North European Understanding of Zero Energy/Emission Buildings

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ABSTRACT

The worldwide CO_2 emission mitigation efforts, the growing energy resource shortage and the fact that buildings are responsible for a large share of the world's primary energy use drives research towards new building concepts, in particular Zero Energy/Emission Buildings (ZEBs). Unfortunately, the lack of a common understanding for this new type of building results in most countries to have their own, unique approaches. This paper presents the northern (Danish, Finish, Norwegian and Swedish) understanding of ZEBs and gathers together information related to ZEBs in these countries. Generally, we may observe a correlation between the zero energy/emission building approach adopted by a country and this particular country's utility grid characteristics. Moreover, it is to be noted that the ZEB concept is not well defined at the national level in northern Europe and that all of the participating countries are still to adopt a national definition for these types of buildings. This results often in more than one understanding of ZEBs in each country.

This study provides a concise source of information on the north European understanding of zero energy/emission buildings. It puts forward a number of similarities among the four studied approaches while highlighting that each country adopts a slightly different ZEB concept depending on its particular realities. This work may be viewed as a useful input to the coordination of sustainable building research in northern Europe and as a good source of information on different possible approaches towards ZEBs.

Keywords: zero energy building, zero emission building, Nordic countries, requirements, multi-disciplinary.

1. INTRODUCTION

Energy use in the building sector accounts for about 40% of world's final energy use and 33% of direct and indirect greenhouse gas emissions, IEA (2008). This fact together with the issue of climate change and the growing energy resource shortage drive research towards continuous improvement of energy efficiency measures. However, the incremental increase in energy efficiency is not sufficient anymore and new solutions for decreasing building's energy use need to be defined in order to cope with the incessant growth of the world's energy consumption. The concept of ZEBs is a promising solution currently gaining in popularity.

The ZEB concept is not a new idea. Literature exists from 1970's, 80's and 90's which describes zero energy/emission buildings; Esbensen and Korsgaard (1977), Gilijamse (1995). Yet, just a few years ago this concept attracted the attention of a wide international audience and a worldwide discussion began. A number of international and national research programmes started to focus on investigating and implementing the ZEB in the real life i.e.

the IEA SHC Task 40 / ECBCS Annex 52 'Towards Net Zero Energy Solar Buildings (NZEBs)', The Strategic Research Centre on Zero Emission Buildings in Denmark, The Research Centre on Zero Emission Buildings (ZEB) in Norway and Zero Carbon Hub in the United Kingdom. In the April 2010 recast of the Energy Performance of Building Directive (EPBD), the European Parliament and Commission declared that by 31 December 2020 all new buildings must be nearly zero energy buildings, however all public owned new buildings must be nearly zero buildings from 31 December 2018. Within the EPBD recast the nearly energy building is understood:

"(...) *a building that has very high energy performance (...) and the nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site and nearby*".

The European Parliament and the Commission advice the Member States to prepare national plans for increasing the number of nearly zero energy buildings. The national plans should at least include:

- *"A detailed application in practice of the definition of nearly zero energy buildings, reflecting their national, regional or local conditions (...)*
- *intermediate targets for improving the energy performance of new buildings for 2015(..)*
- *information on the policies and financial or other measures undertaken nearly zero energy buildings, including details of national requirements and measures concerning the use of energy from renewable sources in new buildings and existing buildings"*

Despite the numerous international/national actions towards ZEBs and the excitement of the term 'zero', major challenges need to be met in the development of such building concept, in particular in relation to the lack of common understanding. In a number of publications, Torcellini and Crawley (2006), Laustsen (2008), Crawley et al. (2009), Marszal and Heiselberg (2009), authors present the wide variety of ZEB definitions and highlight the significant influence the understanding of the zero energy and/or emission building concept has on design and performance of ZEBs.

This paper presents the Nordic (Danish, Finish, Norwegian and Swedish) understanding of zero energy/emission buildings. It puts forward a number of similarities among the different approaches, while highlighting that each country-specific zero energy/emission building concept deriving from local realities. None of the participating countries have yet adopted an official definition/understanding of ZEB concept. This paper thus focuses on the general trend in each of the countries' different possible approaches.

2. DENMARK

The first zero energy building was build in Denmark already in late 1970's, Esbensen and Korsgaard (1977), however it was just a single demonstration project with no significant influence on the Danish building sector at this time. Moreover, in this project the 'zero' reflects solely the thermal energy consumption (space heating and domestic hot water). The real discussion and the intensive investigation of the zero energy and/or emission building concept started around 2007. The Danish approach is more focus on the zero energy buildings. Firstly, since Denmark has a long tradition in calculating and evaluating the building performance based on the building's energy balance. Secondly, due to the fact that the zero energy buildings are seen as a possibility for increasing the share of renewable energy sources in the national energy infrastructure. Denmark has not yet adopted the national definition for ZEBs concept, however in 2009 the Strategic Research Centre on Zero Emission Buildings was established with the main objective of development the zero energy building concept in the Danish context. The centre is a joint collaboration of two main Danish universities: Aalborg University and Danish Technical University and the key Danish companies in the building and energy sector. The lack of common understanding for the zero energy buildings concept results in unofficial approaches, often assign to a single project. In Denmark two main ZEB demonstration projects with well defined approach towards this building concept exist: *Bolig+* and *Active House 'House for life'*.

2.1 Bolig+ concept

The Bolig+ concept was initiated in connection with the EnergyCamp05 where a number of representatives from different parts of the building sector spent 36 hours to solve the task: *How can we develop energy-efficient housing for the growing world population*. The workshop resulted in the development of a unique and dogmatic approach towards residential zero energy buildings. The five (5) dogmas embrace not only the energy issue but also the indoor climate, flexibility of use and architectural quality. In order to meet the requirements of the Bolig+ concept all 5 dogmas have to be satisfied.

The first dogma is *energy neutral on an annual basis*. It means that the total energy use, including heating, cooling, domestic hot water, ventilation, lighting, household electricity, operational energy etc. is optimized to the local context and the energy purchased from the utility grid is offset by produced renewable energy fed back to the utility grid. This dogma sets additional requirement for the building-grid interaction, in particular that the energy delivered back to the national grid must be at least the same quality and usability as the energy taken from the grid. In other words, you cannot buy heat in the winter time and feed it back in the summer period, since the heat usability is different in summer and winter. Moreover, strict building constraints require the fulfilment of the Danish Building Regulations low energy class 1 without including the electricity production. Since the energy balance also includes the electricity for the households, the Bolig+ consortium stated that this should not exceed 1725 kWh/year per apartment.

The second dogma calls for an *intelligent and user friendly house*. A ZEB should be equipped with intelligent energy control systems that both reduce energy use and improve the indoor climate by using the building services in a smart and optimized manner. The control and the monitoring data systems should be easily accessible for the occupants in order to make them constantly aware of their energy use.

The Bolig+ concept requires that the ZEB is *flexible in daily use and over time*. This third dogma focuses on three different types of flexibility. First and foremost, it refers to the flexibility in the building envelope in a way that the thermal envelope will react and adjust to the building's annual and daily rhythm (variable over the year and/or day energy demands and indoor climate conditions) as well as to the changeable weather conditions. Secondly, it means flexibility in easily adapting the dwellings to the individual and varying needs of diverse user profiles. The different room-requirements of family of 2 adults and 2 children or of an elderly couple should be easily met. Finally, it is important that the building construction ensures flexibility in replacing individual building components without destroying other parts of the building.

The long tradition in Denmark of focusing during the building design on reducing the energy use as well as on providing a healthy indoor environment maintains also in the Bolig+

concept. Therefore, the fourth dogma emphasizes the *good and healthy indoor climate in the house*. The focus is put on the daylight and artificial light, atmospheric indoor climate, indoor temperature, air quality, acoustics and finally on choice of the sustainable and healthy building materials.

The last dogma sets the requirement for *high architectural quality and adaptation to the local context*. It states that the ZEB should be a design in agreement with the surrounding architectural style but at the same time express the period of construction. Moreover, it should satisfy the human expectations to harmony and balance while having an innovative and challenging design. Finally, the ZEB must be constructed from environmentally friendly and low polluting materials that suit the local environment.

2.2 Active house – 'House for life'

The Active house concept is initiated by the industrial investor - VKR Holding with the objective of constructing eight demonstration houses in different European countries. The Active house concept strives to design buildings that are energy efficient and with all energy produced by renewable energy sources and/or supplied from the nearby collective energy system (i.e. local district hearing grid) and electricity grid. Moreover, it should have healthy indoor climate, positive influence on the environment throughout the total life cycle and finally high architectural qualities in agreement with the local context. Furthermore, the Active house concept applies to all types of residential and non-residential new-build and renovated buildings. The initiators of this approach emphasize that in order to design and construct the Active house all the above mentioned parameters should be balanced. The best explanation of the idea behind the concept is Fig.1, where all three elements: energy, indoor climate and environment create a common framework of the Active house vision.

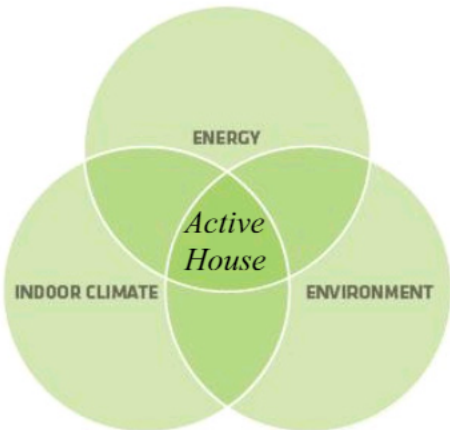

Figure 1. Active house concept. [Active house, 2010]

The first Active house in Denmark the 'Home for life' was built in 2009. Taking the main framework from the Active house concept the working group has moved a step further by designing a plus energy house with the main focus on the comfort of its occupants. The annual renewable energy production surplus should offset within 30-50 years both the energy embodied in the building materials and the energy used for constructing the house. With this approach the 'Home for life' can be seen as a life cycle zero energy building.

2.3 Conclusion

Denmark lacks a national, standardised approach for zero energy buildings. However, two concepts: Bolig+ and Active house can be seen as an initial framework for a future Danish zero energy building definition. Both concepts aim to reach zero energy goal thus put great focus on energy efficiency, healthy indoor climate and architectural qualities. Furthermore, the Danish understanding of a zero energy building concept would probably include one more important aspect; in particular the requirements for the building-grid interaction, since the ZEB buildings are seen in Denmark as a solution for increasing the share of renewable energy in the total national primary energy supply. To conclude Denmark aims to adopt a net zero energy building definition.

3. FINLAND

The Finnish climate and energy policies have two major focus areas. The strategy is to increase the share of renewable and emission free energy in the national primary energy consumption. The national aim is to increase the amount of renewable energy from the present level of 20% up to 38% of the total primary energy by the year 2020. The Finnish climate and energy policies include supply subsidies (e.g. wind power) and a program to substantially increase biomass as the alternative energy source. However, the present government has initiatives to combine the biomass scheme into construction of new nuclear power plants. Furthermore, the Finnish building code will be renewed step vice towards 2020. The main objective is that with a number of intermediate steps, near zero energy house requirements will be set for new buildings in 2020.

There is no commonly agreed definition for a zero energy house in Finland. However, all the zero energy projects utilize the definition of a net zero energy building. Net zero energy building is commonly understood as a building that uses energy from energy grids but at the same time produces energy to be fed into the energy grid. The amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building. A net zero energy building should be based on a very low-energy building concept in order to minimise the energy demand. The low energy demand defines the design of the building integrated renewable energy production systems. There are two important ZEB pilot projects in Finland that follow the above mentioned definition: the IEA5 Solar House in Pietarsaari constructed in 1994 and two twin net zero apartment buildings under construction in Kuopio (latitude 62,9^o) and in Järvenpää (latitude 60,5^o). Moreover, with the second project Finland attempts to verify the possibilities for constructing zero energy buildings at high latitudes.

3.1 IEA5 Solar House, Pietarsaari

The project IEA Task 13 ”Advanced solar low-energy houses”, a part of the Solar heating and cooling programme (SHC) of the International Energy Agency (IEA), aimed at promoting use of solar energy in buildings. The IEA5 Solar house, see Fig. 2, was built at the Pietarsaari housing fair in 1994, Hestnes et al., (1997). The house is a single family house that fulfils the present Finnish passive house and very low-energy houses definitions. The performance of the house has been monitored until the end of 1996 and checked every year since 1996. The results prove that the yearly purchased energy consumption was only 7900 kWh, corresponding to 48 kWh/gross m^2. The average space heating energy consumption was 13 kWh/m^2. The owner of the house is upgrading the building so that it will be a net zero energy building.

The heating system is based on a ground source heat pump with a capacity of 8 kW that is supported by a roof integrated 10 m^2 solar thermal collector system. Heat from the 3 m^3

storage tank is distributed to the rooms with a low-temperature floor heating system. The 48 m^2 photovoltaic system consists of 45 solar panels (amorphous silicon modules) with 2 kWp output power.

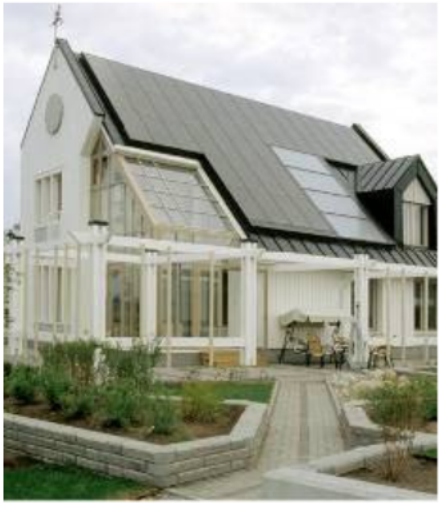

Figure 2. IEA5 Solar House

The upgrading of the building includes refurbishing of the ground source heat pump, ventilation system and the PV system. Table 1 shows the energy balance of the original composition of the house together with the assessed new balance with upgraded systems. The performance of the heat pump has now been tested for a period of some months and shows important increase in the COP (3.5 – 4.0) compared to the original over the year COP of 2.4. The assessment shows that the upgrading improves the performance so that the net zero energy level can be reached. The monitoring system has also been renewed and the performance of the building will be available on-line.

Table 1. Energy balance as built and after renewal (1994 normal/**2010 bold**).

Consumption	Demand kWh/m^2	Produced kWh/m^2	Ground heat kWh/m^2	Purchased energy kWh/m^2
Heating	65/**60**			
- heat pump			27/**30**	20/**12**
- boosting for water heating				6/**6**
- solar heating		12/**12**		
Electricity (household, systems)	33/**25**			
- grid electricity				33/**25**
- solar electricity		11/**43**		-11/**-43**
Total	98/**85**	23/**55**	27/**36**	48/**0**

3.2 Net zero energy buildings in Kuopio and Järvenpää

The buildings serve for the national roadmap towards nearly zero energy buildings referred in the Energy Performance of Buildings Directive under preparation at the EU. The Kuopio building is a student apartment house and the Järvenpää building is a home for elderly people, see Fig. 3. The gross floor area of each building is 2124 m^2. The Kuopio building is located in the dense centre of the City of Kuopio. This location limits the implementation of renewable energy producing technologies to solar thermal panels and solar cells. The Järvenpää building is located in a rather open area at the outskirts of the centre which provide a favourable context to support photovoltaic system by building integrated windmills. At this moment no decision is made on how much of the total electricity demand should be covered by solar electricity production or other renewable technologies and, thus, further studies are needed. Both buildings use district heat and are connected to the local grid. The Kuopio and Järvenpää projects will be finished in 2010 and 2011, respectively.

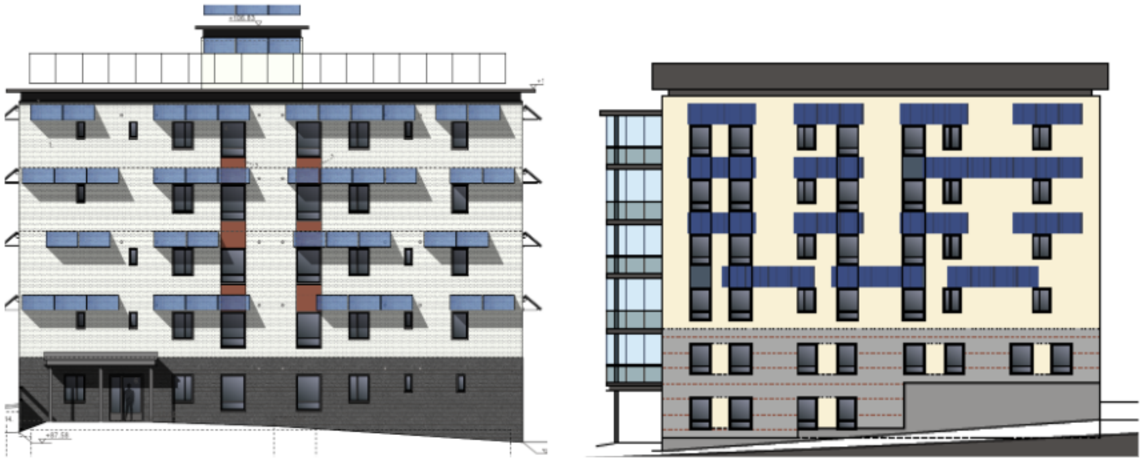

Figure 3. Net zero energy buildings in Kuopio (left) and Järvenpää (right).

Table 2 shows the energy demand of the Kuopio and Järvenpää buildings. It is important to notice that, even if within the Finnish climate conditions the predominant part of the total energy demand in buildings is associated to space heating in those two projects the space heating is not the dominating energy consumption. The major part of the energy use is associated users. Therefore, it is a key issue for achieving the net zero energy level that the occupants are supported and guided in how they should correctly use the building.

Table 2. Energy demands

Energy demand	Space heating	Water heating	Electricity for the systems	Household electricity
	MWh	**MWh**	**MWh**	**MWh**
Järvenpää	18.8	37.8	9.8	28.1
Kuopio	24.5	28.2	11.7	33.1

3.3 Conclusion

The net zero energy building concept is a rather challenging target in the Finnish climate. The approach of nearly zero energy buildings referred in the EPBD under preparation at the EU seems to be more rational for cold climates. The definition implies that the renewable energy can be produced by building integrated energy production or nearby the building. The aim to increase the use of renewable sources by the energy production buildings is generally considered to be the right path towards reduction of fossil fuels and related emissions. In the most cities in Finland combined heat and power production is the dominating source of energy; increasing the share of renewable energy sources in the power and heat generation facilitates will help reaching the ZEB target. This may require the development of a definition for a near zero energy building.

4. NORWAY

Norway is peculiar in ways that influence the local approach to ZEBs. A very large proportion of its electrical production derives from hydropower. The climate is cold and rainy in many locations and, as for Sweden and Finland, large parts of the country are affected by important variations of solar radiation throughout the year. To cope with these realities and promote the development of emission-free buildings, Norway started financing in 2009 The Research Centre on Zero Emission Buildings (hereafter referred to as ZEB-Centre).

Within the ZEB-Centre, work is divided into five (5) focus areas: material technologies, low-energy envelope technologies, energy supply system and services, energy efficient use and operation, concepts and strategies for ZEBs, ZEB-Centre (2009). These focus areas are set up as work packages which are led by experts from various fields, thus highlighting the centre's commitment to a multi-disciplinary approach to the development of ZEBs.[1]

4.1 Sustainability and the United Nation Environmental Programme

The commitment of Norway towards sustainability and the findings of the Intergovernmental Panel on Climate Change (IPCC), Levine *et al.* (2007), are depicted in its approach to ZEBs. While the energy savings and related economical benefits to the development of ZEBs are very well understood, Norway makes reducing the emission of greenhouse gases (GHG) its priority and thus looks at ZEBs as Zero *Emission* Buildings. Furthermore, the approach is meant to encompass a complete life cycle analysis of buildings were mitigation of GHG emissions should take place in the production, operation and demolition phase of buildings.

4.2 A European Approach

Hydropower provides most of Norwegian buildings with a highly renewable mix of energy. In certain countries, reaching a ZEB-status requires only to balance the non-renewable part of the energy consumed by a building during its operational phase, Marszal *et al.* (2010). As such, reaching a ZEB-status in Norway would require balancing only relatively small amounts of energy. In order for a building to reach a ZEB-status over its complete life cycle, aspects related to embodied emissions in materials and the emissions linked to the demolition and end of life should be considered. Norway tends to adopt a broad perspective in which it is understood that the renewable hydroelectricity not consumed by buildings inland may be used to electrify transportation and off-shore installations or may be exported, thus indirectly reducing GHG emissions. Consequently, Norway is to evaluate its buildings' emission footprint based on the European electricity mix, resulting in a more stringent zero-emission target. Doing so, Norway highlights the importance of looking at the European grid as one entity, ease the comparison of European ZEBs and aim at reducing emissions globally, thus tackling climate change from a global perspective.

4.3 A Norwegian approach

The Norwegian approach puts a strong emphasis on the high level of energy efficiency required for a building to reach the ZEB-status. Based on the IPCC findings, improving energy efficiency is the most effective option to mitigate GHG emissions in the building sector. Energy efficiency is part of a larger set of requirements which ZEBs should fulfil prior to offsetting their energy consumption from on-site renewable energy production. This

[1] The Research Centre on Zero Emission Buildings (www.zeb.no)

set of requirements deals, among other things, with minimum levels of comfort and indoor atmosphere aspects. Defining requirements for ZEBs will influences the co-benefits associated with these buildings. Out of the six co-benefits identified by the IPCC, Levine *et al.* (2007), three are of special importance within the Norwegian realities: (1) Improved health, quality of life and comfort, (2) improved productivity and (3) employment creation. These co-benefits are important drivers for the adoption of ZEBs by the users, the industry and by the society as a whole and thus a central focus area of the Norwegian approach.

The Norwegian approach also highlights the importance the users play in the energy consumption of building. To that extend, a dedicated work package studies how energy-efficient use and operation of ZEBs may be achieve, notably by understanding user behaviours. It focuses on approaches and processes which are inter-disciplinary and seek to include end-users.

Globally, the ZEB-Centre advocates for an Integrated Design Process (IDP) where the building performance is optimized through an iterative process that involves the most important members of the design team and inputs from the user community. Such design process may help prevent irreversible choices typically made in the early design phase of buildings and which may limit their energy performance.

Due to the slow regeneration of the building stock and in order to efficiently mitigate GHG emissions from the built environment, the ZEB-Centre also deals with finding retrofitting options for existing buildings, ZEB-Centre (2009). Retrofitting of existing building is linked with the development of ZEB as it uses similar technologies to increase energy efficiency in existing buildings, thus indirectly reducing GHG emissions.

Finally, considering the inevitable changes within the energy supply system, different scenarios are looked upon which depict several possible futures in terms of two main uncertainties: technology development and public attitude towards ZEBs. These scenarios are meant to help develop consistent strategies and indirectly influence the definition of ZEBs. A formal definition for ZEBs in Norway is still to be adopted. At the time of writing, a draft proposal including a set of criteria was under review at The Research Centre on Zero Emission Buildings Sartori *et al.* (2010).

4.4 Conclusions

The Norwegian understanding advocates for a global European ZEB-approach in line with the IPCC findings on the mitigation of climate change in the building sector. ZEBs are understood as zero emission buildings and looked upon from a life cycle perspective. The approach to the design of ZEBs is multi-disciplinary, looks into requirements for energy efficiency and understands the importance of co-benefits in the development of ZEBs.

5. SWEDEN

The Swedish environment policy is based on goals defined within sixteen environmental quality objectives adopted by the Swedish Parliament in 1999 and 2005. The goals, that are ecologically sustainable, describe a desired quality and condition of the Swedish environment. In November 2005 the Swedish parliament adopted 72 interim targets to concretize the work towards reaching the goals. One of the interim targets, within the main objective called "A Good Built Environment", applies among others to energy use in buildings Naturvårdsverket (2009):

"Total energy consumption per unit area heated in residential and commercial buildings will decrease, with target reductions of 20% by 2020 and 50% by 2050, compared with consumption in 1995. By 2020 dependence on fossil fuels for the energy used in the built environment sector will be broken, at the same time as there will be a continuous increase in the share of renewable energy."

In order to reach the above mentioned goals Sweden promotes energy efficiency through several projects, mostly supported by the Swedish energy agency - Energimyndigheten. Moreover, the National Board of Housing, Building and Planning - Boverket has gradually sharpened the Swedish building regulations regarding the energy requirements. New building regulations with more strict energy requirements are planned to come in force in 2011, Regeringskansliet (2009). Furthermore, in order to evaluate energy use based on various energy carriers a system based on weighting factors has been proposed in the Swedish Energy Efficiency Inquiry, Regeringskansliet (2008). The system includes local Swedish weighting factors. These weighting factors have not yet been implemented within the Swedish Building regulations.

5.1 Swedish zero energy house

The Swedish government or Boverket has not yet adopted the national understanding of the ZEB concept. However, an organization – FEBY has presented a concept to certify and verify a zero-energy house. It is included in the voluntary criteria for the passive houses in Sweden, FEBY (2009).

The Swedish requirements for a passive house aim to minimize the peak load for space heating in buildings so that the required thermal comfort can be obtained in a rational manner. This is based on the functional definition of the Passive House, namely that the heat should be possible to supply with a distribution of heat through hygiene air flow (Feist, 2005). For the construction of zero energy houses, an additional note states that, on an annual basis the energy use should be less than or equal to the total produced energy and the same weighted energy form factors should be used for both used and generated energy. Unfortunately, there are no known existing buildings within Sweden that fulfill the requirements of above mentioned zero energy house concept. However, there is a single-family house in the south of Sweden, Villa Åkarp, where the constructor/builder states that the house they constructed is plus energy house.

In addition to the voluntary criteria presented above there have also been suggestions for three other definitions of a zero energy house concept, Blomsterberg (2009), in particular: *zero primary energy use, zero energy costs, zero energy emissions*. All of the four above concepts are based on an annual balance.

5.2 Conclusions

There is no official standard for a ZEB-concept in Sweden. The voluntary standard and the published suggestions for ZEB-concepts are all based the annual energy consumption and generation balance. This may in the future cause problems concerning grid interaction due to the fact that zero energy buildings in a Nordic climate possibly will produce most of the energy in the summertime while using more during winter. To address this problem there is a need for a better defined standard, were the use of different energy carriers and the possible imbalance between production and use of energy in time is taken into consideration. The question of the balancing period: year, month, day or hour will be a fundamental issue that will affect the future design of all upcoming ZEB-projects.

Any concept for ZEB should be based on trying to minimize peak loads and ensuring a very low energy demand of the building. A discussion for a national strategy to achieve zero energy buildings until 2020 has only begun in Sweden.

6. CONCLUSIONS

This paper provided an overview of the Nordic (Danish, Finnish, Norwegian and Swedish) understanding of zero energy/emission buildings. Discussion on ZEBs is at a different stage in each country. Denmark and Norway have already established research centers, which focus on ZEBs concept, whereas in Sweden and Finland the ZEB development is in an early stage. However, all four countries have common aims: to adopt a definition which will reduce the energy use in building, and which will include ZEBs in the national strategies for integration of renewable sources. Investigating the best interaction between zero energy/emission buildings and the national energy infrastructure differentiate the Nordic approach from other national understandings.

The Finish, Danish and Swedish understanding of ZEBs are more focused on zero energy buildings, since it is more in line with their utility grid characteristics. Norway due to large share of hydropower in the national grid strives for adopting zero emission buildings concept that is closer to the country's particular realities and the findings of the IPCC.

Although each country's understanding of ZEB concept is unique and very much related to each specific national context, they all have common features. Firstly, all countries emphasize the importance of energy efficiency measures before the integration of on-site energy production technologies. By adopting such requirement the countries want to eliminate low-quality ZEBs with high energy use and oversized on-site energy producing systems. Secondly, most of the ZEB approaches agree upon the significant influence of the occupants on the energy use in buildings. Therefore, it is a key issue to develop a ZEB definition that aims for user-friendly buildings. Finally, all different understandings highlight that ZEB concepts should focus on energy issues as well as on a good and healthy indoor climate, thus meeting the energy requirements should be balanced with an acceptable indoor environment.

The concept of zero energy/emission building is a challenging target especially for the Nordic countries in which cold climates and large variations in solar radiation need to be dealt with. However, this paper indicates that Denmark, Finland, Norway and Sweden do make efforts to bring the concept into the reality.

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