# Active Houses – development of carbon neutral buildings with healthy indoor comfort

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## Abstract

The European Commission and the European Parliament are calling for national strategies for low to zero carbon housing in their proposal for a revision of the EPBD[1]; the European Commission is also recommending to include application of renewable energy sources, use of passive heating and cooling elements and shading in the design of the building and to ensure indoor air quality and adequate natural light in buildings.

A few Member States have already initiated targets on low energy housing[2], and there are several demonstration projects showing how future housing could be both zero carbon buildings and have a high indoor comfort level.

The European and national strategies for low energy housing must focus on energy efficiency and $CO_2$ reductions, but as people spend approximately 90% of their life inside buildings, future housing also needs to be developed with a focus on healthy indoor comfort.

The different national standards for low energy housing have mainly been focusing on energy savings, but some new standards also focus on energy saving in combination with indoor comfort requirements, like the "Sustainable Home standard" and BOLIG+.

At the same time the German energy legislation and the EU Renewable Energy Directive[3] are setting requirements to integrate a proportion of renewable energy into all new buildings and buildings undergoing major renovation, while others like France and England have targets to move towards energy producing houses.

Therefore, a new approach, where energy efficiency, indoor climate and integration of renewable energy are included, is needed. A number of partners from the construction sector have initiated the first thoughts and, as they intend to move from passive systems to active systems, the network is named Active Houses.

## Introduction

In the industrial countries approximately 40% of the energy used is used in buildings. The energy is used for heating, ventilation, hot water, lighting and appliances. In order to reduce the amount of energy for all the different energy using facilities an approach is needed where one will look at buildings from an overall level.

The European Union has started this approach by the Energy Performance of Building Directive (EPBD) from 2002, where the required calculation methodology takes into consideration the above excluding appliances. The Member States have followed up and included energy performance calculations in their energy legislation.

Also the new EU directive on renewable energy sets requirements for buildings as it requires that all Member States shall include a proportion of renewable energy for heating and cooling in all new buildings and buildings undergoing major renovation.

Through an overall approach where one should both focus on energy efficiency for all kinds of energy in the building and where the integration of renewable energy is optimized, one

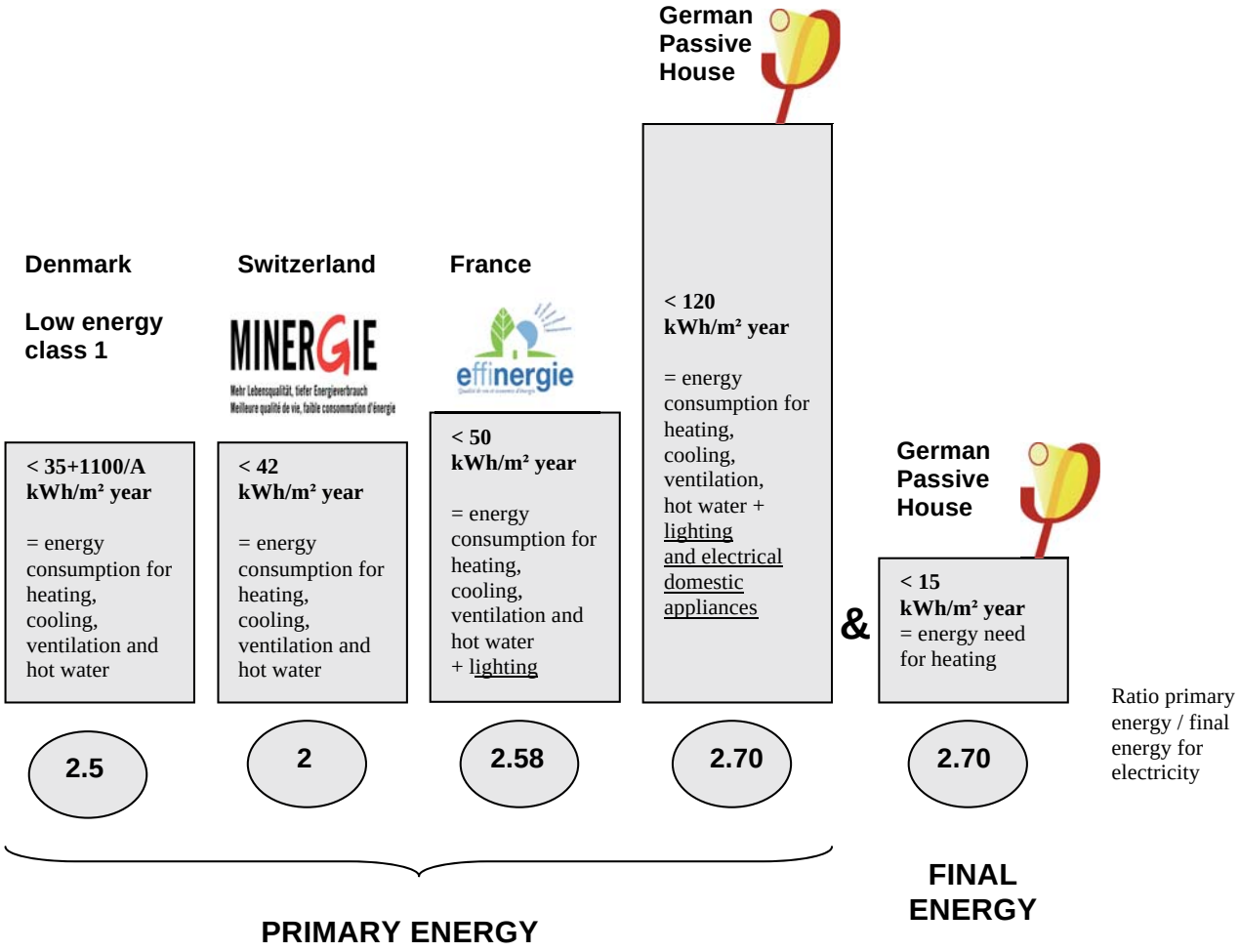


*Figure 1. Examples of national definitions for low energy buildings in DK, Switzerland, France and Germany. Source: EuroACE*

will have the possibility of reducing the carbon emissions from buildings and securing the energy supply.

Another main focus area for new buildings is the overall architectural design of the buildings. In the northern parts of the world we spend approximately 90% of our time indoors. A recent UK study shows that 30% of the existing building stock has very poor indoor comfort that creates illnesses like asthma, allergies, depressions and so on.

The proposal is for a recast of the EPBD focus on the above problems, among others through the requirement to secure indoor air quality and adequate natural light in buildings. As buildings are designed for people to work, live and stay in, it is extremely important that buildings are designed with focus on the indoor comfort. Therefore legislators and authorities should strengthen their use of legislation to ensure that the building stock becomes healthy for humans.

## National low energy housing standards

The first low energy houses and "passive houses" were developed in the mid 1990s as demonstration projects and today we have well known standards for those kinds of houses with more than 9,000 around Europe. However, in the past these standards focused on energy for heating while the other energy uses in buildings had second priority. Further considerations such as indoor comfort and liveability were not included in these standards.

In Switzerland the standard "Minergie" was one of the first that moved the main focus from heating only to include also energy for ventilation, installations and hot water. Through national support schemes the "Minergie" standard has been used for several new houses and there is much experience with those kinds of houses in Switzerland. The "Minergie" standard has, due to the focus on the overall energy use in buildings, been used as references in national legislation and also as inspiration for other countries.

Some countries have set requirements to very low energy standards in their legislation, like Denmark with two low energy classes in the Building Regulations since 2005.

In France a new standard for housing "Effinergie" has been developed by local communities, research institutes and representatives from the construction sector. The standard focuses on the overall energy use in the building including heating, cooling, ventilation, lighting and hot water. Energy for lighting becomes part of the overall use of energy, opening the possibility to save energy by utilizing natural daylight. "Effinergie" sets the maximum requirement for use of primary energy at 50 kWh/m$^2$ which makes it the most ambitious low energy housing standard in Europe at this time. "Effinergie" will be-

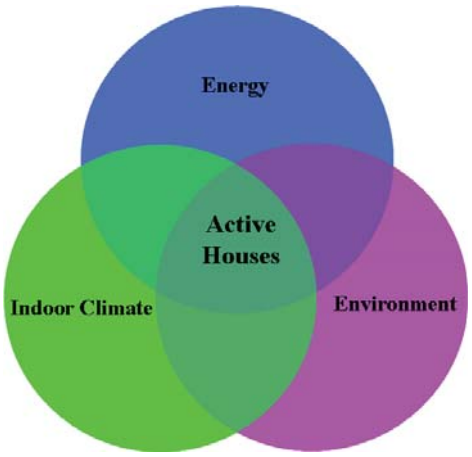


*Figure 2. Illustration of Active Housing*

come compulsory for new buildings in the energy regulation 'RT 2012'.

A recently developed standard in the UK is the standard for "Sustainable Homes"[4], where the focus has been widened further. The standard focuses on overall use of energy in buildings including energy for heating, ventilation, hot water and lighting. It also focuses on indoor comfort, access to fresh air and requirements for adequate natural lightning and the choice of materials. The new focus on indoor comfort makes "Sustainable Homes" a new kind of standard where one also sets requirements that ensure health and sustainability in buildings. The first demonstration projects have been built in England[5] and increasingly stringent levels of the standard will be adopted as the minimum standard for new dwellings over the next eight years with the requirement that all new buildings shall be of the best "Sustainable Home" class from 2016.

Other voluntary standards are being developed, like the Danish BOLIG+ standard requiring that the building shall be energy neutral including energy for heating, hot water, ventilation and also including appliances. Other requirements like healthy indoor climate, intelligent and flexible solutions for control of the building are also included.

Within sustainable design a large number of standards are also developed, like BREEAM, CASBEE, LEED, Total Quality Tool etc. and very recently - and probably most detailed – the German "Gütesiegel für Nachhaltiges Bauen" that also have a broader approach incl. indoor comfort, lighting etc.; nevertheless all these standards mainly focus on materials and fail to focus on energy consumption.

The above is showing a development from focus on energy for heating in the past towards a more comprehensvie approach. The next natural step would be to develop a new standard that includes energy design, renewable energy and indoor climate, and a standard that can be the future requirement in legislation in 2020, where several countries expect to have a requirement for zero energy houses or carbon neutral housing, as the Commission is already asking the Member States to consider a strategy for this.

## Active houses – a new standard

Some countries have set political targets to reach energy producing houses by 2020[6], and voluntary standards for energy producing houses are under development[7].

Future buildings, therefore, need to move from low/zero energy to become energy producing. However, the legislators should remember not only to focus on the energy design of the building, they should also focus on human health and indoor climate.

To ensure that the focus is widened from energy to include human health, a number of international stakeholders[8] have initiated a network called "ACTIVE HOUSES" in order to develop the new housing standard where there is a balance between energy design, indoor climate and environment.

### ENERGY

Some of the most important criteria for the energy design of "ACTIVE HOUSES" are to strive for climate neutrality through energy design.

The orientation and shape of the building have an important influence on the use of energy for heating and each building needs to be optimized with focus on orientation, shape, utilization of passive systems for heating (windows) and cooling (shading and natural ventilation). The use of a dynamic and flexible envelope can reduce the heat transmission during night and winter, while the dynamic solutions can be used to reduce the need for cooling during the day and summer period. A recent CSTB study shows that dynamic windows[9] can reduce the need of energy in buildings in southern Europe[10] significantly.

The user behaviour has a large influence on the energy used in the building and intelligent systems that manage the heating system, the ventilation system, the flexible and dynamic facades, as well as the use of electricity for lighting can reduce the overall use of energy. Several solutions for intelligent control of the building are available today and more will come in the future.

The ventilation of the building must be based on hybrid ventilation where heat recovery is used for winter conditions and natural ventilation for summer conditions.

The energy designs include integration of renewable energy sources, which as a minimum should cover the need for heating, hot water, ventilation and installed appliances. The renewable energy can be integrated with external supply, but must over a year balance the energy needed in the building.

### INDOOR CLIMATE

The main criteria for indoor climate include maximized natural daylight and access to fresh air, maximized to ensure the health and well-being of the residents.

The daylight levels must be documented and demonstrate the energy savings potential for electric light. Windows must have a configuration mix of low positions for view and high positions for best illumination. The house should be treated as a daylight luminaire with the best possible transition so that the daylight will be graduated and spread around the room without creating glare and hard contrasts and with maximized internal reflection on walls and floors. Walls and floors should be in light diffusing colours to maximize internal reflection.

Healthy indoor climate and indoor comfort are to be documented. The houses are built for living, so indoor comfort will be subjected to both scientific measurement and subjective human assessment.

Acoustic parameters should achieve maximum noise reduction.

Automatic control of natural ventilation - a strategy must be defined for automatic control of natural ventilation, based on the difference between temperatures indoors and outdoors. Mechanical ventilation may not be used as primary source of fresh air, but may be used as support/backup for natural ventilation. Openable windows should be used and placed in low and high positions to take maximum advantage of the stack effect in the same zone (under sloping roof/high ceilings).

#### ENVIRONMENT

An "Active House" is designed with with focus on the local conditions and local climate. The design parameter takes into considerations local traditions, local materials and local energy supply systems.

The building should use sound materials with a long lifetime and of a composition that allows different materials to work together. The cost of each house must be calculated using life cycle techniques.

## Demonstration projects

A few demonstration projects that indicate how an Active House could be designed have been developed.

#### SOLTAG

One of the first projects was the Danish SOLTAG[11] that was developed within the international project "Demo houses" under the European Commission's 6th Framework Programme. The purpose of the project "Demo houses" is to show how the existing building stock can be renovated and SOLTAG is developed as a new top storey apartment that can be placed on top of an existing building with a flat roof.

The energy needed for heating, cooling, ventilation and domestic hot water is 60 kWh/m$^2$ which is produced by solar thermal energy in combination with heat pumps driven by Photovoltaic. Thereby the primary energy for the building becomes 0 kWh/year.

#### HOUSE FOR LIVING

Another project is "Houses for living"[12], developed by a number of international construction manufacturers. This house has a very low energy need for heating and hot water, totalling 40 kWh/m$^2$, and all the energy needed is produced by integration of renewable energy like solar thermal and the use of a combination of solar driven heat pump. Thereby the primary energy need becomes 0 kWh/year.

As a surplus to the normal view on primary energy, the amount of photo voltaic is designed to produce electricity for lighting, technical installations and appliances, which is approximately 13 kWh/m$^2$. Thereby the house is not only energy neutral on primary energy for heating, ventilatrion and hot water, but energy neutral for all the energy used in the house.

A very important topic is that the house has been developed with a focus on indoor comfort with large window areas that are strategically placed in order to create very good daylight conditions that will then save energy for lighting. The façade can be shaded and in this way the indoor comfort becomes very good both in summer and winter.

#### SOLAR-ACTIVE HOUSE

Also in Austria where the first developments of very low energy housing were made, a number of Active Houses projects are under development.

One is the "Solar-active house"[13] designed by one of the main leaders within solar architecture in Austria, Mr. Georg W. Reinberg[14], who in the design has focused on development of a "Solar-active house" where the energy required for heating and domestic hot water is fully supplied by solar thermal and heat pumps, while photovoltaics produce the electricity needed for lighting and technical installations. All together Georg W. Reinberg has developed a house with zero costs for heating and no $CO_2$ emissions.

The design of the house also focuses on the materials used and their influence on $CO_2$ emissions, and the materials chosen have been evaluated regarding the possibility for recycling in order to reduce the environmental foot print.

To secure a nice and healthy indoor climate, the façade has been designed with large window areas allowing as much daylight as possible into the building and utilization of passive solar energy. For summer conditions the building is shaded to ensure good thermal comfort, and natural ventilation is optimized through the strategic placement of the windows. Due to the optimal design there is no risk of overheating during the summer.

#### BOLIG+

A number of organisations within the construction sector in Denmark have developed a new standard for housing, "BOLIG+"[15], with a vision to develop energy neutral houses with healthy and good indoor climate.

"BOLIG+" houses only need the energy that they can produce themselves from renewable energy sources. Due to an optimal design the amount of energy required for heating, domestic hot water, lighting and appliances is very limited.

Five dogmas have been identified and have to be fulfilled in order to be allowed to define the house as a "BOLIG+" house.

- The house must be energy neutral over one year, including energy for appliances
- Intelligent control systems shall be integrated
- Flexible design that can change the building's energy performance during the day/night, summer/winter shall be integrated
- Healthy indoor climate shall be proven
- The design shall fit into the local context regarding architectural design and energy design

The first "BOLIG+" building will be designed as a multi-storey building in Aalborg and 5 project teams have qualified to participate in a project competition during spring 2009.

### FUTURE DEVELOPMENT

With the above projects the industry has shown how energy producing houses can be developed. The projects can be used to show how the future requirement for new buildings could be developed and it is now a question for legislators and authorities to develop legislation that will secure that future housing will be active houses with their focus on energy design as well as healthy indoor comfort.

The network "Active Houses" will continually work on and with these developments towards the new minimum standards required for 2020.

## Discussion

The European Commission has suggested that all Member States should have a strategy towards low or zero carbon houses, and the Commission will work to develop a methodology for and a definition of those houses. Such a methodology should include energy optimization and integration of renewable energy, but it should also include optimization of the indoor climate and therefore it must be designed with an overall focus, like the "Active Houses".

The construction sector has showed that they are ready to moves towards very low energy buildings and that zero energy buildings can be designed and build. However the experience is still not common experience within the sector and therefore network and knowledge sharing is needed. The "Active Houses" network will work to develop this further network but there is still a need.

One of the most important tasks is to make zero energy/zero carbon buildings standard solutions. In order to do this demonstration projects is needed. Through demonstration projects manufacturers, designers and constructers learn the process, and therefore the development of demonstration projects is needed. Througt the "Active Houses" network new demonstration projects will be developed.

The poster presentation will present the past and future development of low energy housing including the "ACTIVE HOUSES" network. A discussion on how "ACTIVE HOUSES" can be developed to a future housing standard, first as a voluntary standard and later as a part of the national legislation for new housing, will take place.

## Endnotes

1 Proposal for recast of the directive on the energy performance of buildings (11 November 2008).
2 EuroACE report on National European strategies to move towards very low energy buildings
3 2008/0016 (COD) Directive on the promotion of the use of energy from renewable sources
4 Code for Sustainable Homes www.communities.gov.uk
5 Sustainable homes at Building Research Establishment (BRE)
6 Long term targets for housing in the French Grenelle agreement
7 www.boligplus.org
8 www.activehousing.org
9 A dynamic window is a window with integrated shading/shutters, which is automatic operated by an intelligent controlle system that optimize the energy performance
10 Impact of roof window on energy consumption, thermal comfort and daylight conditions in Southern Europe – Nicolas Couillaud ESE/DE/AGE-2008.076R
11 Carbon neutral attic apartments www.soltag.org,
12 Houses for living (Boliger for livet) www.velfac.org
13 Solar Active house www.solar-aktivhaus.com/solaraktivhaus/index.asp
14 www.reinberg.net
15 www.boligplus.org