Experiences with ventilative cooling in practical application

Recently built Active Houses provide experience with ventilative cooling in practical application as a means to prevent overheating in energy efficient residential buildings. Detailed measurements of energy performance and indoor environment have been made in five single family houses, located in Austria, Denmark, England, France and Germany. The houses have generous daylight conditions, with a design target to reach a Daylight Factor of 5% in the main habitable rooms. This increases the risk of overheating, but the measurements show that the houses generally achieve thermal comfort category 1 of EN 15251 during summer, which means that overheating has not occurred. To succeed, natural ventilative cooling and dynamic solar shading was applied and controlled to avoid overheating (which is possible under European climate conditions, where humidity is not a main issue during summer). Some of the experiences from applying ventilative cooling can be generalised to other houses and are presented in the article.

Some barriers limit the use of ventilative cooling. Firstly, the current methods in standards and legislation that are used to determine the performance of ventilative cooling need to be further strengthened. Secondly, affordable, intuitive and simple control systems for residential hybrid ventilation and dynamic solar shading are needed to tap the full potential of ventilative cooling.

The Active House Specification is based on a holistic view on buildings including Comfort, Energy and Environment. It uses functional requirements to indoor air quality and thermal comfort.

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Introduction

Overheating is an important issue for building designers. Even in Scandinavia, demonstration houses have frequently experienced problems with overheating, often due to insufficient solar shading and use of natural ventilation (Isaksson, 2006, Larsen, 2012, Rohdin 2013). Similar results were found in a review on the situation in UK, stating that in certain cases, dwellings that were recently built or refurbished to high efficiency standards have the potential to face a significant risk of summer overheating (AECOM, 2012). Porritt et al. (Porritt, 2011) found that living room temperatures could be maintained below the CIBSE overheating thresholds, as a result of a combination of intervention measures that include external wall insulation, external surface albedo reduction (e.g. solar reflective paint), shading (e.g. external shutters) and intelligent ventilation regimes. Orme et al. found that night ventilation is a particular important measure to prevent overheating (Orme et al., 2003), and also found that the risk of overheating will increase in the future due to climate change.

The Active House Specification (Eriksen et al., 2013) has requirements in three categories, and has a main ambition that the three categories should have an equally high focus. The three categories are:

- Comfort (incl. indoor environmental quality)
- Energy
- Environment

Four categories of maximum operative temperature are defined, setting requirements to air-conditioned and non-air-conditioned buildings, using the definitions of EN 15251. For non-air conditioned buildings, the adaptive approach is used:

1. $\Theta_{i,o} < 0.33 \cdot \Theta_{rm} + 20.8°C$, for Θ_{rm} of 12°C or more
2. $\Theta_{i,o} < 0.33 \cdot \Theta_{rm} + 21.8°C$, for Θ_{rm} of 12°C or more
3. $\Theta_{i,o} < 0.33 \cdot \Theta_{rm} + 22.8°C$, for Θ_{rm} of 12°C or more
4. $\Theta_{i,o} < 0.33 \cdot \Theta_{rm} + 23.8°C$, for Θ_{rm} of 12°C or more

Where Θ_{rm} expresses the average outdoor temperature (°C) weighted over time according to EN 15251 and $\Theta_{i,o}$ is the indoor operative temperature (°C).

Natural ventilation in combination with dynamic solar shading is a key instrument to avoid overheating with minimal use of energy, but there are no specific requirements in the Active House Specification to use the measures.

Daylight is important for humans, and the requirements are based on average daylight factors on a work plane in the main living room, which must be determined by a validated simulation tool. The criteria are:

DF > 5% on average
DF > 3% on average
DF > 2% on average
DF > 1% on average

Criteria for energy and environment are found in the Specification (Eriksen et al., 2013), which can be downloaded at no cost from the website of the Active House Alliance.

Experiences from completed active houses

Ventilation System Configurations

Many of the realized Active House have been built with demand-controlled, hybrid ventilation systems for optimal IAQ and energy performance.

An example is from the project Sunlighthouse in Austria. Natural ventilation is used during warm periods and mechanical ventilation with heat recovery is used during cold periods. The switch between mechanical and natural ventilation is controlled based on the outdoor temperature. The set point is 12.5°C with a 0.5°C hysteresis. Below the set point the ventilation is in mechanical mode, above the set point 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 IAQ, and a set point of 850 ppm CO_2 is used.

LichtAktiv Haus in Germany is an example of a house where natural ventilation is used as the only ventilation system.

Measured IAQ

Temperatures and CO_2-concentrations have been measured continuously for 1–2 years in several inhabited Active Houses, e.g. in LichtAktiv Haus (LAH), Germany. The measurements were supplemented with systematic qualitative feed-back from the inhabitants. LAH is designed with a demand controlled IAQ, with the aim to achieve category 1 (500 ppm above outdoor levels) or 2 (750 ppm above outdoor levels) (Feifer et al., 2013). The measured CO_2-concentration in the living/dining room is presented in **Figure 1**.

It is seen in **Figure 1** that category 1 or 2 is achieved for 60% to 70% of the time during winter, and approx. 100% of the time during summer. The CO_2-concentration is lowest during the summer period as natural ventilation is also used to prevent overheating in this part of the year. Good summertime IAQ is thus a positive side-effect of applying ventilative cooling to prevent overheating. CO_2 concentration above category 2 during winter is caused by user override of automated controls. These results are similar to those seen in Active Houses with mechanical/hybrid ventilation.

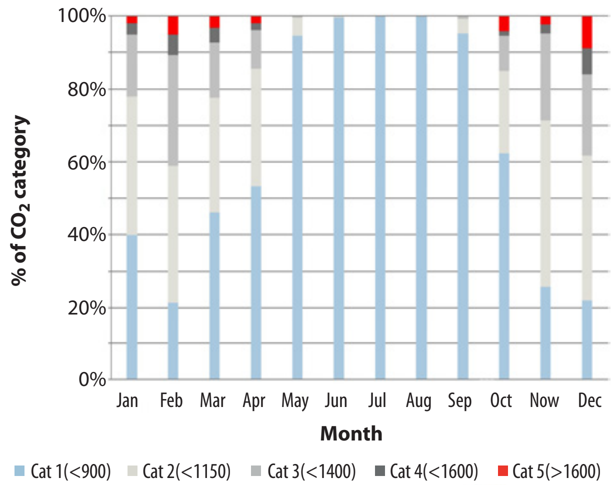

Figure 1. Measured CO_2 concentration in the kitchen/living room of LichtAktiv Haus, Germany. The data is categorized according to the Active House Specification. The outdoor CO_2 level is assumed to be 400 ppm.

It is the general experience that both natural, mechanical and hybrid ventilation systems are able to deliver the right ventilation rates and achieve the right IAQ. The key issue is that the systems must be designed, installed and maintained correctly, and most importantly, the controls must be transparent and intuitive for the occupants of the buildings.

Measured Thermal Comfort

Foldbjerg (Foldbjerg et al., 2013) reported on the thermal comfort in LAH and two other Active Houses. A typical characteristic of the realized Active Houses is that they have very generous daylight conditions. It is seen on **Figure 2** that the living-dining room in LAH achieve category 1 in most months, with the exception of a limited number of hours during the three summer months. Annually, the room achieves category 1. There are very few hours with temperatures below category 1. This means that there is no issues with overheating or low temperatures (undercooling).

Prevention of overheating is a key issue, as low energy buildings can easily overheat, as reported by Larsen (Larsen, 2012) and others. It is the general experience from the realized Active Houses those good thermal conditions with only insignificant periods with high or low temperatures can be achieved. The important elements to consider are natural ventilation and dynamic solar shading, as combined in ventilative cooling (venticool, 2014).

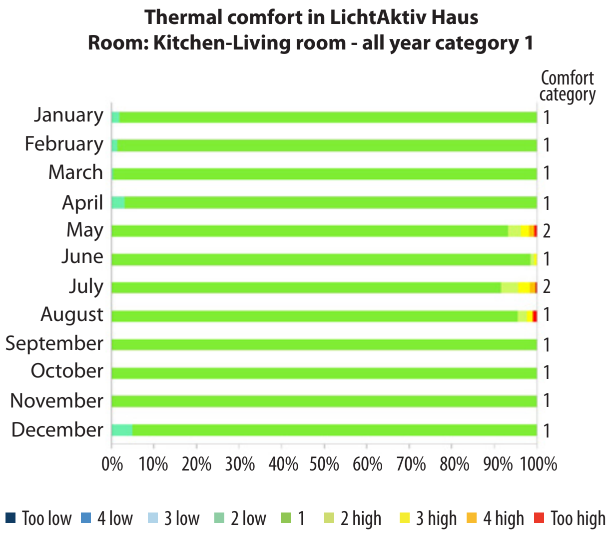

Figure 2. Measured indoor temperature in the kitchen/living room of LichtAktiv Haus, Germany. The data is categorized according to the Active House Specification. The number on the right side of the figure is the Active house category achieved for each month (max 5% of the time can exceed the category).

Ventilative Cooling in Standards

Peuportier (Peuportier et al, 2013) measured the air change rates achieved with natural ventilation as the means of ventilative cooling in the Active House called Maison Air et lumière near Paris, France. Air change rates in the range of 10 to 22 ACH were achieved. These results were confirmed by simulations in CONTAM. However, later calculations with the methods presented in EN 15242 show much lower results despite similar geometry and boundary conditions. This is to some extent explained by the fact that EN 15242 only includes single-sided ventilation. BS 5925:1991 presents a method that allows for a two-sided window configuration, still with very conservative results. In the on-going revision of EN 15242 it is being discussed if a more accurate and generally applicable method can be included. The work in IEA Annex 62 will further support this goal.

Ventilative Cooling in legislation

Ventilative cooling is only to a limited extend addressed in legislation through building codes and compliance tools. Recent years, several national building codes have included ventilative cooling with simplified calculation of ventilation flow rates that are not directly addressing the performance of the actual ventilation and building design. To correctly account for the effect of ventilative cooling, more accurate methods are needed. A method was recently implemented in the Danish Be10 compliance tool, and there is currently work on-going in France to improve the methodology for the calculation of ventilative cooling and to integrate summer comfort better in the French national code and compliance tool.

Also in France and Denmark, requirements to thermal comfort are likely to be more elaborated in coming revisions of the national building codes. This is a necessary step to prevent overheating, but requires that the underlying methodology adequately accounts for the actual performance.

Experience with Control Systems in Active Houses

An effective control of dynamic shadings and natural ventilation is important for achieving good summer comfort. Such control may be based on manual operations, knowledge and good habits but in the Active Houses described here, the full step towards fully automated control was taken. The automatic control was in general appreciated by the users, though the users needed some time for adjusting to the system. The user feed-back showed clearly that they appreciated the automatic control if override was possible. It is essential to offer intuitively manually operable devices such as windows, doors, and awning blinds allowing the users to override the automatic system.

There are few control systems currently available that deliver control of both mechanical and natural ventilation (as a hybrid solution), and which controls both ventilation, window openings and dynamic solar shading in a combined effort to maintain both good IAQ and good thermal comfort. Such systems should be cost-effective and are needed for the residential market to tap the full potential of dynamic building elements and to reach the ambitious nZEB targets of EU-28.

Conclusions

Good IAQ can be achieved with both natural, mechanical and hybrid ventilation systems. The important lesson is that they must be planned, installed and maintained right. This has been achieved in the investigated houses. By correct planning in the design process good IAQ can be reached with a minimum use of energy. Particular good IAQ during the summer period has been observed as a positive side-effect of applying ventilative cooling.

Whereas the above themes have been relatively unproblematic, some issues, mentioned below, have a greater need for increased focus regarding quality and compliance.

The realized houses are characterised by generous daylight conditions, which could potentially lead to overheating. This has not been the case. The houses show that good thermal comfort can be achieved in all seasons, regardless whether natural, hybrid or mechanical ventilation is used. But a strong relation between efficient natural ventilation in the summer (ventilative cooling) as well as dynamic solar shading has been a key element in achieving this, supported by windows being located towards more than one orientations in each room and not mainly towards the south as sometimes seen in low energy houses.

There is currently only limited support in standards and legislation to give a true and fair account of the performance of ventilative cooling and dynamic solar shading, and this needs to be improved.

There remains a need to identify and to discuss how ventilative cooling can become a standard solution in legislation and standards throughout Europe especially regarding renovation but also regarding Nearly Zero Energy Buildings.

Transparent and intuitive control systems scaled for residential buildings with regards to system architecture and price are needed. Such a control system should be able to control ventilation and dynamic solar shading to maintain both good IAQ as well as good thermal comfort. ■

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