EXPERIENCE WITH MEASUREMENTS, VENTILATION AND INFILTRATION IN THE ACTIVE HOUSE CONCEPT. QUALITY ISSUES AND IMPLICATIONS FOR COMPLIANCE

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ABSTRACT

The present paper addresses experiences with infiltration and ventilation in the Active House concept, based on the Active House Specification and realized Active Houses. 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, and does not have component requirements to airtightness or specific ventilation solutions. Experiences from realised Active House projects show that better airtightness than nationally required has been achieved. Indoor air quality is generally good, independently of the type of ventilation system installed (mechanical, natural and hybrid have been used). Good thermal comfort can be achieved in houses with generous daylight conditions. To succeed, natural ventilation and dynamic solar shading (ventilative cooling) must be applied and controlled to avoid overheating, which is possible under European climate conditions, where humidity is not a main issue during summer. The identified issues for quality and compliance have been that the current methods in standards and legislation that are used to determine the performance of ventilative cooling need to be further strengthened. And that affordable, intuitive and simple control systems for residential hybrid ventilation and dynamic solar shading are needed.

KEYWORDS

Active House, natural and hybrid ventilation, renovation, standards, controls systems

1 INTRODUCTION

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 environment)
- Energy
- Environment

The Specification addresses residential ventilation as functional requirements to Indoor Air Quality (IAQ) and thermal comfort. All main rooms for occupancy must be evaluated separately. Four categories of IAQ are defined, based on the CO2-concentration, which must be achieved for minimum 95% of the occupied time:

1. 500 ppm above outdoor concentration
2. 750 ppm above outdoor concentration
3. 1000 ppm above outdoor concentration
4. 1200 ppm above outdoor concentration

It is a requirement that the air change rate can be manually influenced in all main living rooms, regardless whether mechanical, natural or hybrid ventilation is used. To reduce the risk of overheating, operable windows are recommended. Ventilation inlets, including natural ventilation openings, must be located so that draught risk is minimised.

There are no specific requirements to airtightness, or to performance of ventilation components, and no specific type of ventilation systems is required. The designer of the project can choose the most relevant system for the specific project, but to meet the ambitious requirements to energy performance, an energy efficient ventilation system and an airtight building envelope is needed (and therefore required indirectly).

Natural ventilation in combination with dynamic solar shading is a key instrument to avoid overheating with minimal use of energy. 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. $T_{i,o} < 0.33 \times T_{rm} + 20.8°C$, for T_{rm} of 12°C or more
2. $T_{i,o} < 0.33 \times T_{rm} + 21.8°C$, for T_{rm} of 12°C or more
3. $T_{i,o} < 0.33 \times T_{rm} + 22.8°C$, for T_{rm} of 12°C or more
4. $T_{i,o} < 0.33 \times T_{rm} + 23.8°C$, for T_{rm} of 12°C or more

All other criteria are found in the Specification (Eriksen et al., 2013), which can be downloaded at no cost from the website of the Active House Alliance.

2 EXPERIENCES FROM COMPLETED ACTIVE HOUSES

2.1 Increasing number of Renovation Projects: Climate Renovation as new Paradigm

Two types of Active Houses have been completed: New buildings and Renovation projects. New buildings dominated in the first years after the launch of the Specification, but in recent years a shift towards more renovation projects have been seen. A common characteristic for the renovation projects is that they do not have improved energy performance as the only objective – improved indoor climate is often just as important. Climate Renovation has been adopted by some Active House Alliance members as the term to describe this new paradigm. Examples of recent renovation projects are:

- LichAktiv Haus: A typical 1950's post-war, one-family house in Hamburg, Germany. The renovation has transformed it to a modern, spacious house
- De Poorters van Montfoort: Ten row-houses in a social housing corporation were renovated to offer excellent energy performance, more space, better daylight conditions and improved indoor climate.

2.2 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.

2.3 Measured airtightness

It is not required in the Active House Specification to measure airtightness. But in order to meet energy efficiency targets, airtightness has been measured with blower door tests in many cases. Table 1 presents examples of measured airtightness in realised Active Houses. This is in most cases well below the requirements in the national building codes.

Table 1: Measured airtightness in five Active Houses

	Home for Life **DK, 2009**	**Sunlighthouse** **AT, 2010**	**Maison Air et Lumiére** **F, 2011**	**Carbonlight Home** **GB, 2011**	**LichtAktiv Haus** **D, 2010**
n50 (h^{-1})	1,5	0,52	0,60	-	1,07
$l/s/m^2$ @ 50 Pa	-	-	-	1,33	-

The experience from the completed Active Houses and other houses built according to other standards for low energy buildings, is that the achieved airtightness is related to the competence level of the craftsmen building the house. It is also the experience that the competence level has increased in the relatively short period from 2009 to 2011 due to the increased awareness of the importance of airtightness for low energy buildings.

2.4 Measured IAQ and Thermal Comfort

Temperatures and CO_2-concentrations have been measured on hourly level in several projects, e.g. in LichtAktiv Haus (LAH), Germany. 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.

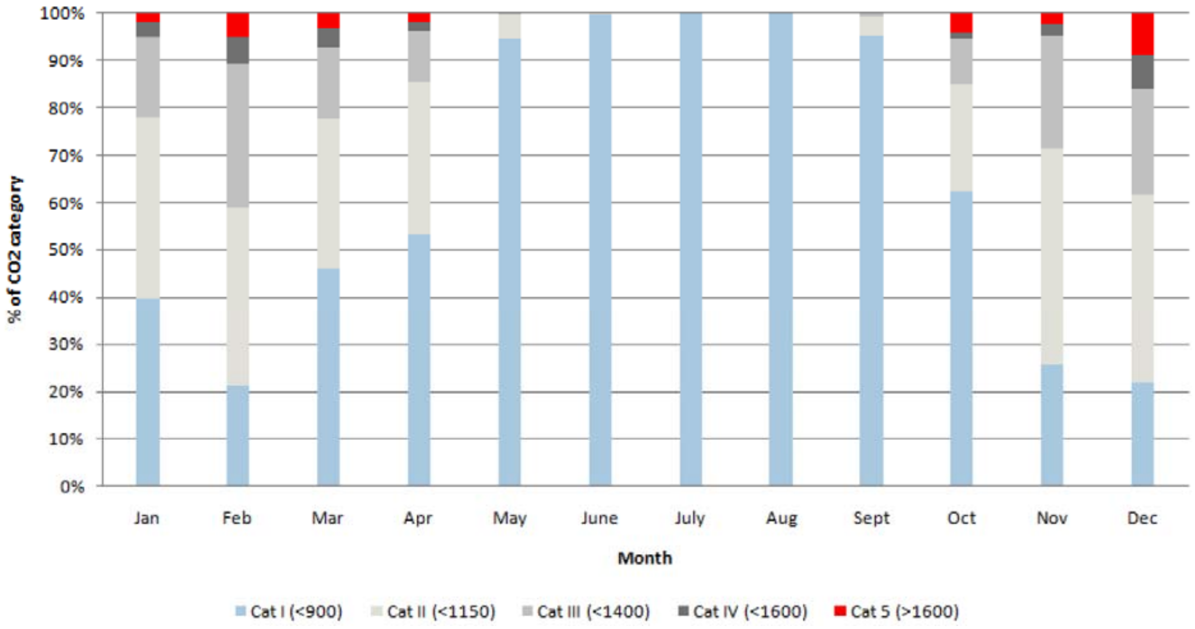

Figure 1: Measured CO_2 concentration in the kitchen/living room of LichtAktiv Haus, Germany. The data is categorized according to the Active House Specification

It is seem on 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 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.

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.

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 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).

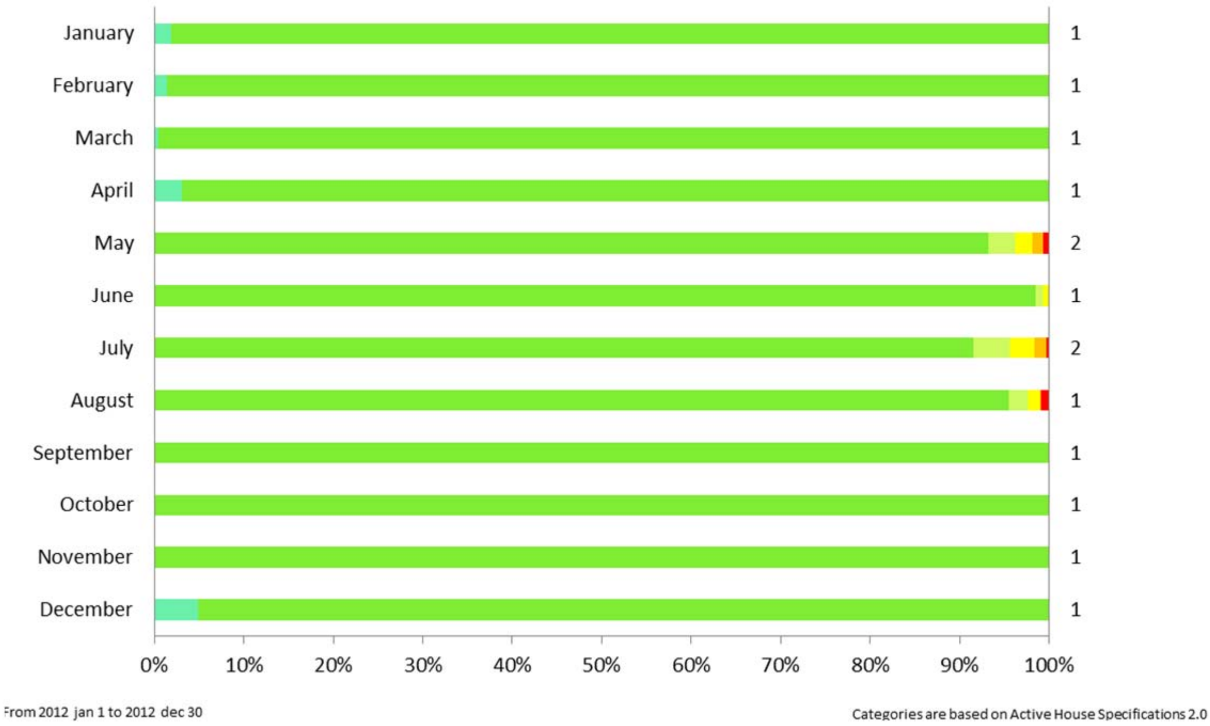

Figure 2: Measured indoor temperature in the kitchen/living room of LichtAktiv Haus, Germany. The data is categorized according to the Active House Specification. The number on the right side of the figure is the Active house category achieved for each month (max 5% of the time can exceed the category)

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

2.5 Ventilative Cooling in Standards and Legislation

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.

To correctly account for the effect of ventilative cooling, more accurate methods are needed in standards, and in legislation. Regarding legislation, there is currently work on-going in Denmark and France to tighten the requirements to thermal comfort during summer – this process underlines that reasonably accurate methods are needed to predict the performance of the measures that can be used to prevent overheating.

2.6 Experience with Control Systems in Active Houses

Holzer (Holzer et al, 2014) is investigating the characteristics of Active Houses and particularly how the control systems should be designed to allow the houses to deliver the expected performance, and at the same time offer the occupants the experience they expect.

The preliminary conclusions are:

- Active Houses are react fast towards direct sunlight. Thus, an effective and fully automatically controlled system of dynamic shadings is obligatory for achieving good summer comfort.
- Hybrid ventilation systems stand the test, combining automated window operation, and mechanical ventilation systems as well as manual window operation. The learning is to consequently separate the operation periods of automated window and mechanical ventilation, depending from outside temperature.
- Beyond technical automation it's essential offering intuitively manually operable devices such as windows, doors, and awning blinds. Furthermore it's preferable having some devices literally manually operated than having them only manually telecommanded.
- Sun protection together with night ventilation is an effective combined strategy towards summer comfort, which turned out to be preferably automized. At least in central and northern Europe areas there turned out to be a somehow weak intuitive understanding of heat protective building operation.

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.

3 CONCLUSIONS

There are several experiences with completed Active Houses regarding ventilation, quality and compliance.

A shift from focus on new buildings to also focus on renovation projects has been observed. The main driver is improved energy performance, but multiple benefits are actually expected, mainly related to good indoor climate. Some Active House members have used the term Climate Renovation to describe this new paradigm.

Airtightness is important to ensure the planned energy performance, and relies to a large extent on the competences of the craftsmen. There are indications that the competence level is increasing from year to year, and good results have been observed in the most recent houses. There seems to be a reduced need for focus on building airtightness now compared to the situation 5 to 15 years ago.

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 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 weak 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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