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INDOOR ENVIRONMENTAL QUALITY OF THE FIRST EUROPEAN MODELHOME 2020 : HOME FOR LIFE

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ABSTRACT

The Indoor Environmental Quality (IEQ) of our buildings is essential to our health. In developing sustainable residential buildings of the future there lie a great challenge in combining energy efficiency with healthy and good IEQ while creating beautiful buildings and environments that give more than they take. The Active House vision approached exactly this challenge by combining energy indoor climate and environment to develop ideas and knowledge of our future buildings. The ModelHome 2020 project grasps the Active House vision and materialises it by designing and constructing six buildings as suggestions on our future sustainable buildings. These buildings constitute a live scaled laboratory for exploration of every aspect possible. Real people move into these buildings to make it possible to explore not merely the technical performance of the buildings but especially also creating the possibility of exploring the qualities and experiential performance of the house. This paper focus on exploring the IEQ in the first of the ModelHome 2020 projects the residential single family house *Home for Life* in Denmark. The house is measured through one year while a test family live in the house – carrying out normal everyday-life-activities. Thereby both the technical performance of the house is measured and the occupants' experiences are measured. To be able to perform this holistic hybrid measurements methods from different scientific fields are applied. Natural and engineering science methods support measuring the quantitative performance of the buildings as temperature and CO_2-level. Methods from artistic and humanistic sciences are applied for measuring occupants experiences – and thereby the building's ability to perform in a more qualitative manner. These methods include observation, interviews and cultural probes. The paper describes results on the daylight environment, the thermal environment and the indoor air quality – presented through both quantitative and qualitative means. Lastly the paper discuss how the different results can challenge and support each other and support creating a wholesome evaluation of our future sustainable homes – based on a human centric perspective.

INTRODUCTION

In the Northern European countries we spend up to 90 percent of our time indoors – often in buildings with doubtful indoor environment [1]. Therefore, Indoor Environmental Quality (IEQ) of our residential buildings is a central subject that affects us all in our everyday lives – whether we are conscious of it or not. We wish to do something about these issues and aim at creating better and healthier environments for people with plenty of daylight and fresh air. Through the Active House vision we aim at developing buildings that give more than they take by uniting carbon neutral buildings with good IEQ adapted to the surrounding environment [2]. The vision is realised in an extensive living laboratory through the ModelHome 2020 project [3]. The purpose of the project is to demonstrate different solutions and approaches to the challenge of combing a healthy and comfortable indoor environment with carbon neutrality. The project is unfolded through design and construction of six demonstration buildings. Architecture and energy systems are optimised to each of the six specific locations and seven criteria for both energy performance and IEQ are defined to realise the vision of the project [3]. When built, test families move into the houses for a one year period to test and experience these designs of a future generation of sustainable homes.

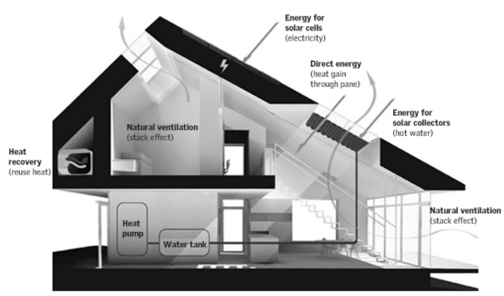

Fig. 1. "Home for Life". South facade (left). Daylight, ventilation and energy concept (right)

This paper studies the IEQ of the first realised ModelHome2020 through considerations and analysis of *both* quantitative *and* qualitative aspects. This first house, *Home for Life,* is constructed in Denmark and has been tested for a one year period by the Simonsen family.

The paper describes the methodology used for measuring the house – a mixed methods approach combining quantitative methods from natural and engineering science with qualitative methods from the artistic and humanistic sciences. The setup aim at exploring the IEQ from various sides by illuminating how the sciences can support each other when e.g. the measured optimum IEQ does not meet the occupants experiences. We wonder, should a good IEQ be determined through means of numbers solely – or can human experience be as good an indicator? Through presenting results on daylight, thermal environment and indoor air quality we illuminate how respectively quantitative and qualitative methods can provide data that tells the story from different perspectives. Lastly we discuss how the different results can challenge and support each other and support creating a wholesome evaluation of our future sustainable homes – based on a human centric perspective.

METHOD

In this paper the case study house is subject to explorations and analysis using both quantitative and qualitative methods with focus on the kitchen/dining room as it is the most used room in the house (also see fig. 2).

The Mixed Methods approach [4] combined methods from different sciences while considering all of them equally important. This approach illustrates that the aspects are inter-dependent and inter-connected – it is often possible to explain the quantitative aspects by studying the qualitative aspects and vice versa. Below, we summarise the quantitative and qualitative methods used for exploring and assessing the IEQ of Home for Life.

Methods for quantitative and qualitative evaluation

Results on daylight are based on calculated daylight factor levels as continuous measurements of daylight levels will require a permanent grid of sensors in the house during occupancy – an impossible setting in a family's everyday life. As the daylight factor is independent of actual weather conditions, a calculation based on the actual geometry of the house provides a good indication of the actual conditions [5]. Indoor temperatures (^oC), CO_2 levels (ppm) and relative humidity (%) are continuously measured in 11 zones (rooms) and hourly values are recorded providing a detailed illustration of the indoor environment dynamics during both day and year. EN 15251 is used to evaluate the thermal comfort and indoor air quality categorizing a space from I to IV - where category IV indicates an unacceptable situation [6].

Methods for qualitative evaluation of IEQ are a rather un-explored field of research regarding sustainable homes – however a few examples have surfaced during the last couple of years (e.g. [7] [8]). The evaluation is approached in a holistic manner by using a triangulation of methods deriving from artistic and humanistic sciences. A triangulation implies a combination of methods making it possible to approach the problem of interest from several different angles [4]. Thereby the various methods can support or contradict each other in the quest for making an extensive exploration of the problem. The qualitative measurements include an anthropological study through participant observations of the families' experiences in the house [4], diaries written by the family following a Cultural Probes [4], semi-structured interviews carried out between researcher and occupants [4] and photo documentation.

Data registration and analysis are carried out through the same weaving approach where quantitative and qualitative aspects merge together to support and challenge each other.

RESULTS

Extensive qualitative and quantitative measurements have been performed on IEQ of *Home for Life* between July 1st 2009 and July 1st 2010. The results presented here are from that period through which the commissioning and adjustment of all systems also took place during this period which influenced the results.

Daylight Environment

The daylight factor calculations show an average daylight factor (DF) above 5% in the main rooms on the ground floor and in most of the bedrooms at the upper floor. Especially the kitchen/dining room at the ground floor receives high daylight levels. [5]

Fig. 2. Calculated daylight factor iso contours for ground floor (left) and upper floor (right).

Rooms with an average DF of 2% or more are considered daylit. A room will appear strongly daylit when the average DF is above 5% in which case electrical lighting will most likely not be used during daytime, according to CIBSE [9]. Through the semi-structure interviews the occupants verbalise the quality of having high daylight levels: *"The best thing about the new house compared to the old is the daylight. The daylight is better*" and *"What characterizes the house is the huge intake of daylight – and that is what I want!"*

The plenty amounts of daylight also bring side effects and the anthropologist observed that the daylight levels sometimes are too resulting in the occupants closing the curtains. When confronting the occupants with this they explain their frustration about this relation – because they are very much aware of the energy aspects knowing that the sunlight brings heat into the house which supports reducing the heat demand of the building. *"Yes, one doesn't really fell called upon to draw back the curtains – it is almost too much (the light)"*.

Fig. 3. The test family in the kitchen/dining room (left). Kitchen/dining room (middle + right).

The well-lit house influences the way the occupants use the electrical light and they experience using considerable less electrical light than in their previous house: *"It is very obvious! We actually don't switch on the electric light. Of course we do it at night. When it becomes dark outside it is necessary, but we actually don't switch on the electric light much."*

Thermal Environment

The family experiences large temperature swings relating to whether the sun falls directly into the house or not and express this experience as a deterioration of the indoor climate: "*So temperature fluctuations are much more dependent on whether the sun or not is outside."*

When evaluated against EN 15251 [6] the kitchen/dining room meets cat. III when both overheating and under heating is considered, while it meets cat. II when only overheating is considered. See Fig. 4. Underheating (uncomfortably low temperatures) is generally caused by airings performed by the occupants during winter and spring/autumn. Underheating is considered less problematic than overheating as the cause of underheating in this case is a matter of occupant preference rather than a consequence of the house design. The observations tell that the family is very aware of the indoor climate in the house. They use the information screen to follow the different levels but are not always satisfied with temperatures. Overheating occurs particularly during the spring period. This is to some extent due to the control system for the solar shading, which initially had two modes of operation; winter and summer. During the first year of operation those was changed. The family actively uses the sun screening and blinds to prevent overheating. This has resulted in an increasing awareness of the consequences of preventing e.g. view out: *"We can also look out over the bay [...] it's fantastic!"* Often the family has deactivated the automatic solar shading to be able to enjoy the view out; in this case they – subconsciously – accept mild overheating as the view is more important in the specific situation.

The use of solar shading illustrates a choice between different alternatives which the family often has to make; dependent on the actual situation, the family balanced indoor temperature against the nice view out and the visual connection to the outdoor. Often they prefer the view.

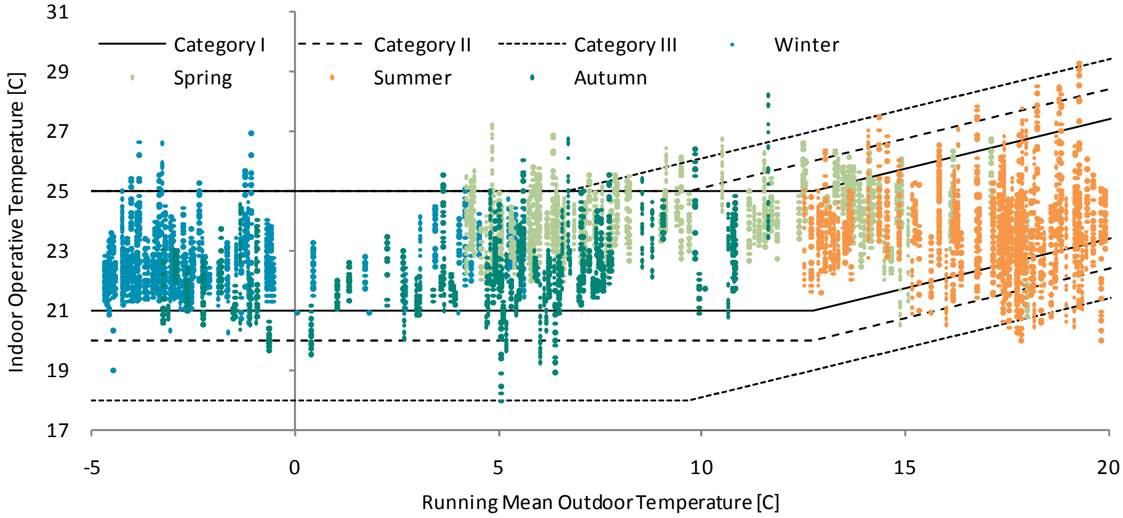

Fig. 4. Operative temperature in the kitchen/dining room depicted vs. outdoor temperature and comfort range limits according to the adaptive method of EN 15251.

Indoor Air Quality

The CO_2-level is used as indicator of air quality. The CO_2 concentration in the kitchen/dining room was above 1200 ppm for 210 hours during the measured year. The kitchen/dining room meets cat. III of EN 15251, see fig. 5.. The natural ventilation scheme during summertime provides low CO_2 levels, whereas the CO_2 levels during wintertime were higher.

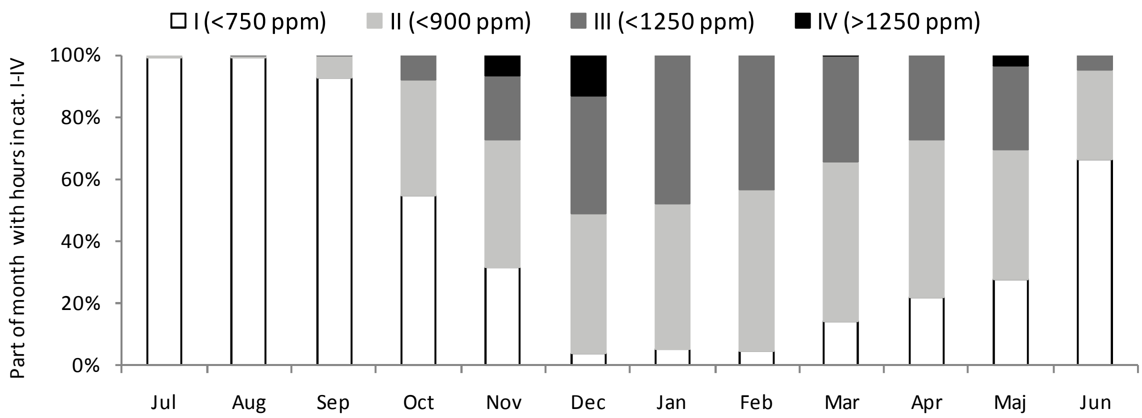

Fig. 5. Monthly CO_2-levels in the kitchen/dining categorised according to EN 15251.

"There is much more CO_2 since we do not get aired out automatically. And it is clear that when I've been here and open doors, typically so you can see that the CO_2-level goes down. It improves the CO_2 levels." The quote illustrates how the family has developed a dependency of the information screen – they have a firm belief that the quantitatively measured CO_2-levels solely determine their health, but they are not able to judge if a specific CO_2 level is too high; they often react on a rising trend. They air out for long periods even though the change of air is not needed and has no effect regarding health.

DISCUSSION

The adaptive evaluation approach of EN 15251 of thermal environment seems in accordance with the family's experience of the thermal environment. The building is free running during the summer time, as it is naturally ventilated, and the family could control solar shading and open windows on room level, giving them control over their environment, which generally contributed to increasing their satisfaction.

Results on thermal comfort show both some underheating and some overheating. The overheating occurred mainly in the spring period when the automatic external solar shading remained in "winter" mode, indicating that the family either trusted that the "system" was working correctly, or was unable to make efficient use of the shading. Another explanation could be that they simply enjoyed the elevated temperatures along with the light after a long Nordic winter, and preferred the view out. Their statements support the last explanation.

The calculations of daylight performance showed high daylight levels, and the occupants particularly expressed satisfaction with the daylight conditions in the house.

It is challenging to present the IEQ of a house through both quantitative and qualitative aspects due to the differences in their representation. Can a recorded quotation weigh as much as a measured number?

As de Dear [10] showed, the concept of thermal adaptation is better explained when a psychological angle is applied. Similarly, many nuances are added to a quantitative recording of e.g. temperature, when a structured analysis based on social sciences is applied. Qualitative recordings provide insight into what the family actually liked and disliked in their house.

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