Active House – a global guideline for NZEB

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Abstracts

The European and Nordic countries has to implement nearly Zero-Energy Buildings for domestic buildings before 31 December 2020, however a common methodology has not been developed by the European commission; leaving the individual countries with their own interpretation of nearly Zero-Energy Buildings (NZEB).

The objective of this paper is to illustrate the possibility for implementation of the Energy Performance of Buildings Directive and development of a methodology for nearly Zero-Energy Buildings and CO_2 neutral building, which at the same time sets high requirement for comfort, environment and sustainable development.

This can be done by focusing on Active House Vision and the use of the Active House specification, based on the combination of the principles Comfort, Energy and Environment. The Active House vision can be a tool for member states in their implementation of nearly Zero-Energy Buildings and tools towards a carbon neutral and sustainable development within buildings.

The paper also gives examples on two Active House projects from Denmark which has been measured and evaluated and the paper proofs that a high indoor comfort level can be reached in low energy housing and nearly zero energy buildings, as long as the requirement for indoor comfort is taken into consideration already in the early design phase as it is done in Active House.

Finally the paper it discuss the need for commissioning and monitoring in nearly zero energy buildings.

Keywords: Design guidelines, Nearly Zero-Energy Buildings, Energy Efficiency, Indoor Comfort, Performance and evaluation, Active House, Active House Radar.

Active House Vision

The background for the development of Active House and an Active House Alliance is the political focus on reduction of CO_2 emissions and the security of supply. The political focus force the construction sector to build very low energy buildings throughout the world and to build Nearly Zero-Energy Buildings in EU member states by the end of 2020. (End of 2018 for public buildings).

As people spend 90% of their time inside buildings, it is also important to focus on human health and the need for ambitious requirements for comfort in the future nearly zero energy buildings.

The global resources are limited and the amount of waste keeps increasing. Therefore an environmental focus is highly needed and it includes more than just traditional LCA analyses of products, it needs to move towards a view on the building and the use of, for example water.

The above encouraged the development of the Active House Vision, which is based on a holistic view on Comfort, Energy and Environment. It is a vision of buildings that create healthier and more comfortable lives for their occupants without impacting negatively on the climate – moving us towards a cleaner, healthier and safer world. **Fig 1.**

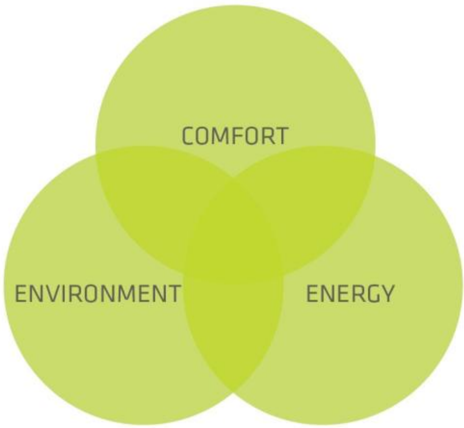


Figure 1: The Active House Vision

The Active House Alliance

The Active House Alliance is an alliance with representatives from the whole supply chain for the construction sector. The alliance focus on the development of future sustainable buildings worldwide and it includes activities like demonstration projects, specifications and tools for evaluation of buildings.

One of the main positions of the alliance is that sustainability has to be integrated into the design of the building already at the start of a project, from the first meeting between the investor, client and the architects. It is in this phase that one can optimize the building without much higher costs than for standard solutions. The design and construction process of buildings also includes involvement of engineers and builders and these sectors are extremely important to include early in the process for the development of sustainable buildings. It is also important to involve manufactures into the process as early as possible as manufacturers have knowledge about use of their solutions and how to integrate these in a sustainable design process. Such knowledge includes a wide range of technologies from bricks, insulation materials, glass, to solutions based on use of natural ventilation, daylight, shading and renewable energy integrated in the design, and technical systems, including the management and intelligent control of the building.

Another position of the alliance is that the knowledge gained from the many demonstration projects throughout the world, from Active Houses as well as other visions, need to be gathered and shared within the construction sector. Several universities participated in the establishment of the alliance and therefore the alliance also focuses on development of the national and international network with and between institutes, universities and branch organizations.

Active House Specifications

Members of the Active House Alliance and other experts have participated in the development of the Active House Specification. They have shared knowledge, experiences and feedback on their experience with development of energy efficient sustainable buildings, in order to develop this second edition. The new edition has been substantially improved, especially in terms of usability.

An Active House is evaluated on all together 9 parameters (Daylight, Thermal comfort, Indoor air quality, Energy demand, Renewable energy, Annual primary energy, Environmental load, Freshwater consumption and Sustainable construction) within the three main principles of Comfort, Energy and Environment. The performance can be described through the Active House Radar **Fig 2** showing the level of ambition of each of the three main Active House principles and the 9 parameters.

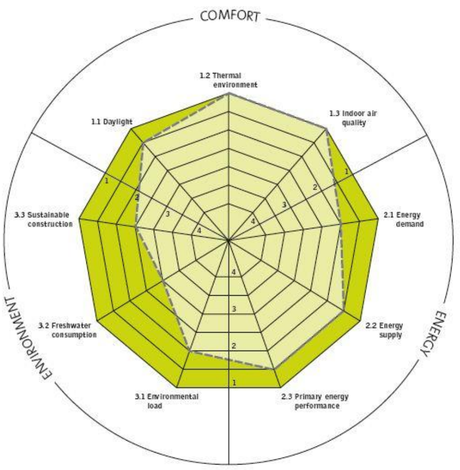


Figure 2: Active House Radar

The integration of each parameter describes the level of ambition of how 'active' the building has become. For a building to be considered as an Active House, the level of ambition can be quantified into four levels where 1 is the highest level and 4 is the lowest. The ambitious requirement for Active House includes all nine parameters and recommends the lowest level for each of them. As long as the parameters are better than or equal to the lowest level of ambition, it is an Active House within the specific parameter.

The active house specifications are available from www.activehouse.info, where they can be downloaded for free.

Experience from existing projects

The Active House specification is based on national conditions and climate and can be used throughout the world. Experience from a number of European and international projects are gathered and presented by members of the Active House Alliance, including projects under very cold climate in Norway, Russia and Canada, as well as project under central European and American climate.

In the following chapter this paper focus on the experience and learnings from two Active House projects in Denmark where the use of energy and the indoor comfort in the buildings has been monitored over a period of one year.

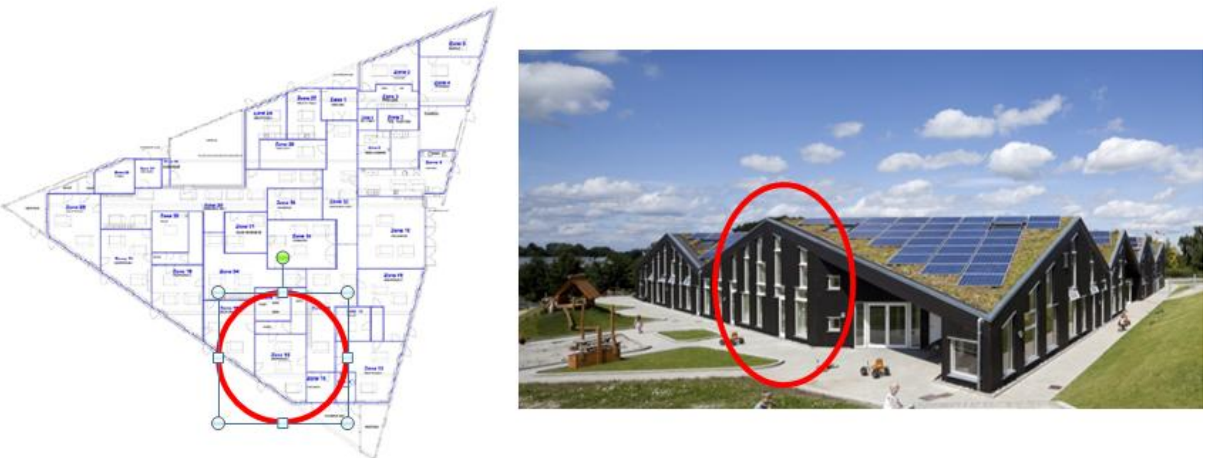
Solhuset - Lions Active House

Childcare centers and schools have a particular need for a good and healthy indoor climate as it strengthens wellbeing and learning capacity as well as reduces the risk of diseases.

Solhuset, Photo by Adam Mørk

Solhuset (Sunhouse) is a 1300 m^2 integrated childcare centre with 100 children and 30 employees. The vision was to set new standards for future sustainable childcare centres. It rests on the Active House principles of buildings that give more than they take – to the children, adults, environment, and surroundings. Solhuset is showing the way; it has the framework for a healthy indoor climate where children learn to live in harmony with nature and without negative impact on the environment.

Solhuset was designed in 2010-11 in a strategic partnership between Hørsholm Municipality, VKR Holding A/S and Lions Børnehuse, and designed by Rambøll A/S and the architects: Christensen & co arkitekter a/s, who also designed Denmark's first CO_2 neutral public building Green Light House, also designed according to the Active House Principles.



Figur 3 Monitoring zones for Solhuset, exposed room for the paper

The rooms which are most exposed for passive solar energy and thereby also overheating during the summer period has been equipped with automatic external solar shading and strategically placed windows allowing for natural ventilation.

The use of energy and the indoor comfort has been measured over a period of one year, and each room has been measured individually given hourly data for temperature and CO_2 level. The individual measurement of each room also allow for individual control of the room, depending on the use of the room and the amount of children using the room.

Comfort

Solhuset has been designed with high ambitions to create a healthy and comfortable indoor climate with plenty of daylight and access to fresh air. It has high-ceilinged rooms and strategically placed windows to ensure optimum use of daylight.

Daylight:
The daylight conditions has been evaluated with daylight simulation tools and has thereby reached a daylight factor of 7% in living rooms and up to 4% in the innermost part of the rooms – even with a window area of only 28% of the floor area.

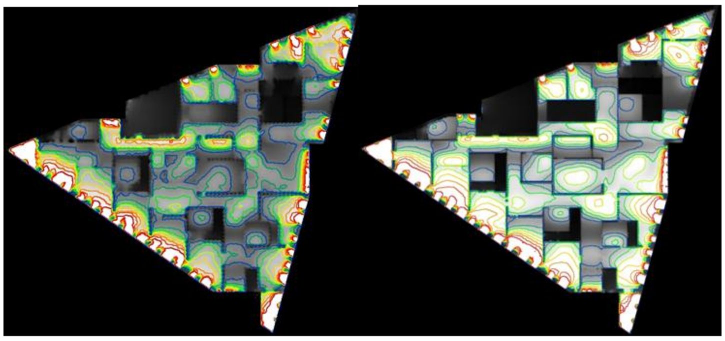


Figure 4: Daylight condition before and after evaluation

The large daylight factor gives a very good indoor climate for the children to learn and play in, and at the same time it reduces the need for electricity for lighting

Indoor Comfort temperature:
The building is designed without air-condition system and the indoor comfort temperature is controlled by use of automatically controlled external solar shading and natural ventilation.

The automatically controlled shading and ventilation optimize the indoor temperature during winter and summer and the temperature can easily be kept at a good comfort level as showed below in group room 5, which is a room exposed for south and south west sun, se fig 3.

The Active House specification classifies the thermal comfort temperature into 4 levels, which is based on the adaptive method equal to EN15251. The diagram (fig 5) shows that even during the hottest time of the year, the thermal comfort temperature is in the best class, whereas the thermal comfort temperature in winter period looks to be lower than recommended.

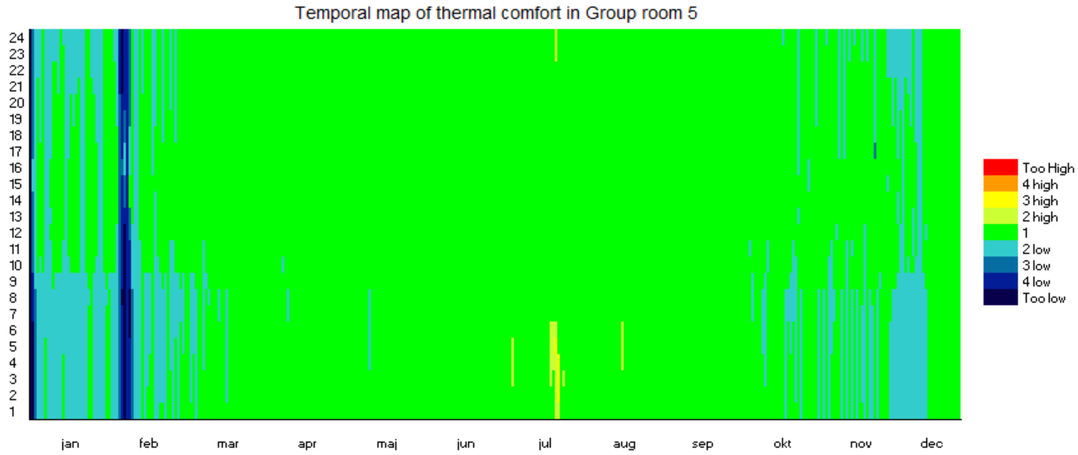


Figure 5 Indoor thermal comfort in group room 5

Graphical presentation of the measured data above is reported by using a temporal map, which is a map with the day of the year mapped along the X axis and the time of day along the Y axis.

The lower temperature can be due to opened windows or due to the ventilation or heating system. Therefore it is relevant to look into the use of the buildings and as it has been registered when the windows has been opened, one can easily identify the problem.

If the indoor temperature is to low and the window is open at the same time, it will be shown with red in the below figure. If the window is closed and it is the heating and ventilation system that cannot deliver the needed heat, the below figure will be orange. The figure shows that the lower temperature is due to insufficient heating and ventilation system.

The green dots in the below figure below also shows that the windows are used to keep the building cooled by ventilative cooling during and thereby keeping the indoor comfort temperature in the best category in spring, summer, and autumn, whereas they are closed during the winter, where the mechanical ventilation is in place.

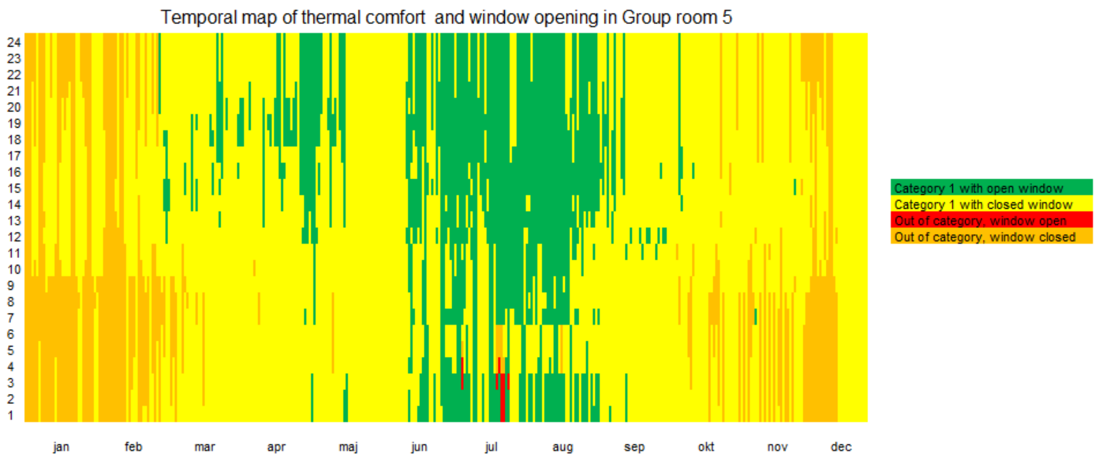


Figure 6 Indoor thermal comfort and use of windows for ventilative cooling in group room 5

Indoor Air Quality:
The indoor air quality is also managed by hybrid ventilation, where automatically controlled natural ventilation for spring, summer and autumn are prioritized, supplemented with a mechanical ventilation system for with heat recovery for the winter period.

Active House specifies the indoor CO_2 level in 4 categories following the principles in EN 15251. The CO_2 level equals the best category which is 500 PPM above outdoor conditions during the summer, where natural ventilation is used, whereas the CO_2 level only reaches the second best class in periods with mechanical ventilation.

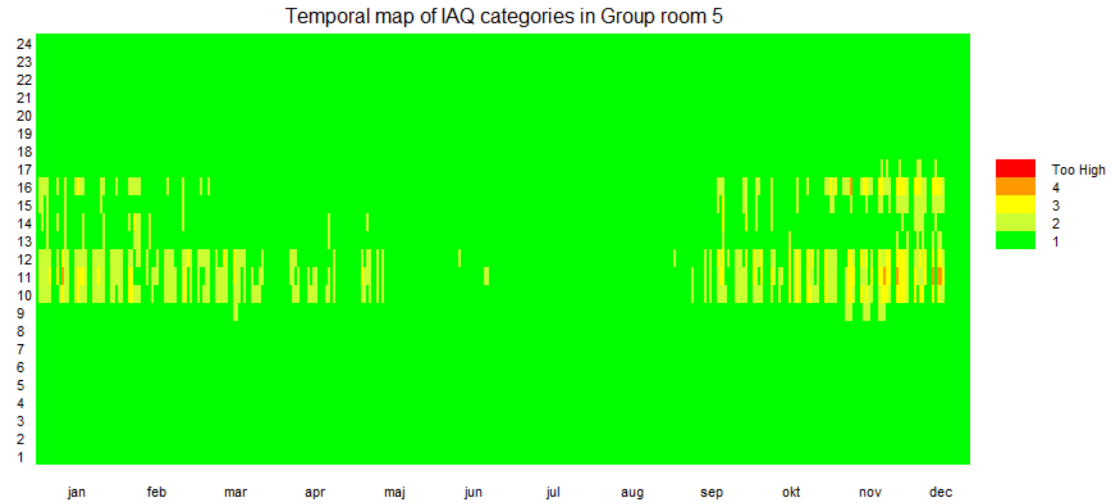


Figure 7 Indoor air quality in group room 5

Analyses of the use of the windows shows that the CO_2 level are kept low with natural ventilation in place, whereas the higher indoor CO_2 levels occurs when the mechanical ventilation is in place.

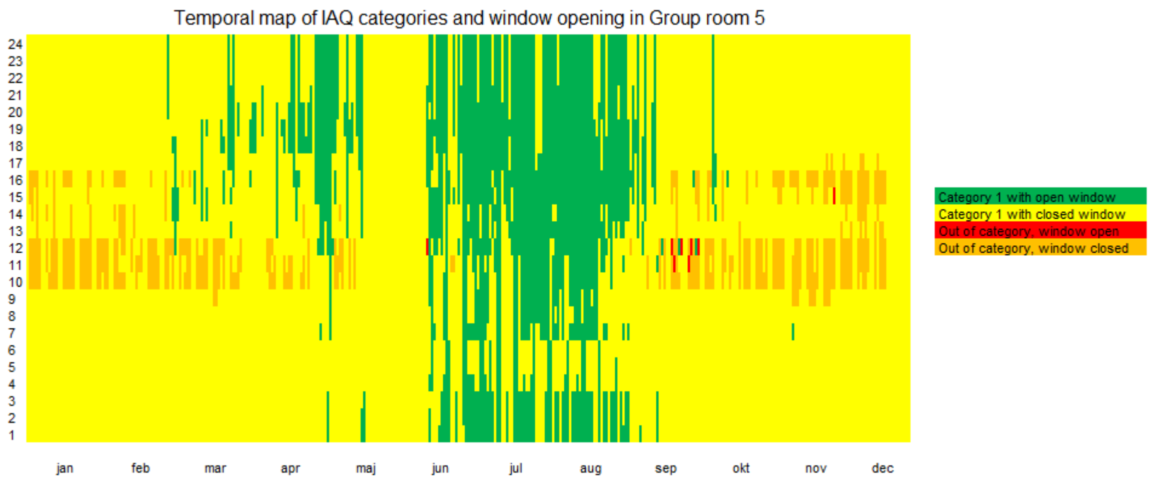


Figure 8 Indoor Air Quality and use of windows for ventilation in group room 5

Energy

The architectural solutions – the form of the building and the choice of materials including high performance glass and generous amounts of insulation – ensure that even without any renewable technologies the buildings calculated energy demand is 34 kWh/m^2 for space heating and hot water and 19 kWh/m^2 for technical installations, ventilation.

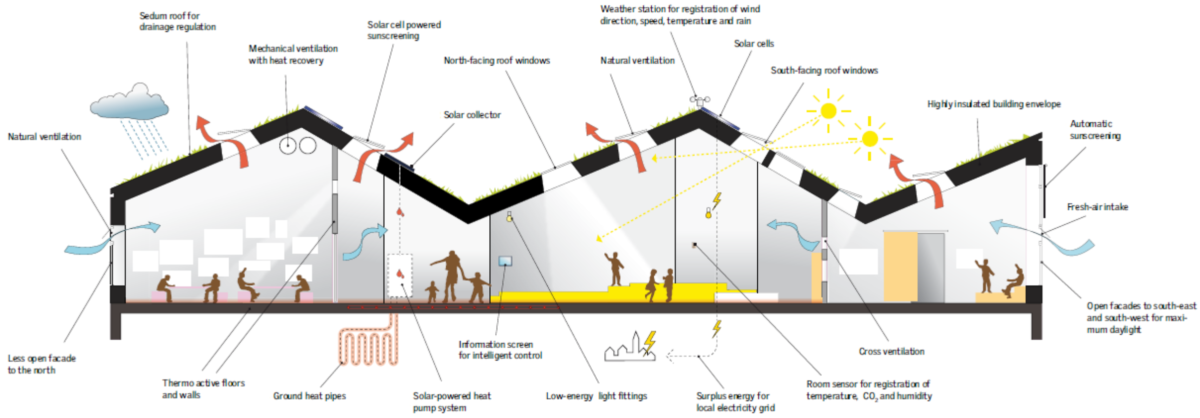


Figure 9 Principle for indoor climate and energy system in Solhuset

The building is equipped with renewable technologies in a combination between solar thermal, solar cells, ground heat and heat pumps, supplying the building with even more energy than the energy demand. Strategically positioned on the southern facades of the roof are 50 m^2 solar collectors that provide heating and hot water, and together with the heatpump produce 52 kWh/m^2 which is more energy than needed in the building. There is also installed 250 m^2 photovoltaic panels to generate 27 kWh/m^2 of electricity.

As the energy production on the building is above the energy demand, the annual primary energy performance is below 0 kWh/m^2 and thereby fully meeting future expected energy requirement for nearly Zero-Energy Buildings.

The energy performance for the first year has been meassured and shows that the uses of energy reach a level that is higher than calculated. The heat consumption for space heating is larger than expected which results in a larger heat production from the heat pump than expected. This also requires higher demand for electricity.

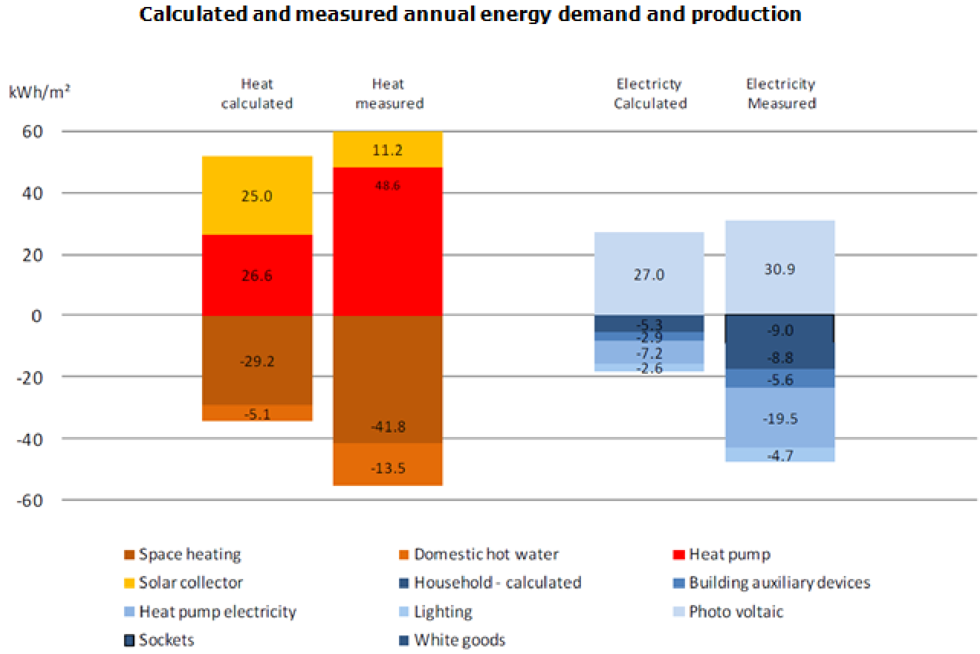


Figure 10 Calculated and measured energy in Solhuset

Environment

The design of the kindergarten has integrated environmental issues for two reasons. Firstly as a proof and demonstration of future sustainable buildings to the construction sector and the society; secondly as a tools for education of the children in the kindergarten. The building design has become an integrated part of the children's playing and education. It is designed to educate its young users about protecting the environment, with greenhouses where staff and children can grow plants, and touch-screen TVs that will allow the children to monitor the centre's performance

The roof surface has been planted with sedum – a hard wearing plant, which not only encourages biodiversity, prevents water runoff and provides both sound and temperature insulation, but also helps to cool the photovoltaic panels. Water evaporating from the planted roof helps to cool the panels, which work more efficiently at lower temperatures. It's a simple, effective and attractive solution.

The exterior of the building is clad with timber product that is impregnated in a method, based on impregnation by means of supercritical CO_2 as a solvent. By this method, the use of chemicals per m^3 wood is significantly reduced compared to conventional methods, and the use of heavy metal salts and boric acid is avoided.

The structure of floor and inner walls are made with concrete in order to optimize the performance of the building, as the material has a high thermal massing, meaning that solar energy streaming in during the day is absorbed by the walls and floors and then gradually released as the inside temperature cools in the late afternoon and evening. Concrete does require a lot of energy to create, but its capacity to absorb heat and its durability make it a good choice over the life time.

Home for life – a single family house

With 190 m^2 and one-and-a-half-storeys of living space, Home for Life is a single-family house focused on functionality, comfort and energy efficiency. The home's layout offers both private and open family areas. And floor-to-ceiling windows make the rooms feel spacious, airy and bright.

The home's numerous façade and roof windows face all directions to provide abundant, even lighting and fresh air throughout the day. The large windows also act as doors to the outside, creating an organic flow between inside and out, and a unique architectural statement.

Home for life. Photo: Adam Mørk

Figure 11 Active house radar for Home for life

This section describes in short the performance of Home For Life, based on the Active House Vision and Specification with specific focus on the thermal comfort and the analysis of measured data for indoor climate. The results are based on the measurements and analyses from November 2010 to October 2011. The results are based on the measurements and analyses for the second year of occupancy. The main part of commissioning and adjustment of all systems took place during the first year of occupancy from 2009-2010.

System for control of indoor comfort

The ventilation system is hybrid, i.e. natural ventilation is used during the summertime and mechanical ventilation with heat recovery during the wintertime, while hybrid ventilation is used spring and fall. The switch between mechanical and natural ventilation is controlled based on the outdoor temperature. The setpoint is 12,5 °C. Below the setpoint the ventilation is in mechanical mode, above the setpoint the ventilation is in natural mode. In both natural and mechanical mode, the ventilation rate is demand-controlled. CO_2 is used as indicator for the Indoor Air Quality, and a setpoint of 850 ppm CO_2 is used. Besides that, relative humidity is also used as indicator.

There is external automatic solar shading on all windows towards South, and overhangs are used where appropriate. The solar shading is controlled by external solar radiation for each facade, and not at room level. Each room is an individual zone in the control system, and each room is controlled individually. There are sensors for humidity, temperature, CO2 and presence in each room for occupancy.

The building occupants can override the automatic controls, including ventilation and solar shading at any time. Override buttons are installed in each room, and no restrictions have been given to the occupants. As house owners they have reported a motivation to minimise energy use on an overall level, and to maximise IEQ on a day-to-day basis.

Thermal comfort

The focus in the analyses of thermal comfort is on overheating and undercooling. It is investigated if the building design and control systems are able to provide good thermal comfort and specifically how windows and solar shading contribute to the performance.

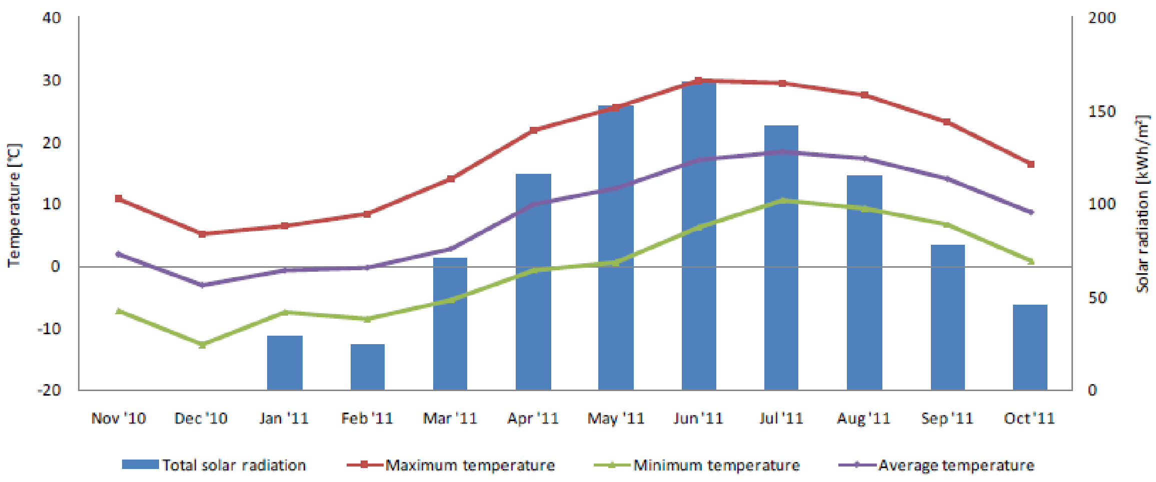


Figure 12 Outdoor conditions during the reported period

The focus of the present paper is on the performance related to ventilative cooling and potential overheating. The further analyses will focus on the performance of the kitchen, which is a combined kitchen and dining room with a large south-facing window section. The graphical presentation of the measured data is reported by using a temporal map, which is a map with the day of the year mapped along the X axis and the time of day along the Y axis.

The variation over time-of-day and time-of-year is further investigated in the below figure. It is seen that the episodes during winter with temperatures below category 1 can last for several days during the winter, but that in many of the episodes, the temperature reaches category 1 between 12:00 and 20:00, possibly due to solar gains throug the windows. It is also seen that during summer, only few episodes with temperatures beyond category 1 are observed.

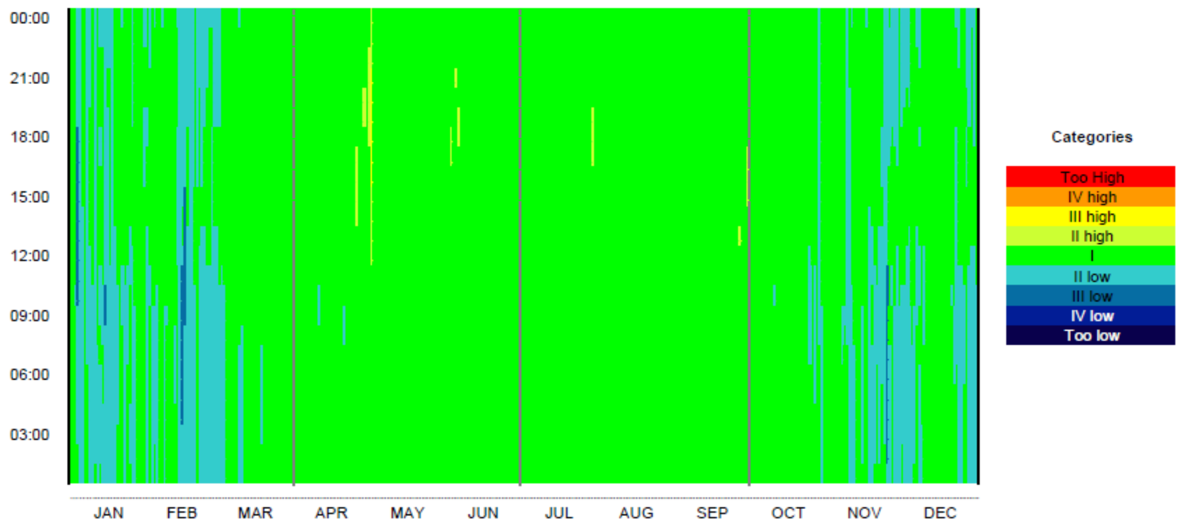


Figure 13 Comfort category for each hour of the year in a temporal map (kitchen and dining room)

The above figure shows that an very good thermal comforts can be achived in low energy buildings during the summerperiod, as long as the comfort requirement has been a part of the design process as it is in the Active House Specification. The summercomfort is established by the use of natural ventilation and winter comfort is established by use of mechanical ventilation. Figure 14 below shows that windows were not open during the winter episodes with temperatures below category 1 (orange), indicating that these episodes were not caused by airings.

The heating system during winter is controlled in such a way that the supply temperature for the floor heating system is set at the heat pump control. The lower the supply temperature, the better the system efficiency. The occupants have reported that they set the supply temperature so that the room temperature would reach 20-21 oC to reduce heating consumption. The episodes with winter temperatures below category 1 can thus be attributed to user preferences.

Figure 6 further shows that during the summer, windows are almost permanently open between 9:00 and 22:00 and that category 1 is maintained during these hours (green). The figure shows many episodes with open windows between 22:00 and 9:00 (green), which can be assumed to be caused by automatic window opening for night cooling. Also in the transition periods (March to May and September to October) windows are used to a large extent, with openings between 12:00 and 18:00

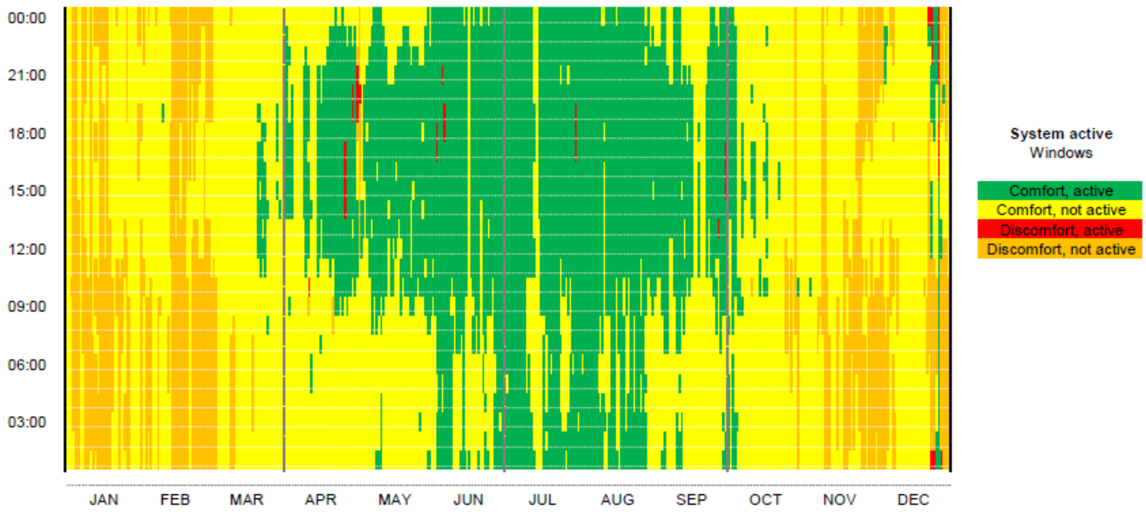


Figure 14 Temporal map for kitchen and dining room, showing comfort or discomfort and if windows were open or closed (active or not active).

Conclusions and discussions

Thermal comfort and indoor air quality

As people spend up to 90% of their time inside buildings, it should be a future requirement that all new buildings meet a minimum requirement to the indoor comfort level. The Active House specification sets strict requirement to indoor comfort.

The outcome of this paper and the learning from the Active House projects calls for a debate about the ventilation strategies for new low energy buildings and nearly zero energy buildings. It looks as the indoor comfort level is to low during the winter period with mechanical ventilation, whereas it the indoor comfort level is almost in class 1 during the summer period, with natural ventilation.

In the Nordic countries there has been a debate about over heating in the summer period in very low energy buildings, however the learning shows that overheating can be avoided if indoor comfort temperature is taken into account already in the design phase.

One solution can be use of hybrid ventilation with mechanical ventilation during winter and natural ventilation during summer. The evaluations of the existing Active House projects proves – as in this paper – that sufficient indoor temperatures are reached during the summer period, whereas the indoor comfort temperature during winter might need further evaluations as it looks at it is too low, when the mechanical ventilation is activated.

One can then evaluate to reduce the ventilation flow during the winter period, in order to avoid low comfort temperature. However the paper also shows that the indoor air quality is lower during the period with mechanical ventilations, which indicates that air exchange is to low and thereby it cannot be reduced further.

It is recommended to discuss further ventilation strategies for nearly zero energy buildings and it is also recommended to set requirement to indoor comfort at the same level and ambition as for reduction of energy and implementation of renewable energy.

Energy

The outcome of this paper and other papers shows that the use of energy often is higher than the expected and calculated values. One reason is a different use of the building as it was planned for, like a higher indoor temperature or installations that have not been commissioned correctly.

In the future when all new buildings need to be nearly zero energy buildings, the need for commissioning and training of the users become important in order to reach the low energy level as calculated. It is recommended to have a discussion on how it can be secured that the calculated levels of energy use also become the measured.

Environment

The resources used in the production of materials, construction of buildings is growing and will soon become a bigger proportion than the energy used in the building itself. There is a need to strengthen the focus on those issues also regarding the use of water in and around the building. It is recommended to include environmental requirement to future buildings.

Implementation of nearly zero energy buildings

The European and Nordic countries has to implement nearly Zero-Energy Buildings for domestic buildings before 31 December 2020, however a common methodology has not been developed by the European commission; leaving the individual countries with their own interpretation of nearly Zero-Energy Buildings (NZEB).

The Active House Specifications sets ambitious requirement to use of energy and can be used as a reference for implementation of nearly zero energy buildings. As the Active House specifications also focus on comfort and environment, they move the focus wider to include sustainability from a holistic view. The requirement for comfort reflects methodologies included in international standards, methods and national legislation. Thereby those requirements easily can be included in the legislation for nearly zero energy buildings.