Environment Innovations includes three R&D programs and their key themes under preparation:

- BIM based business
 - Transaction based information sharing and distributed information management
 - Building information model based product data management in industrialized construction supply chain
 - Innovation based supply chain of infrastructure
 - New Business Model based on Process Network and BIM
 - New Ways of Working
 - Platform for community level digital models of build environment
- Indoor environment
 - User friendly indoor environment
 - Management of indoor conditions
 - Energy-efficiency
 - Indoor environment for learning and creativeness
 - Indoor environment in real estate transaction
- Energy-efficient community concepts with digital world
 - User driven concepts
 - Urban structure
 - Asset management
 - Eco-efficiency

Ministry of Environment

The Ministry of Environment's support on research and development on Build environment focuses on three thematic areas:

- Challenges of climate change and eco-efficiency: development of communities and construction
- Land use and construction: healthy living environment, safety and cultural values
- Living conditions: housing needs and housing markets

The Housing Finance and Development Centre of Finland is a governmental agency operating under the supervision of the Ministry of the Environment. ARA is an agency to implement social housing policy. ARA's main task is to finance state-subsidised rental housing production. The Centre has also other obligations such as to make grants for housing repairs and to supervise the granting of state guarantees on loans for owner-occupied housing.

The Centre's target is to promote well-planned quality housing at reasonable housing cost, to promote housing development and to produce information concerning housing market. Properties to be constructed must be located at comfortable and safe areas in municipalities with housing demand.

Ara supervises the Ministry of Environment's research programs such as Suburb to Neighbourhood program (2008 - 2011). The aim is to improve the competitiveness of neighbourhoods in the housing markets and creation of positive images and identity of neighbourhoods. The program includes several projects on neighbourhood renewal and refurbishment. The neighbourhoods of the 1960's and 1970's are main focus area.

Examples of pilot building projects

Examples of very low-energy houses in Finland are given in table below. The design temperature refers to design of the heating system's maximum heat load.

House	Building information	Heating / total energy kWh/m ²	Extra cost compared to typical, %
	Pietarsaari 1994 Detached house 166 m ² $n_{50} = 0,8$ 1/h Design temperature -29°C <u>Three key features:</u> Window U = 0,7 W/m ² K PV and solar thermal Up-grading to NZEB planned	13 / 48	Not available
	Vantaa 2009 Semi-detached house 2 x 187 m ² $n_{50} = 0,3$ 1/h Design temperature -26°C <u>Three key features:</u> U values 0,07 - 0,09 W/m ² K Heat recovery efficiency 80% Ground heat exchanger (liquid)	18 / 60	5,0
	Mäntyharju 2010 Detached house 150 m ² $n_{50} = 0,2$ 1/h Design temperature -29°C <u>Three key features:</u> Air tightness Construction process SME company development	25 / 50	< 5,0
	Valkeakoski 2009 Detached house 240 m ² $n_{50} = 0,35$ 1/h Design temperature -29°C <u>Three key features:</u> North facing main facade Challenging architecture U - values 0,06 - 0,09 W/m ² K	24 / 70	< 7,0
	Helsinki 2009 Apartment house $n_{50} = 0,4$ 1/h Design temperature -26°C <u>Three key features:</u> Cost-efficiency Ventilation heating Industrialized construction	20 / 60	2,0

	Heinola 2009 Apartment house $n_{50} = 0,4 \text{ 1/h}$ Design temperature -29°C <u>Three key features:</u> Cost-efficiency Ventilation heating Industrialized construction	20 / 70	2,0
	Kuopio 2010 Apartment house 2129 m^2 Net zero energy house Design temperature -32°C <u>Three key features:</u> First full scale NZEB Building integrated renewables District heat	Yearly net energy balance 0	Not available yet
	Järvenpää 2011 Apartment house 2200 m^2 Net zero energy house Design temperature -26°C <u>Three key features:</u> Second full scale NZEB Building integrated renewables District heat	Yearly net energy balance 0	Not available yet

A6 Market Possibilities and Needs for an Innovation Program - Interviews

Denmark

Denmark has carried out 10 interviews. The interviewees represent the Danish building industry in the following manner:

- Sundolitt as (Insulation material)
- Rockwool A/S (Insulation material)
- Lundgaard & Tranberg Architects (Architects)
- Henning Larsen Architects (Architects)
- Velux Danmark A/S (Windows)
- Protec Windows (Windows)
- Cenergia (Consultant)
- Esbensen A/S (Consultant)
- Danfoss A/S (Heating/Cooling systems)
- Municipality of Egedal (Municipality)

Question 1

Past projects concerning LEB?

All respondents have been involved in one or more R&D projects related to LEB in the past.

- a) Only two respondents have undertaken research as a direct consequence of user/customer demand of specific products/services. The rest have initiated research for different reasons.
- b) Producers of building materials, building contractors, architects, consultants, construction companies, housing associations, craftsmen, research institutions and universities.
- c) A lot of time, resources and finances have been invested in the projects.
- d) Experiences are generally positive, however, there is also a tendency towards experiences where the building industry is conservative and hard to move in "the right direction".

Question 2

Present projects concerning LEB?

All respondents except one are presently engaged in R&D projects related to LEB.

- a) Focus areas encompass: Key technologies, ventilation systems with low electricity use, external insulation for facades, solar energy, utilisation of excess heat, renovation of buildings, design processes for LEB, focus on whole buildings, windows, foundations, insulation on ground, biomass, power planted heat, ventilation systems with heat recovery, heat distribution for local district heating, CTS-systems, day-

lighting, lighting, indoor climate, simple intelligent solutions, heating systems based on heat recovery and heat pumps.

- b) A lot of time, resources and finances are being invested in LEB, and there is a tendency towards an increase in focus and extent of the research.

Question 3

Future projects concerning LEB?

All respondents expect to be engaged in R&D projects related to LEB in the future, and the expectations show a further commitment towards projects revolving around LEB solutions.

- a) Focus in future projects will be on: Energy technologies and – systems, impartial demonstration buildings, the relation between city/building (a wider perspective of LEB), calculation programmes to ease the early design process, both specific products and end-to-end solutions, education, constructional understanding, documentation and experience-gathering, system solutions, increased focus on financing and business plans for projects.
- b) It is expected that even more time, resources and finances will be invested in future research projects related to LEB.
- c) All respondents agree that there is a need for a common Nordic innovation programme for LEB. The program should have a wide perspective and allow for discretion (i.e. not necessarily sharing of research results).
- d) PSO, EUDP, EU, Greenlabs and Realdania (... and more).

Question 4

Barriers for development?

The respondents see a lot of possible barriers in the way of the development. The following list is seen as the most important barriers: Financial, technical, architectural, network, conservatism in the building industry, focus on products rather than entire end-to-end solutions, standards and regulations, missing political statements concerning the future, small innovative companies have problems marketing products and solutions.

Question 5

What should be the focus of a Nordic innovation program?

Components, common incentives, end-to-end solutions, solid concepts for LEB, follow-up on buildings (are expectations met), indoor climate, health, services (spreading of knowledge), standards and regulations, methods for calculating performance parameters (not just energy), focus on the "important" attributes (i.e. E_{eff} for windows rather than U-values), larger perspective, electricity, renewable energy sources and standards for renovation of existing buildings, influence on international standards.

Question 6

Advantages of a Nordic innovation program?

The respondents see a lot of advantages of having a Nordic innovation program: Larger market, save time and resources, strengthening of the Nordic co-operation, export of knowhow to the rest of the world, reduce the vulner-

ability of individual countries, synergy, knowledge, concepts, consensus on methods for evaluating products and solutions, networking between Nordic countries and better and broader utilisation of research results.

Question 7

Consequences of not having a Nordic innovation program?

The respondents all see negative consequences of not having a Nordic innovation program: The Nordic countries will be overtaken by countries like Germany, Austria and Switzerland which will increase the import of products and services (and reduce export and thereby increase unemployment). We have a strong position to begin with, and the time to move forward is now otherwise we will lose initiative; we need the program to take advantage of this. We will lose our competitiveness and relevance, and risk moving in the wrong direction.

Question 8.

Necessary conditions for increased development and market for LEB products and services?

- a) The respondents have very different backgrounds and therefore different demands as to the amount of financing necessary for them to partake in research projects. Producers of building materials, building components and whole building solutions can typically accept from 0-75% financing, as they can see the project as an investment which will bring future earnings. The consultants, architects, municipalities and knowledge institutions will typically require a higher rate of financing (50-90%), as the knowledge they gain from a project can not be readily sold after the project has finished.
- b) Research institutions, universities, organizations, consultants, architects, producers of building materials, producers of building components, construction companies etc.

Iceland

Nine interviews have been carried out with Icelandic stakeholders, some were performed as telephone interviews, other were answered in writing.

- Arkis (Architects)
- Tark (Architects)
- Almenna (Consultants)
- Efla (Consultants)
- Verkís (Consultants)
- Istak (construction)
- Innovation Iceland (Knowledge institute)
- University of Iceland (Knowledge institute)
- Government Construction Contracting Agency (Developer)

Question 1

Past projects concerning LEB?

All respondents have been involved in R&D projects that somehow involve optimization of energy performance of buildings, although the focus and demands to energy performance of buildings in Iceland has not been as stringent as in the other Nordic countries. One project involves adjustment of demands in EPBD to Icelandic conditions. The knowledge institutes have naturally more activities in research projects than the private companies that

mostly focus on development within their services. Some of the projects have been related to the introduction of BREEAM and LEED (certification methods for sustainable buildings) into the Icelandic building sector, where energy performance of buildings is one of many subjects involved.

- a) Few respondents have undertaken research as direct consequence of user/customer demands, many respondents have started development work within their company due to users/customer demand (such as customer asking for fulfillment of LEED or BREEAM demands).
- b) Building authority (ministry), University of Iceland, Innovation Center Iceland, Iceland Academy of the Arts, National Energy Authority, energy research center (Orkusetur), consultants, architects, building users, international collaboration.
- c) Significant amount of resources have been invested in the projects.
- d) Experiences are generally positive.

Question 2

Present projects concerning LEB?

Many respondents are involved in R&D projects related to optimization of energy performance of buildings, carbon footprint, etc. although none of the projects are within development of low/zero buildings in Iceland.

- a) Focus areas include: Energy performance, energy savings, material consumption, insulation improvements, local conditions, natural ventilation, pilot projects with the use of heat pumps, development of small zero energy buildings for tourists services in the highland, designing according to certification standards. The Governmental Construction Contracting Agency participates in a Nordic project with the Nordic Governmental agencies (Norisk kontakt om statsbygninger) with focus on Energy label and energy performance of buildings.
- b) Considerable amount of time and money have been invested in those projects.

Question 3

Future projects concerning LEB?

Many participants have plans for future projects that involve energy performance of buildings (although none mentioned low/zero energy buildings).

- a) CTS-systems, information systems, energy performance of building materials/parts, energy performance of buildings, heat pumps, local conditions, cold climate. Also design according to sustainable certification methods for buildings and communities within urban area (Reykjavik and surroundings). Energy savings and performance of communities (rural area, population less than 1000).
- b) The extent and financing of the projects are in many cases not yet solved, significant amount of resources and money will hopefully be invested.
- c) All respondents agree that there is a need for a common Nordic innovation program with focus on energy performance of buildings. The program should have a wide perspective (acknowledging the different conditions within the Nordic countries).
- d) Not much in Iceland at the moment, mostly EU and The Icelandic Centre for Research funds (Rannis).

Question 4

Barriers for development?

Most respondents mentioned lack of demand from both market and authority as the most important past barriers in Iceland. This means that the market and authorities have just not required LEB due to low energy prices and abundance of sustainable energy in Iceland. One respondent mentioned that energy should be considered as valuables.

The most important barriers Iceland is facing now are financial. At the same time the market demands are changing and clients are now requiring building certification and more focus on energy performance. The certification process is also expensive. Few funding possibilities in Iceland are available.

It was also mentioned that the focus in Iceland is different than in the other Nordic countries.

Question 5

What should be the focus of a Nordic innovation program?

- a) General solutions for new and existing buildings, services, common standards and requirements within the Nordic countries, common incentives, adjustment of standards to Icelandic conditions, also in broader extent (sustainability, environmental performance).
- b) Strengths: Respondents mentioned good knowledge within the Nordic countries, good technical knowledge and environmental thinking,

Weakness: Respondents mentioned the size of the market, few people and knowledge is spread which decreases the possibilities for development within each party, costs, different conditions within the countries, barriers within common market. Iceland is the only country without energy labeling of buildings. Need for common standards and comparability within energy labeling within the Nordic countries (with climate adjustment)

Question 6

Advantages of a Nordic innovation program?

Improving knowledge, research and development, strengthen the Nordic co-operation. Possibilities for comparable Nordic standards and requirements. Possibilities for research and development of theory adjusted to Nordic conditions and climate. Increases the possibilities for development in rural areas and lowering the energy costs. Avoids double work and double research within the Nordic countries.

Question 7

Consequences of not having a Nordic innovation program?

Lesser performance, slower development, especially very slow development in Iceland, lesser Nordic cooperation and the Nordic countries will lose their position in the frontline.

Question 8

Necessary conditions for increased development and market for LEB products and services?

- a) The respondents have very different backgrounds and therefore different demands as to the amount of financing necessary for them to partake in

re-search projects. Also the type of projects influences the demands for funding. Most respondents mentioned at least 50%, some up to 75%.

- b) Mixture of research institutes and private companies to secure interdisciplinarity, could also be important to have municipalities etc. in some projects. At least 2-3 countries should be involved.

Norway

14 persons have been interviewed:

- A director of energy and environment at a national association of construction companies
- A chairman of a producer of solar thermal systems
- A professor in HVAC systems at NTNU
- An associate professor in intercultural studies of energy at NTNU
- A senior associate of a large HVAC consulting company
- A director of energy and building physics of a large consultant company
- A senior consultant at the Norwegian Energy Agency (Enova)
- A director of a small supplier of PV and wind power systems
- A senior architect at a leading architectural company
- A market director of a leading producer and supplier of facade systems
- An R&D manager of a leading construction company
- An R&D manager and a market director of a producer and supplier of wood stoves
- An R&D manager of a large supplier of total technical solutions and supplier of services for operation and maintenance.

Question 1

Do you already use an innovation that has been requested by user? Nature? Amount? Lessons learnt?

Almost all (except 2) of the respondents use an innovation that to some degree has been requested by user. The innovations include:

- Windows and envelope systems with high thermal insulation and air tightness
- Facade systems with integrated solar shading, PV, and natural and mechanical ventilation with heat recovery
- Double facade systems
- Low energy and passive building concepts
- Testing and quality assurance methods
- Building integrated solar thermal collector systems
- Low emission and effective wood stoves
- Control and visualization systems for water based heating systems
- Information and incentive programs
- Demand controlled ventilation systems
- Ventilations systems with low SFP
- Ventilation heat recovery systems
- Thermal storage systems

In most of the cases, the innovations have not directly been requested by the user, but the development has happened due to market trends and due to new and future energy and environmental requirements in national building codes and/or EU regulations. The perceived market for LEB services is considered to be quite high, while the market for LEB products and concepts is still considered to be quite small. Initial costs are reported as the main obstacle, and secondly the lack of knowledge and competence (see barriers below).

Question 2

Are you involved in any R&D projects related to your LEB business? Nature? Amount?

All except two of the respondents are involved in one or more R&D projects related to LEBs. The projects include:

- Air tight and well insulated building envelopes
- Building integrated solar collector systems
- Zero Emission Buildings, www.zeb.no
- Low energy commercial buildings, www.leco.no
- BIM
- Sustainable re-development of existing buildings
- Low energy hospitals
- Analysis of future energy use with respect to climate change
- Evaluation of buildings in use (Post-Occupancy Evaluation)
- Measurement and verification of energy performance
- Energy efficient ventilation systems
- User involvement in carbon neutral settlements

The projects involve several national and international partners, ranging from suppliers and producers of products, through architects, developers and consultants, to R&D institutes and universities. All of the respondents considered the R&D projects as useful related to their core business. All together, the reported R&D activities amount to several millions NOK per year.

Question 3

Do you have any plans for future R&D activities? Nature? Amount? Need for support? Are there other sources for support?

All of the respondents have plans for future R&D activities, including the following topics:

- Design guidelines and information
- Pilot projects involving low emission buildings
- Certification systems
- Air tightness
- High insulation building envelopes
- Integrated design
- Life cycle costs
- BIM
- Environmental data for products, materials and concepts
- Common systems for green building assessment
- Solar thermal and PV systems: new concepts, products, materials, and production processes
- Wood stove systems: low peak power, low emissions, thermal storage
- Control and visualization systems
- Energy exchange in multi-use buildings
- Evaluation of buildings in use, measurement and verification of energy use, emissions, indoor environment and user satisfaction.
- Demand controlled ventilation, concepts and controls
- Integrated control systems
- Cooling systems
- Heat pump systems

All of the respondents answered yes on the question of the need for a Nordic Innovation program. Some mentioned the need to combine support from Nordic Innovation program with other national funding. Other sources of support mentioned include Enova, Norwegian Research Council, Skattefunn (Tax Refund), Nordic energy R&D programs, and EU programs.

The length of projects indicated range from 1-4 years. Needs for support indicated range from 25%-100%, depending on the type of project. Generally, projects involving many small actors and having a nature of “common goods” are in the higher range, while product development projects with only a few partners are in the lower range.

Question 4

What are the barriers to overcome in order to start business development (innovation processes)? (I.e. development of products or services or their processes with manufacturing, financing, competence, marketing, staffing, contact with R&D institutions etc.)

The barrier mentioned by most of the respondents as being most important is the lack of knowledge. This includes lack of knowledge about the potential energy and cost savings, the technical possibilities, performance issues, reliability, etc.

Another main barrier mentioned by many is the lack of competence about LEBs among architects, consultants, construction companies, installers, craftsmen, and clients.

A third barrier mentioned by several is the financial barrier. This includes the lack of economic investment strategies that take into account societal costs and life cycle cost, the lack of economic support mechanisms for R&D, pilot projects, and implementation, and little known or bureaucratic support mechanisms.

Also, an important barrier mentioned by several respondents is related to “the fight against the existing infrastructure and system”, e.g. it is difficult to introduce new products and services that are to replace well established products and services. This involves changing established user patterns and preferences, fighting traditional strong businesses, e.g. small distributed power suppliers vs. centralized power suppliers.

Also, several respondents mentioned that the Nordic clean energy supply system is an obstacle for innovations related to LEBs.

Other barriers mentioned were the lack of risk-prone capital, and the lack of incentives that are stable and predictable.

Question 5

What should an innovation program for LEB focus on? Technical status? Business strongholds? Opportunities? Status compared to other countries? Does a large market exist? What are the needs?

- components (products)
- concepts (overall system solutions)
- services
- common standardization
- common incentives
- common regulations
- etc

The following focus areas are mentioned by the respondents:

- Methods and tools for integrated energy design, strategic energy planning, and life cycle costing
- Design support and guidelines
- Pilot building projects – reference projects
- The development of verification and documentation procedures

- The evaluation of LEBs in use: monitoring and verification of energy performance, indoor environment and user satisfaction
- Development of components, products and concepts that are more cost-effective and robust with respect to user behavior
- Development of information and education services
- Common principles and requirements for codes, standards, documentation/certification, and incentives
- Effective solutions and incentives for energy-efficient renovation of existing buildings
- Analysis of the development of the Nordic and European energy market
- Information exchange between the Nordic countries about all the above points

None of the respondents considered the current Nordic market for LEBs to be large, but expected it to grow in the future. The product producers currently had their main markets in central and southern Europe. Several of the respondents considered the central European LEB market to be more evolved than the Nordic one, due to higher public interest in environmental issues and better incentive programs. Generally, no big differences between the Nordic LEB markets were reported, but differences in regulations and energy supply infrastructure were pointed out. One respondent considered the Norwegian LEB market to be more evolved compared to the Swedish, and another one vice versa.

Question 6

What are the benefits with a Nordic innovation program for LEB?

All of the respondents considered a Nordic innovation program to be useful. They thought that a common program could increase the Nordic LEB business strongholds, and lead to higher market penetration for Nordic LEB products and services both within the Nordic region and toward increased exports, particularly to Northern and Central Europe, Russia, the Baltic's and North America.

Several mentioned that cultural and climatic conditions are quite similar among the Nordic Countries, which facilitates cooperation across borders. However, some differences were brought up, e.g. related to the property structure, but these were not considered a main obstacle.

The benefit of information exchanges among Nordic countries was also mentioned by several, e.g. the benefit of learning from each other.

A couple of the respondents mentioned that the Nordic perspective with respect to clean production, high quality design, democracy and the valuation of common goods should be a pre with respect to taking the world leadership in green innovations.

One of the respondents answered elegantly: "There is an obvious beauty in combining the Swedish engineering science, the Danish pleasure of life and pragmatism, and the Norwegian fighting spirit".

Question 7

What will the conditions be if these things not will be developed within the Nordic Countries?

On this question, most of the respondents answered that the Nordic market and businesses will develop slower and fall behind. Other, more specific consequences mentioned were:

- Inefficient use of the R&D capacity

- Inefficient use of resources
- Higher failure rates
- More different solutions with lower market shares
- More expensive solutions
- Small actors that cannot bring major changes alone

Question 8

What are the business framework conditions needed for the development and increased market penetration of LEB? Main collaborative partners? Needs and wishes? Amount of support needed (25%, 50%, 75%)?

Main business framework conditions mentioned were:

- Need for public financial support in the innovation phase, to reduce risk.
- Development of incentives and regulations
- The economic support mechanisms must be predictable and non-bureaucratic
- Support should be related to % improvement relative to current regulations
- Economic support for planning and market introduction (of buildings and products)
- Economic support for pilot buildings, especially integrated energy design
- Feed-in tariffs for distributed renewable energy
- Public institutions must lead the way, drive the development
- Well documented pilot projects should lead the way – show that technology is performing as expected.
- Profound technical knowledge need to be developed
- Developers/buyers/clients must have competence and give specific and concrete energy requirements

Most of the respondents expressed interest in collaborating with other Nordic partners, and with other types of businesses and institutions. All types of actors in the value chain of LEB were mentioned, the most frequently mentioned include knowledge and R&D institutions, architects, consultants, material and product suppliers and producers, installers, construction companies, developers, and end users. However, some of the respondents stressed that they should be allowed to choose collaborative partners freely (not to be dictated by the innovation program). Also, many respondents stated that users (end users or businesses) should be actively involved in R&D projects and that they should feel ownership for the innovation.

With respect to the amount of financial support for increased market penetration, the respondents answered from 25-100% of the development costs, and covering most of the extra LEB related costs for investors in pilot projects. Several of the respondents pointed out that extra support for the renovation market was needed.

Sweden

Thirteen interviews have been carried out in Sweden. The interviewees represent the Swedish building business in the following manner:

Architects

- EFEM
- Kjellgren Kaminsky Architecture

Building constructor

- Hökerum bygg
- NCC Teknik
- Veidekke

Building owner

- Fastighetsägarna GFR
- Viskaforshem

Consultant

- Bengt Dahlgren
- WSP Environmental

Heat pump producer

- Nibe

Solar heating

- Chalmers University of Technology
- SSolar

Air handling systems

- Swegon

The answers vary depending on background of the interviewee. Generally in this study, building owners tend to focus on issues such as rent levels, usable area, thermal comfort and other concerns related to their core business. Building entrepreneurs mainly focused on investment costs, local environmental policies, building permissions, etc. Consultants and architects wanted guidelines, pilot projects and an increased awareness of LCC. The solar heating company and the heat pump company mainly focused on certain technology prescriptions in building codes/guidelines and financing of pilot projects for technical development.

Question 1

Past projects concerning LEB?

Most of the respondents have been involved in LEB projects lately. The definition of LEB is however a bit vague (see below). Several of the respondents have been involved in R&D projects related to LEB.

Those with R&D experience tend to consider R&D as a part of their business idea - an ongoing process.

Some of the respondents claim that almost all their building projects are LEB, even though only a few of them can be defined as passive houses or other buildings with very good energy performance. They rather refer to Green Building, LEED, BREAM or other assessment methods. The reason for their involvement in LEB projects differ; some municipalities require LEB as a part of their local environmental policies while some customers are just simply interested in LEB. Individual engagement and conviction among the

interviewees are probably also examples of reasons why LEB-projects are carried out.

There are also those who hesitate. One interviewed with no LEB experience claimed that “the technology” still is too new and untested. He said they are interested, but they want the bigger companies to try it thoroughly first. Moreover, he claimed that a big company would keep on going even if they would fail with one or a few LEB projects, such failure would however be very costly and difficult to overcome for smaller companies.

Question 2

Present projects concerning LEB?

As mentioned above; those with R&D experience tend to consider R&D as a part of their business idea - an ongoing process. Examples of ongoing R&D activities are think-tanks, development of internal guide-lines on how to build LEB and experience feedback from LEB projects.

Question 3

Barriers for development?

Besides low energy prices, the main barrier seems to be financing. The financing barrier could be divided in three main categories:

- Lack of interest from financial institutes. It is hard to get loan for the extra investment cost that comes with the LEB concept (5-10 % extra according to the interviewed) since the banks mainly care about investment costs, not management (LCC).
- Rigid regulations regarding housing rent levels i.e. “fixed” and benchmarked Swedish rent levels and regulations saying that the rent has to be equal for equal buildings.
- Few customers are aware of the “LCC concept”. Few consultants can provide customers with reliable LCC analysis, which leads to focus on investment costs only.

Other barriers often mentioned where:

- Reduced accessible floor area (thick walls reduce the area)
- Fear of reduced thermal comfort
- Limited amount of “success stories” (not many LEB's in Sweden). The LEB concept is not enough marketed.
- Lack of competence (all parts and levels)
- Different local environmental policies regarding LEB

The solar heating representatives admitted that lack of whole systems (packages that cover 100 % of the heating requirement) reduces the interest for their products. Example: many solar heating retail dealers today only provide their customers with solar heating systems, not systems for the total heating requirement. The customer's actual need would rather be solar heating + pellets etc.

Another barrier could be the lack of business agreement with building entrepreneurs.

Question 4

What should be the focus of a Nordic innovation program?

Most of the interviewed claimed that information campaigns should be the main focus. Information campaigns for all parts including financial institutes, building owner societies and tenant organizations.

The ideas on how information campaigns could be arranged differs, one suggestion was to set off working team with gathered Nordic competence. This group of experienced (financed) expertise could ensure that certain issues, such as R&D projects etc., will be taken care of fundamentally and knowledge could be gathered systematically. Moreover, the group of expertise could carry out a guideline with qualified illustrative example on how to build LEB, not just a list of defined requirements. This guideline must be frequently revised or supplemented in corporation with the industry to avoid technical stagnation and limitation of "new solutions". The group of expertise must involve several categories of people, not only scientists or politicians. Building owners, building constructors and other people with economical over-view and responsibility must also be involved.

With regard to one of the main barriers above (lack of competence) some of the interviewed wanted producers of building services systems in general and building workers/craftsman in particular to undergo education and training programs leading to certificates, preferably certificates on a Nordic level. A Nordic certification system would most likely raise the status of these categories which may attract young people to the branch. Moreover, it would make a good example for the rest of Europe to follow.

Here are some other desirable outcomes from the group of expertise:

- Information campaigns (what is LEB? statistics from validated LEB's, LCC, benchmark, shining examples, etc. etc.)
- List of arguments (based on statistics from validated LEB's) for discussion with financial institutes
- A guideline with illustrative examples on how to build LEB (refurbishment included), not just a list of defined requirements. Here the heat production representatives (solar heating and heat pump) wants there technology to be prescribed in the guideline
- Permission for LEB to be built outside the development right (as a compensation equivalent to the thicker walls)
- National incentive models. Example: less expensive site price for LEB
- Possibility for building owners to sell electricity (this is possible in Germany)
- Building codes designed to encourage LEB's
- Common local environmental policies regarding LEB. The solar heating representatives want solar heating to be prescribed in the environmental policies
- Financed (or partly financed) pilot projects for development of technical systems

Question 6

Advantages of a Nordic innovation program?

Apart from realised issues according to question 4 above, following advantages are mentioned:

- Sharing of knowledge
- Sharing of costs for realising of "pilot projects" or other projects that needs extra financing

Question 7

Necessary conditions for increased development and market for LEB products and services?

Many of the interviewed could not come up with any answer to this question, however most of them said they did not want subsidies (even though they most likely would use it if it existed).

Here are all the answers on this question (apart from the answers regarding subsidies):

- Nordic information on validated LEB projects. Preferably LEB projects from many different geo-graphical locations.
- National building codes should require some amount of solar heating (as in Portugal, Spain, South Africa, some countries in South America and soon in Italy).
- Make it possible to sell heat surplus (to neighbours) and solar electricity