The Nordic market for climate friendly buildings – status, barriers and opportunities

Åsa Wahlström
CIT Energy Management AB
SE-412 96 Göteborg
Sweden
asa.wahlstrom@cit.chalmers.se

Inger Andresen
SINTEF Building and Infrastructure
N-7465 Trondheim
Norway
ia@linkarkitektur.no

Kirsten Engelund Thomsen
Danish Building Research Institute, SBi
Aalborg University
DK-2970 Hørsholm
Denmark
ket@sbi.dk

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Abstract

This paper summarizes the findings of a project financed by the Nordic Council of Ministers. The main goal was to establish a knowledge and decision base for a Nordic innovation program. The project included a survey of the Nordic market for low energy buildings (LEBs) related to codes and regulations, incentives, technologies, design and planning strategies, concepts and demonstration projects for LEBs. Interviews with 45 representatives of the building industry were performed.

All the Nordic countries except Iceland have introduced energy requirements for new buildings in line with the EU regulations. However, the requirements differ from country to country, and different advantages and disadvantages were identified. In general, the building energy codes for new buildings are quite advanced in the Nordic countries, but there is an urgent need to plan for the needed upgrading of the existing building stock.

Statistics about the market for LEBs are relatively poor, however, it is estimated that for residential buildings, the market share of LEBs is about 10 % in the Nordic countries (except Island). The Nordic countries have developed a range of technologies for LEBs, in particular solutions for thermal insulation and air tightness. Also, technologies such as very efficient windows have been developed. However, the technologies have not reached wide spread use.

New design and planning practices like integrated energy design (IED), partnering, and energy performance contracts are being used to a limited degree. There is a great need for well documented and successful pilot projects to serve as "leading stars" for the development of the LEB market.

The interviews indicated that a common Nordic 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.

Introduction

Several studies show that significant efforts in energy efficiency improvements are needed in order to reduce the global greenhouse gas (GHG) emissions. For example, the IEA World Energy Outlook clearly illustrates that more than half of the needed GHG emissions reductions stem from energy efficiency measures. In Europe, buildings are responsible for as much as 40 % of the energy use and 36 % of the CO_2 emissions. The EU Directive on Energy Performance of Buildings (EPBD) states that energy performance of buildings is key to achieving the EU Climate & Energy objectives, namely the reduction by 20 % of the greenhouse gas emissions and a 20 % energy saving by 2020.

Moreover, the McKinsey report on GHG cost abatements[1] showed with great clarity that improving the energy performance of buildings is among the most cost-effective ways of fighting climate change.

1. Enkvist, P-A. et.al (2007), "A cost curve for greenhouse gas reduction. A global study of the size and cost of measures to reduce greenhouse gas emissions yields important insights for businesses and policy markers", The McKinsey Quaterly 2007, Number 1, Stockholm.

Thus, there is a tremendous potential for energy savings and CO_2-mitigation by developing the market for low energy and climate friendly buildings. A recent study by EuroACE[2] suggests that the European energy and CO_2-emission savings may be as much as 568 PJ and 36 Mt CO_2 per year if all new buildings are constructed as low energy buildings from 2012.

Another important benefit of pursuing low energy buildings is increased value creation. Although it is difficult to quantify the potential of value creation within the building industry, the following examples serve to illustrate the potential of "greening" the building industry:

- In Norway, two recent studies estimate that a strongly increased emphasis on the construction and renovation of low energy buildings is needed in order to reach the EU 2020 goals. The reports estimate such activities will create an increased business potential of NOK 80 billion, and about 80,000 new jobs from 2010 to 2020[3],[4] (1 EUR = 8.0 NOK).
- In Finland the government's energy and climate strategy includes yearly support to renewable energy of 340 million Euros by 2020. It is estimated that the support enables more than 20,000 direct or indirect (subcontracting and manufacturing) new jobs. The present turnover of the climate and environment business is roughly 15–20 billion Euro, of which exports cover 10 billion Euro. The export of energy technologies was 5 billion Euro in 2009.
- In Denmark, the value of exported energy and environmental technologies comprised 58 billion DKK in 2009 (including wind power technologies), or 11 % of the total value of all Danish exports[5] (1 EUR = 7.5 DKK).
- In Sweden, the turnover for energy and environmental technologies is constantly increasing and was 135 billion SEK in 2008[6] (1 EUR = 9.6 SEK). Of this, 37 billion SEK were exports, with Germany and China as the largest export countries. The sector has nearly 6,600 companies with 42,000 employees. Wind power and solar energy have the highest turnover increase by about 60 % compared to year 2007, and turnovers of 8 billion SEK and 4.5 billion SEK, respectively. A report from the Swedish Construction Federation[7] estimates that there is a need for 30,000 new jobs in the construction industry to take care of the needed energy renovations of existing multifamily houses towards 2020. The report also predicts an increased turnover of 35 billion SEK per year related to energy renovation of those buildings.
- Reports from both Sweden and Denmark show that the export of technologies within the energy and environmental sector are less affected by the financial recession than other sectors. Currently, however, the construction of dwellings in the Nordic countries seems to be increasing. In Sweden, 24,500 constructions of dwelling units are planned in 2011, an increase of 50 % compared to 2009. In Finland, it is estimated that 27,500 dwelling units will be realized in 2010, which is an increase of 44 % compared to 2009.

This paper summarizes the findings of the work conducted within the project "Nordic Analysis of Climate Friendly Buildings", financed by the Nordic Council of Ministers[8]. The main goal of the project was to establish a knowledge and decision base for a Nordic innovation program that will promote the development and demonstration of low energy and climate friendly buildings. The innovation program should support a development that brings the Nordic countries to an international forefront with respect to business strongholds and market penetration of low energy and climate friendly buildings.

There is no universally accepted definition of *low energy and climate friendly buildings*. In this project the term will encompass buildings with an energy performance at least 25 % better than current national building regulations, and includes passive houses and zero energy/emission standards. In the following text, such buildings will be denoted ***LEB** (**L**ow **E**nergy **B**uildings).*

Overview of Codes and Regulations

Due to the Energy Performance of Buildings Directive (EPBD 2002/91/EC) all Member States of the European Union have implemented energy performance requirements for new buildings, or will do so in due time. The definitions and levels of the energy performance requirements are set on a national level.

In order to evaluate the market possibilities for products, services and processes for low energy buildings in the Nordic countries, a comparison is made on how national regulations manage energy performance issues and what differences there are between the Nordic countries. National future plans for higher requirements of the building regulations are also described in brief.

RECAST OF THE ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE

The accepted recast of the EPBD published in June 2010 will have major influences on the national building codes. The directive sets requirements that the Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set. Requirements may differentiate between new and existing buildings. The Member States shall ensure that by 31 December 2020, all new buildings are nearly zero energy buildings, and after 31 December 2018, public authorities that occupy and own a new building shall ensure that the building is a nearly zero energy building. Furthermore, the Member states shall have intermediate targets for improving the energy performance of new buildings for 2015.

The directive also requires that Member States shall take the necessary measures to ensure that when buildings undergo ma-

2. Jensen et al (2009): "Towards very low energy buildings. Energy saving and CO_2 emission reduction by changing European building regulations to very low energy standards", SBI 2009:03, Danish Building Research Institute, Aalborg University.

3. Dokka et al (2009): "Energieffektivisering i bygninger – mye miljø for pengene", Prosjektrapport 40, SINTEF Byggforsk, Norway.

4. Arnstad et al (2010): "Energieffektivisering av bygg. En ambisiøs og realistisk plan mot 2040", Statens bygningstekniske etat, Norway.

5. http://www.ens.dk/da-DK/Info/TalOgKort/Statistik_og_noegletal/Energierhvervsanalyse/Sider/Forside.aspx

6. www.swentec.se

7. Sveriges Byggindustrier (2010): "Hur når vi de samhälleliga energimålen?", www.bygg.org.

8. Andresen, Engelund Thomsen, Wahlström (2010), "Nordic Analysis of Climate Friendly Buidlings", Report to the Nordic Council of Ministers. http://www.norden.org/da/publikationer/publikationer/2010-404

jor renovation the energy performance of the building or the renovated part thereof is upgraded in order to meet minimum energy performance requirements.

Moreover, the directive implies that the building regulations for both new construction and renovation may get higher requirements within the next years. This means that products, services and processes for low energy buildings for the construction and building sector must be adapted to the new requirements.

COMPARISON WITH OTHER EUROPEAN COUNTRIES

The EPBD allows for definitions and levels of the energy performance requirements to be set on a national level. As a consequence, the requirements are not only different between the member states, but it is also very difficult to compare the performance levels between the member states, since they are based on different definitions.

Furthermore, the large differences in climate conditions between European countries make the comparison even more difficult. For example, the insulation level of a house in Finland may be much higher than for a house in Italy. Still the energy consumption of the Finnish house may be higher than the Italian house, due to the more severe Finnish climate.

However, all the Nordic countries except for Iceland have implemented the EPBD, and the requirements set for energy efficiency of buildings seem to be among the strictest in Europe. Also, the governments have signaled plans for increasing the energy efficiency requirements in the future, although not all countries have established clear goals.

PROSPECTS FOR A COMMON NORDIC MARKET

It is not easy to compare the building code requirements in kWh/m² between the Nordic countries since all countries have slightly different definitions of included energy, heated area and boundary conditions. Even though the building codes differ, they have a lot of similarities and there are good prospects for inventions of products, services and processes for low energy buildings within a common Nordic market. See, for example, table 1.

DIFFERENT ADVANTAGES WITH THE NORDIC BUILDING CODES

Danish regulations have the advantage that they include two definitions of low energy buildings within the building code. This gives a well-defined way of new construction for the building proprietors that want to go a step ahead. The other advantage with the Danish regulations is that they have announced well in advance when, and how much, the requirements will be strengthened in the future. 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 with new requirements only a year in advance. This also means that the building market has expanded with the introduction of products and materials that comply with the new requirements for low energy buildings.

Norwegian regulations have the advantage that they include all energy use within the building, i.e. energy use for lights and equipment is included. This implies that efficiency measures on lights and appliances are also encouraged. However, this is only possible for lighting energy use, since the values to be used for calculating the appliance energy use are standardized.

Swedish regulations have the advantage that they require verification of energy performance with measurements within two years of operation. This means that quality assurance during the building process will be very important.

Finnish regulations have the advantage that they set requirements of heat load and Swedish regulations have requirements of maximum installed heating power in electrical heated buildings. This is an important regulation that may reduce the need for electrical power from the electrical system in the future.

COOPERATION NEEDS FOR UPGRADING AND IMPLEMENTATION OF CODES

The previous examples of advantages and differences between Nordic building regulations show that the Nordic countries have different knowledge and experiences that would be useful to share between them. A Nordic collaboration is therefore likely to be beneficial.

Table 1. Definitions for total or primary energy demand including weighting factors.

	Total (primary) energy demand [kWh/m²]
Denmark	The total primary energy demand of the building for supplied energy for heating, ventilation, cooling, domestic hot water and, for non-residential buildings, lighting. The limit is expressed as follows (as at 1.1.2011): Dwellings: (52.5+1650/A) kWh/m² per annum, Other buildings: (71.3+1650/A) kWh/m² per annum, where A is the heated floor area in m² 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. (Contains requirements on specific technical performance (U-values and air tightness).)
Iceland	No requirements (Contains requirements on specific technical performance (U-values and air tightness).)
Norway	Total energy demand: Separate requirements for 13 different building categories, calculated with Oslo climate and standardized use. Examples: One family house: 125 kWh/m² per annum + 1600/m² heated floor area, Apartment building: 120 kWh/m² per annum. 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	Delivered energy excluding household appliances (kWh/m² per annum). Dwellings: Southern Sweden. 110; Central Sweden 130; Northern Sweden 150 Premises: Southern Sweden. 100; Central Sweden 120; Northern Sweden 140 All buildings heated with electricity: Southern Sweden. 55; Central Sweden 75; Northern Sweden 95. Solar thermal or photovoltaic systems placed on the building site are not included in the energy performance requirements.

The recast of the EPBD implies that all new buildings must be "nearly zero energy buildings" by the end of 2020. The national building codes will be affected extensively in the future by the requirements within the recast of the EPBD. Furthermore, there is still an urgent need to plan for the necessary upgrading of the existing building stock. Building regulations are in their infancy for renovation in all Nordic countries.

Cooperation between the Nordic countries will facilitate the implementation of these new requirements. Thereby the development and introduction of products, services and processes for low energy buildings would be strengthened, which in turn may strengthen both the Nordic internal market as well as the export market.

Overview of incentives

Besides codes and regulations, several incentives may be used with the purpose of getting the construction and building sector to voluntarily speed up the implementation of low energy buildings. Incentives address a specific target group to voluntarily focus on, take actions, or perform measures with a specific purpose.

The section gives a brief overview of environmental and energy assessment methods for buildings. The overview also includes financial deals that support energy efficient buildings. The purpose is to illustrate possibilities for experience exchange that would be beneficial between the countries.

ENVIRONMENTAL AND ENERGY ASSESSMENT METHODS WORLD WIDE

There are innumerable amounts of assessment methods on "the market"; international, national and local methods. A rather large share of these methods focuses mainly on environmental issues, where energy is just one of many issues to pay regard to. But there are also energy assessment methods that have totally focused on energy.

Examples of international environmental assessment methods are BREEAM (UK), SBTool (Canada), Green Star (Australia), LEED (USA), CASBEE (Japan) and DGBN (Germany). Examples of well established energy assessment methods are the Passivhaus standard (Germany) and the Minergie standard (Switzerland). Minergie is an example of a successful voluntary incentive. The Minergie concept has led to dramatically changed performance requirements in the Swiss building code and more than 15,000 certified buildings have been built or planned with very good energy performance. Meanwhile, a great number of buildings in Switzerland have been built with much better energy performance than required according to national building codes, as a non certified spin off effect of Minergie.

ENVIRONMENTAL ASSESSMENT METHODS USED IN NORDIC COUNTRIES

In Finland, an environmental classification system called Promise has been developed for comparison of building performance and for managing environmental life cycle issues in building projects. The system covers environmental loadings, use of natural resources, health of occupants, and environmental risks. However, the system has not been widely used so far.

In Norway, a tool for calculating the greenhouse gas emissions of a building has been introduced (www.klimgassregnskap.no). The tool has so far been used in a few projects, and will be used in all the pilot building projects of the program FutureBuilt (www.futurebuilt.no).

Miljöklassad Byggnad is a Swedish environmental assessment method that has been developed and tested in recent years. The classification covers energy, the indoor environment, and chemical substances in the building. It is now ready to be used and a few buildings have been certified.

The Nordic Swan includes a labelling system for residential buildings, but this has not been widely used in any of the Nordic countries.

The British BREEAM system and the American LEED system are slowly gaining ground in the Nordic countries, but there are several difficulties to adopt them to national conditions. At the moment several projects are ongoing within the different countries in order to interpret the LEED and BREEAM rules for the different national requirements.

ENERGY ASSESSMENT METHODS USED IN NORDIC COUNTRIES

To a minor extent the German Passivhaus certification has been used directly within the Nordic countries. However, there are some difficulties with using the German Passivhaus directly. These difficulties are primarily that the climate conditions within the Nordic countries are different, considering temperatures and solar conditions. The more severe climate conditions in the north makes the requirements set for the German climate very difficult to reach. There are also several differences considering commonly used definitions on, for example, dimensioning, outdoor temperature, and air leakages and also on requirements on ventilation rates. Furthermore, the template values for internal heat from persons and domestic appliances are not directly suitable for Nordic building users.

Sweden, Norway and Finland have therefore made their own national interpretations for a requirement specification of Passive houses. These energy assessment methods have now started to be implemented with certification schemes.

Also the EU assessment method GreenBuilding is gaining ground in Sweden, but the energy requirements are rather weak compared to the other voluntary energy assessment methods.

ENERGY LABELLING SYSTEMS

The Energy Performance of Buildings Directive (EPBD 2002/91/EC) implies that the Nordic countries should have implemented energy labelling systems. All buildings, from very energy efficient to buildings that waste energy, are supposed to get energy labels. The incentives are to get a better score within the labelling system.

Denmark implemented an energy labelling system for all buildings already in 1997. Iceland has decided not to implement an energy labelling system due to their favourable energy supply. In Sweden, the system of energy labelling was implemented from October 1, 2006, for multifamily houses and public premises and from January 1, 2009, for all buildings. In Finland the system was introduced from January 1, 2008, and in Norway from July 1, 2010. Potentially, the energy labelling system may also provide a knowledge base for energy performance measurements and innovations within the building energy sector. However, this requires efforts both from the authorities and from the building industries.

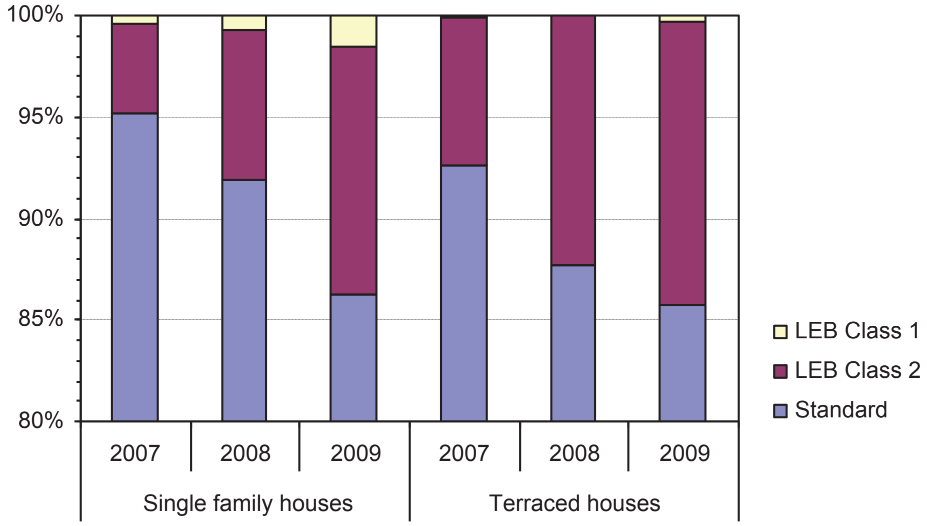


Figure 1. Relative distribution of houses completed in LEB class 1 and 2 in Denmark from 2007–2009.

FINANCIAL INCENTIVES

Financial incentives are generally scarce within the Nordic countries, except for Norway that has had an increased implementation of LEB with instruments from the Norwegian State Housing Bank (NSHB) and Enova. The NSHB has for several years promoted environmental quality in buildings with advantageous loans, grants, and information. Almost half of all new homes financed with the NSHB's basic loan have a special environmental quality.

COOPERATION NEEDS FOR COMMON NORDIC INCENTIVES

Generally speaking, the Nordic countries have been fairly slow to implement voluntary incentives such as energy and/or environmental assessment methods. An earlier and stronger focus on such incentives would most likely have led to a faster market growth for LEBs, as can be seen in for example Germany, Switzerland, and Austria.

Since the Nordic countries have difficulties to directly adopt the successful international assessment methods, it would be advantageous to create a Nordic common voluntary energy and environmental assessment system, that consider more aspects than the labelling systems connected to the EPBD-directive. It should be possible to define LEB while regarding the differences between the building regulations within the Nordic countries. The construction and building sector would definitely benefit from a more harmonized incentive market situation.

Market Shares

This section gives a brief overview of the classification of LEB in the Nordic countries together with an overview of the market share of LEB. Overviews of the market share of LEB in selected European countries are also included. Comparing market shares of LEB in the Nordic countries to lead European countries, the following conclusions may be drawn:

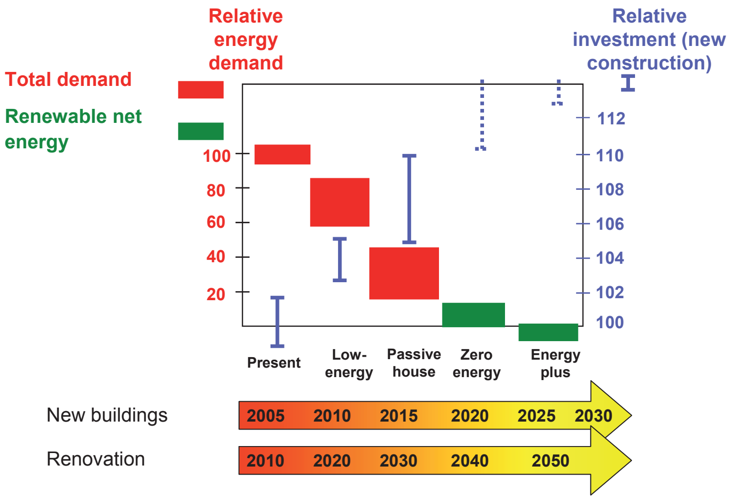
- Although the statistics and verification documentation are insufficient, it seems as if the Nordic countries (except Island) are barely equal European lead countries like Germany and Austria with respect to the deployment of LEB. When it comes to very low energy buildings like passive houses and zero energy houses, the Nordic countries have been well behind the European lead countries but are starting to catch up. Taking the colder Northern climate into account together with the obvious possibilities of collaboration, the Nordic countries ought to be leading countries. The study showed that the Nordic countries would have to improve significantly in order to obtain the position of being leaders in this field.
- One may conclude that both statistics of LEB and verification of actual LEB performance in the Nordic countries are poor. Also, official definitions of LEB have not been available within the Nordic countries (except in Denmark, where there has been a clear definition of LEB within the building code for several years), but are now being established.

DENMARK

In Denmark the term low energy building has been well known since the mid seventies. The current Danish Building Regulations, BR08, defines two low energy performance levels termed Low Energy Class 2 and Low Energy Class 1. Furthermore, together with the implementation in Denmark of the Energy Performance of Buildings Directive (EPBD) in 2006, the existing energy certification scheme was adjusted and the accompanying database containing the energy certificates issued was updated.

Based on the definitions and on combining the Energy Certificates Database and data from Statistics Denmark, the market share of LEB in Denmark is estimated to be about 10 % for single family houses and 5–10 % for each of the categories apartment blocks, offices and educational buildings. Figure 1 shows how the market share of houses in low energy classes 1 and 2 has increased from 2007 to 2009.[9]

9. The figure is based on combining data from the Energy Certificate Database and Statistics Denmark: www.dst.dk/homeuk.aspx



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

Figure 2. Estimated market penetration of passive and very low energy buildings in Finland.

FINLAND

In Finland, a low-energy building was first defined in the early 1990s. Private builders built hundreds of low-energy houses, however, although the interest in low-energy buildings increased, the development was quite slow. Now, the basic requirements of the National Building Code 2010 guide the construction towards low energy buildings. The investment in energy-efficiency is in the range of 2–5 % compared to a standard house of 2010. The Finnish passive or very low-energy house definition has spurred a rapid development and construction of passive house concepts. There are specialized companies that build only passive or very low-energy houses. The City of Helsinki, for example, has ordered that when the building site is located on land owned by the city, all buildings must fulfil at least the requirements of energy label class A.

There are no official statistics on the amount of low energy or passive buildings available, but based on information from various industries, the market share of these buildings is estimated to be between 10 and 20 % of all new housing. The market share is growing steadily.

NORWAY

In Norway, the interest in low energy and passive houses is quite large and several hundred projects are in the planning phase. Also, several hundred low energy buildings have been built, but only a few passive houses.

Currently, low energy and passive house levels are officially defined for dwellings only (NS 3700:2010), but work is underway for establishing a standard for other types of buildings. However, the energy labeling system includes requirements for calculated delivered energy for 13 different building categories. There is no national register of low energy and passive buildings. Estimations of the market share of LEB are therefore subject to substantial uncertainty. Nevertheless, the market share of new LEB is estimated to be about 10 % for residential buildings – both single family houses and apartment blocks – about 8 % for office buildings and less than 1 % for other types of buildings including educational buildings. However, there is virtually no information about the actual (measured) energy consumption of the alleged low energy buildings.

SWEDEN

In Sweden, market introduction of low energy houses and passive houses has been very slow. A few good examples including passive houses were realised around 2000 and 2001, but it was not until 2004 that LEBs were realized at a larger scale.

There have not been clear definitions or certification schemes for either passive houses or low energy houses in Sweden. A Swedish standard with definitions was introduced in 2010, and a certification scheme for passive houses has just launched. Therefore, it is difficult to exactly define the buildings between them. Furthermore, there is currently no national register of low energy and passive buildings. A new study[10] about the market situation shows that the market share of new LEB in 2010 were about 8 % for residential buildings (12 % for apartment blocks) and about 8 % for offices and other types of buildings. In 2010 over 5 % of new apartment blocks were very low energy buildings like passive houses.

ICELAND

In Iceland there are no limitations for the total primary energy demand and therefore no registration of low energy buildings in Iceland exists.

EUROPE

Across Europe low energy buildings are known under several different names. Furthermore, what energy use is included in the definition varies from country to country, and in addition the definitions for passive houses and equivalent concepts are very heterogeneous. According to the Commission's Info-Note on "Low Energy Buildings" of September 2009, more than 12,000 low energy houses have been built in Europe, mostly located in Germany, Austria and Scandinavia. Exact figures are difficult to obtain due to the fact that in most countries there is no national register of low energy buildings.

The statistics regarding passive houses is more developed. It is estimated that in Germany there are about 8 000 passive house dwellings (May 2008) equalling a market share of about 1 %. There are indications, however, that to some extent not all of the houses actually built according to the passive house standard are certified and hence registered as passive houses.

Overview of LEB technologies, solutions, and R&D activities

This section presents an overview of LEB technologies, solutions, and R&D activities, including main topics, examples of pilot building projects, and future needs and trends. The analysis clearly indicates that there are a lot of similarities between the Nordic countries and only a few differences. Below is a summary of the findings.

10. Wahlström et al. (2011): "Marknadsöversikt av uppförda lågenergibyggnader", Lågan rapport 2011:01, februari 2011, www.laganbygg.se.

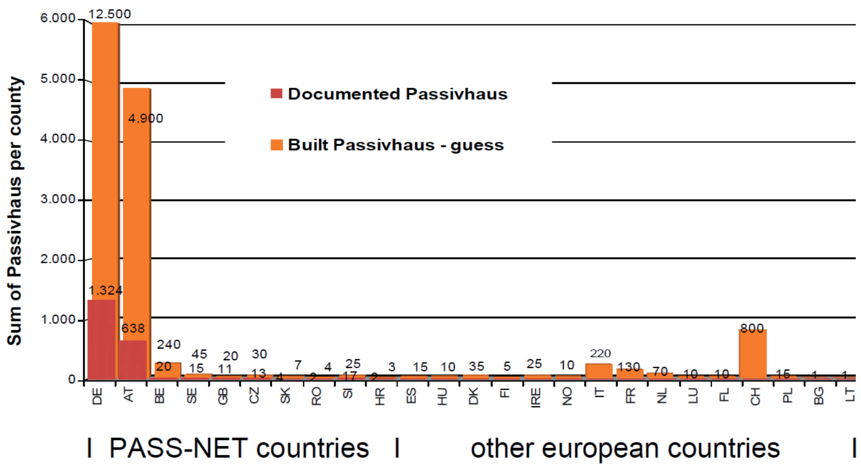


Figure 3. Documented and built – guess – passive houses in Europe. Source: International Passivhaus Database, Establishment of a Co-operation Network of Passive House Promoters (PASS-NET), 1. Period of documentation 2007–2009, http://www.pass-net.net/index.htm.

LEB DEVELOPMENT FOCUS AREAS AND BUSINESS STRONGHOLDS

The following focus areas and business strongholds with respect to LEB technologies and solutions have been identified:

Construction details for air tight and highly insulated building envelopes

This has been a focus area in all the Nordic countries, and has led to the development of new insulation and air tightness products, as well as new construction methods and increased use of verification procedures (blower door tests and thermography). Major market players include Nordic product manufactures, consultants, construction companies and R&D institutes.

Passive house windows and doors

The first Nordic passive house window was produced by a Finnish company in 1994 (with total U-value 0.7 W/m²K). Later, several Nordic passive house windows have been introduced to the market with total U-value down to 0.6 W/m²K. Still, there is a need for further development, in particular of high insulating doors and improvement of the products with respect to thermal insulation, air-tightness, solar and light transmittance, and environmental loadings.

Balanced mechanical ventilation systems with heat recovery

Ventilation systems with high efficiency air-to-air heat recovery units for LEB have been developed by several Nordic companies. In Norway, rotary heat exchangers are the most commonly used in LEB projects, while in Sweden, counter flow systems are more wide spread. In the passive house concept from Germany and Austria, space heating with ventilation air is prevalent. Such systems have been introduced with success in Swedish, Danish and Finnish LEB projects. In Norway, however¸ ventilation space heating has been met with scepticism, due to uncertainties about indoor climate. This shows a need for transfer of experiences between the Nordic countries.

Energy efficient tap water devices

In Sweden, 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. The development is focusing on reducing water consumption while still keeping the end users requirements of comfort.

Heat pumps

Spurred by building regulations and financial incentives, heat pumps have gained a significant market share in all the Nordic countries (except Iceland). This includes all types of heat pumps including air-to-air, air-to-water, and ground/water source systems, ranging from small residential units to large multi building installations. Several Nordic manufacturers exist. Ground source heat pump systems are gaining interest, due to higher reliability and requirements to cover a higher fraction of the heating and cooling loads. Further development and optimization of the systems are needed in order to reduce costs and increase reliability.

Partnering organisation and integrated energy design

Several of the LEB demonstration projects in Sweden have successfully tested a new way of organisation, called partnering. Partnering is a cooperation contract model where the client, construction companies, architects, consultants, and other key actors are solving the assignment together and share the responsibility for achieving the energy and environmental goals. A related concept of cooperation is integrated energy design (IED). In these processes, new computer based tools like advanced energy/environmental tools and Building Information Modelling (BIM) play an important role. Both partnering and IED have been introduced in the other Nordic countries, but have so far not seen wide spread use. Finland seems to be the most advanced on the use of BIM.

Total LEB concepts

The development of total concepts for low energy buildings include taking into account the whole range of challenges related to the realization of successful LEBs; planning and design strategies, integrated energy technologies, building layout, envelope design, and construction, operation and maintenance issues for different types of buildings in different climates and local settings. Financing and life cycle costing, as well as implementa-

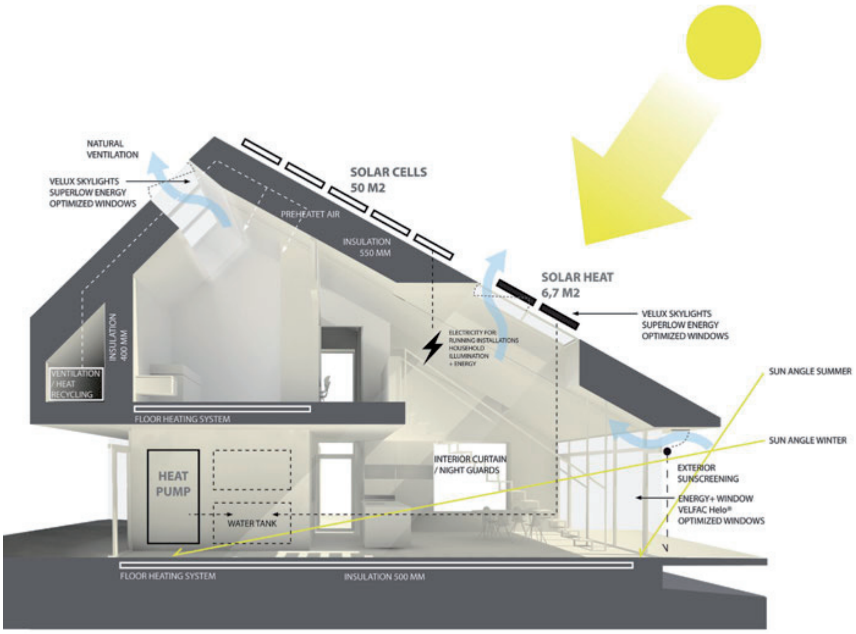


Figure 4. The energy concept of the Danish "House for Life" – an "active house" from Velfac, www.velfac.dk.

Figure 5. Vargbroskolan, Storfors. Example of a low energy building project that has been thoroughly monitored with respect to energy performance. All the different energy uses have been monitored and reported, including space heating, hot water, ventilation fans, pumps, lighting, and appliances. Also the energy production of the PV system has been monitored. The total energy use is less than one third of the requirement of the Swedish building code.

tion strategies are also parts of the concept development. These issues have been part of the activities related to pilot building projects in all the Nordic countries. However, Sweden has worked most extensively in a structured manner with this issue, and has also developed a "total concept for renovation" to LEB standard (BELOK).

Pilot building projects

Several pilot LEB projects have been carried out in the Nordic countries. The projects provide highly valuable testing grounds for new technologies, solutions and strategies. Also, a very important role of the pilot projects is to serve as "success stories" and frontrunners for others to follow and learn from. However, the number of pilot projects is still limited, and only a few of the projects have been thoroughly measured and evaluated with respect to energy performance and user satisfaction. Thus, there is a large need for a coordinated effort to learn from Nordic pilot building projects.

From the analysis it is clear that the Nordic countries have had more or less the same focus and development concerning low/zero energy buildings during recent years. This focus has resulted in the launch of strategic national research and implementation programmes or innovation centres, e.g. Zero Emission Buildings (ZEB.aau.dk) in Denmark, Zero Emission Buildings (ZEB.no) in Norway and LÅGAN (laganbygg.se) in Sweden. The research programmes typically encompasses the national research institutions, universities and governmental institutions along with a broad representation from the building industry (including architectural and engineering companies, developers, construction companies and producers of materials). In conclusion, this demonstrates a strong and unified collaboration of government, researchers and building industry within the Nordic countries towards low/zero energy buildings in the future.

FUTURE R&D NEEDS

The Nordic countries agree on several R&D topics that need to be addressed in order to achieve the future goals concerning low/zero energy buildings:

- Highly insulated building envelope constructions with further reduction of thermal bridges.
- Energy efficient ventilation systems, with high-efficiency heat recovery, and hybrid ventilation systems utilizing thermal storage.
- Integration of combined heat and power systems in the building.

- Energy efficient lighting with focus on developing dynamic façade solutions where daylighting and shading systems are combined.
- Heat pump systems and biomass systems optimised for low loads combined with heat storage systems and other forms of renewable energy sources.
- Passive house windows and balcony doors with reduced transmission heat loss and increased solar gains.
- Increased focus on the users, and developments concerning utility interactive systems, user friendly and efficient energy management systems and research into user cultures and attitudes towards low/zero energy buildings.
- 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.
- District heating net techniques for areas with LEB.
- Combination of different systems such as heat pumps or bio fuel systems with solar energy systems (PV and thermal) 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 energy efficient building products and services systems with low environmental impact in a life cycle perspective.
- Development of complete concepts for construction and renovation of LEB including near zero energy houses concepts.

Overall, a strong Nordic research collaboration concerning the development of new and innovative solutions for future low/zero energy buildings is obvious. Although the Nordic countries may face some individual problems, it is evident that the majority of challenges are common Nordic problems. This indicates a huge potential for reaping mutual benefits from sharing and exchanging knowledge concerning research and experimental projects with focus on energy savings in both new and existing buildings.

Analysis of Market Possibilities and Needs for an Innovation Program

The purpose of this activity was to give an overview of the market possibilities of low energy buildings, both in each Nordic country as well as market possibilities for export mainly inside the EU. The analysis was based on interviews with key persons from selected companies and institutions. The interview questions were mainly framed to highlight business strongholds, barriers and general ideas on how to improve the LEB concept and business. Key persons were interviewed in Denmark, Iceland, Norway, and Sweden, altogether 45 interviews. The key persons represent 11 categories related to the building industry, more exactly:

- Architects
- Consultants
- Construction
- Developers
- Financing institutions
- Building managers
- Knowledge institutes
- Insulation materials, nano-materials, air tightness products
- Windows, glazing
- Solar collector systems
- Photovoltaics
- Heat pumps
- Biomass/gas systems
- Ventilation systems
- Heating and heat recovery systems (wastewater, earth heat exchangers)

The answers to the questions differed depending on background of the key persons. Some general answers are accounted for below.

LEB EXPERIENCES

Most of the respondents are frequently involved in LEB projects. 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. The definition of LEB is generally a bit vague.

The reason for their involvement in LEB projects differ. Several of the respondents mention that they expect higher requirements with respect to LEB from both authorities and the general public. 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 interviewed are probably also reasons why LEB projects are carried out.

R&D EXPERIENCES

Several of the respondents have been involved in R&D projects related to LEB, generally projects that somehow involve optimization of energy performance of buildings, etc.

The projects often involve several national and international partners, ranging from suppliers and producers of products, through architects, developers and consultants, to R&D institutes and universities.

Other examples of R&D experiences were think-tanks, development of internal guidelines on how to build LEB and experience feedback routines from LEB projects.

BARRIERS FOR DEVELOPMENT OF LEB MARKET

The main barriers seem to be *financing and lack of knowledge and competence*. The answers indicate that the first barrier quite often seems to be a result of the second barrier since the

Figure 6. More well documented demonstration projects like the Finnish IEA5 house build in Pietarsaari, is needed, www.vtt.fi.

knowledge and use of life cycle cost analysis (LCC) is very limited within the real estate profession. The aspects mentioned with respect to financial barriers differ depending on country, but lack of long term perspective seems to be a main problem. Many of the interviewed persons claim that this limited perspective is valid for all categories; from financial institutes to proprietors. Several respondents mention that there is a need for stable and predictable financial incentives.

Other barriers often mentioned were:

- Limited amount of information from "success stories". The LEB concept is not marketed enough.
- Structural barriers, e.g. the difficulties in introducing new technologies and solutions to replace well established products, services and infrastructure.
- Reduced accessible floor area (thick walls reduce the area).
- Fear of reduced thermal comfort (mostly when it comes to passive houses).
- Different local environmental policies regarding LEB.
- Lack of "crisis consciousness", i.e. lack of serious commitment to sustainable development.
- The Nordic energy supply system is perceived to be "clean", which reduces the interest in energy efficiency measures.

WHAT A NORDIC INNOVATION PROGRAM SHOULD FOCUS ON

The interview answers gave no unanimous conclusion with respect to what topics a Nordic innovation program should focus on. Nevertheless, several of the respondents mentioned the following topics:

Knowledge exchange

Most of the interviewed claimed that exchange of knowledge among the Nordic countries would be useful. This could be done in several ways, e.g. through a common knowledge platform or through information campaigns targeted at different stakeholders. Knowledge platforms should include participants from industry (producers, consultants, developers, construction companies, etc.), as well as authorities, universities and R&D institutes. The target group of information campaigns may be financial institutes, building owner societies and tenant organizations. Information campaigns should contain knowledge from shining examples (thoroughly investigated).

Education and training

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 profession. Moreover, it would make a good example for the rest of Europe to follow. Bygga Bo Dialogen in Sweden is a good example of national training courses, free of charge, in sustainable building and maintenance (even though it does not contain certification), see: www.byggabodialogen.se.

Evaluation of LEBs in use

This includes structured monitoring and verification of energy performance, indoor environment and user satisfaction. Such reliable information from one or more Nordic countries would be very beneficial for introducing the products in other Nordic countries or similar markets abroad.

Increasing the cost-effectiveness of LEBs

Development of components, products and concepts that are more cost-effective and robust with respect to user behavior.

Common principles for codes, standards, certification and incentives

More Nordic cooperation on developing common principles and requirements for codes, standards, documentation/certification, and incentives. This would make it easier for the Nordic companies to adapt and market their products and services in all Nordic countries.

Efficient solutions for renovation of LEBs

There is a great need to develop effective solutions and incentives for energy-efficient renovation of existing buildings.

Other focus areas mentioned were:

- 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.
- Analysis of the development of the Nordic and European energy market .
- 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.
- Permission for LEB to be built outside the development site (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 LEBs.
- Common local environmental policies regarding LEB.
- Financed (or partly financed) pilot projects for development of technical systems.

ADVANTAGES OF A NORDIC INNOVATION PROGRAM

All of the respondents considered a Nordic innovation program to be useful. Generally, they thought 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.

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 and knowledge exchange among Nordic countries was also mentioned by several, e.g. the benefit of learning from each other. It would also reduce duplication of work and research within the Nordic countries

CONSEQUENCES OF NOT HAVING A NORDIC INNOVATION PROGRAM

Most of the respondents answered that a possible consequence was that the Nordic market and businesses would *develop slower and fall behind*. It would lead to less good performance, slower development, less Nordic cooperation and the Nordic countries would lose the opportunity to be in the frontline.

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.

NECESSARY CONDITIONS FOR INCREASED DEVELOPMENT AND MARKET FOR LEB PRODUCTS AND SERVICES

Many answers here are similar as for – *What a Nordic innovation program should focus on* (see above). However, a lot of the answers here focused on financial support. But the opinion differs a lot depending on country, which makes the answers hard to summarize. One can basically say that an overwhelming majority of the respondents asked for financial subsidies except in Sweden where literally none of the respondents wanted direct subsidy.

Those *in favor of financial subsidies* answered:

- Need for public financial support in the innovation phase, to reduce risk.
- Support should be related to share of 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.
- The economic support mechanisms must be predictable and non-bureaucratic.

As mentioned, the Swedish respondents said they did not want financial subsidies, but if there were they would use them. Anyway, not all of the answers dealt with financial subsidies. Some other answers about necessary conditions included:

- Development of incentives and regulations.
- 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 needs to be developed.
- Developers/buyers/clients must have competence and give specific and concrete energy requirements.
- Nordic information on validated LEB projects. Preferably LEB projects from many different geographical 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.

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 were 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.

Suggestions for main topics for a Nordic innovation program

Based on the findings in the project, the following main focus areas were recommended for the innovation program:

- Analyzing and evaluating principles and experiences with codes, standards and incentives.
- The development of total LEB concepts including evaluation and verification of demonstration buildings with very high energy performance.
- The development and testing of cost-effective technologies for LEBs, especially with respect to high performance envelope technologies and energy supply systems for low loads.

The first focus area would pave the way for a larger common Nordic market, making it easier for exchange of products and solutions across borders. The second focus area would serve as "Nordic leading stars" for developing internal markets, for making the Nordic countries more visible and providing striking power versus the larger mid-European countries, as well as serving as testing ground for new products and solutions (third focus area) for the internal Nordic market and export to other countries.

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