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Interaction between high daylight levels and thermal comfort in five single-family houses after a full year of measurements - 9 key point summary of VELUX Building Monitoring

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Abstract

The VELUX Group launched the Model Home 2020 project back in 2008, a vision for climate-neutral buildings with a high livability level. From 2009 to 2011, the selected experimental domestic demo-houses presented in this paper have been located in four countries; Germany, France, Austria and UK. All houses have an extensive monitoring program for the indoor environment (daylight, thermal comfort, indoor air quality and ventilation) and energy performance, as well as subjective responds from a test family living in the house for one year. The houses reflect and respond to three main principles – efficient energy design, high degree of livability and minimum climate impact – as well as the different climatic, cultural and architectural conditions of the countries in which they are built.

This paper combines physical measurements of daylight and indoor environment with Post-Occupancy Evaluation (POE) of the five families living, for one year or longer, in the Model Home 2020 houses. The survey is carried out seasonally to capture and explore variation on a seasonal basis. The results give an indication of what the families think of the houses, of its interior environment, and how the environment is experienced.

The collective results, summarized in this paper has nine key points based on building monitoring, to form a platform for discussion, definition and suggestion of a recommendation catalogue of conclusions for learnings to be transferred to the wider building stock, new as well as existing.

Keywords - Residential buildings; Ventilation & Indoor Air Quality; Daylight; Thermal comfort; Info-Graphics

1. Introduction

The Model Home 2020 project is a vision for climate neutral buildings with a high degree of liveability. The intent with the Model Home 2020 strategy is to combine excellent indoor environment with high quality homes mainly driven by renewable energy sources as contextually optimized design solutions. Each building in the project is designed to reflect and respond to the different climatic, cultural and architectural conditions of the countries in which they are built. The demonstration houses, built during 2009-2011, is located in Austria (Sunlighthosue, SLH, 2010, newbuild), Germany (LichtAktiv Haus, LAH, 2010, renovation), France (Maison Air et Lumière, MAL, 2011, newbuild) and United Kingdom (CarbonLight Homes, CLH, 2011, newbuild) (see Fig. 1). All houses are designed following the Active House principles [1].

Model Home 2020

LichtAktiv Haus was built in 2010 and the family moved in December 2011. LichtAktiv Haus is the first CO_2-neutral modernisation of a so-called Siedlerhaus, a semi-detached house from the 1950s located in the Wilhelmsburg district of Hamburg. The once tight and closed structure of the building has been transformed into spacious rooms with high levels of daylight and natural ventilation to provide the resident with the best living comfort. All rooms feature façade and roof windows that are positioned to ensure optimum distribution of daylight. The floor area of the house is 185 m2, and the glass area is equivalent to 58 % of the floor area.

Sunlighthouse was built in 2010 and is Austria's first carbon-neutral, single-family home. The vision is to build a house with exciting and appealing architecture focusing on the sloping roof. The house must be generally affordable and therefore meet certain specifications of dimensions, material and appearance. Sunlighthouse provides an exceptionally high proportion of daylight and will achieve a positive energy balance by reducing its overall energy consumption and by using renewable energy. The net floor area of the house is 201 m2, and the total window area is equivalent to 51 % of the net floor area.

Maison Air et Lumière was built in 2011. The unique features of the house lie in intelligent use of the sloping roof to combine well-being and energy efficiency. The architectural concept is based on different roof pitches that increase its ability to capture sunlight, making it an energy-positive home. Carefully positioned façade and roof windows bring in sunlight from all directions. The windows also fill the space with fresh air to ensure a comfortable living environment all year long. The 130 m² floor area extends over one and a half storeys, with the spaces under the roof put to full use, with a window-floor ratio nearly 1:3.

CarbonLight Homes, built in 2011, are the first new home in the UK designed and built to the new UK Government definition of zero carbon and will achieve level 4 of the Code for Sustainable Homes. CarbonLight Homes use nature in an intelligent way to incorporate high levels of daylight and natural ventilation intended to minimise energy consumption. The net floor area of the houses is 230 m2, and with a window-floor ratio of 1:4.

Fig. 1 Exterior photo of the five single-family houses, Model Home 2020. LichtAktiv Haus (Germany) is upper left, Sunlighthouse (Austria) is upper right, Maison Air et Lumiére (France) is lower left and the Carbon Lighthouse (UK) is the lower right (Photo by Adam Mørk).

2. Methods and approach applied

Measurements of Indoor Environmental Quality (IEQ) included light levels, thermal conditions, indoor air quality, occupant presence and all occupant interactions with the building installations, including all operations of windows and solar shading. All sensors were part of the building control system, so each sensor was used for both control and monitoring. Each room is an individual zone in the control system, and each room is controlled individually. The building occupants can override the automatic controls, including ventilation and solar shading at any time. The IEQ measured data is recorded for each individual zone as an event log, and the event log files are automatically converted to data files with fixed 15-minute time steps, which are used for the data analysis.

As part of the evaluation, a Post Occupancy Evaluation (POE) survey is carried out seasonally during the test year allowing to capture and explore variation on a seasonal basis with approximately three months in-between [2]. The intent with four replies per house is twofold. Firstly, this is to identify if the occupants experience their perception changes during the stay; for instance – is their perception of indoor environment, expression, comfort or automation changing through their stay. The second aspect to the seasonal distribution is to explore if seasonal changes in weather (e.g. outdoor temperatures, daylight) influence occupant experience. In total 18 responses were made.

The overall purpose of the evaluations is to get indications on how successful the houses are, if there are challenges or problems, and what can be learned and improved.

3. From data to knowledge

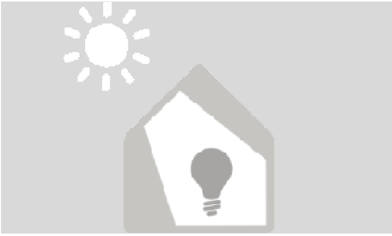
Studies show that most people on an average spend up to 90% of their lives indoors. The immense amount of hours in which we confine ourselves inside our homes, offices and public buildings not only increases the need for proper daylight and ventilation, but also raises the question of energy consumption. In Europe, buildings account for 40% of all energy consumption. This makes buildings a key component in terms of shaping a sustainable future with less CO_2 emissions and reduced global warming.

The Building Monitoring examines how these demonstration buildings perform in terms of daylight, thermal comfort, indoor air quality and ventilation. The paper focuses on an array of different subjects such as operation routines, temperature fluctuation and CO_2-levels and uses technical readings as well as personal feedback from the residents to create valuable knowledge on how to optimise the overall performance of the buildings. The collective results form a platform for discussion, definition and suggestion of a recommendation catalogue of conclusions for learnings transferred to the wider building stock, new as well as existing. This paper will illustrate how large data sets can be made coherent with visual representations intended to present information quickly and clearly

Daylight

Plenty of daylight usually requires big window solutions with lots of windowpane. For this reason, all buildings were designed for good daylight conditions, expressed by a target average daylight factor of 5% or higher in the main rooms, exceeding most national standards by a factor of 3 to 5. According to [3] with daylight levels of this magnitude, electric lighting will most likely not be used during daytime (see fig. 2). As an example of illustrating key point 1, the temporal map of lighting use (marked with blue bars) show, for every hours within a year, that in the morning, lights is switched on in the winter months, when it is dark outside, while sufficient daylight in the summer months, limit morning lighting use. Light use in the evening show a clear tendency of light switched on after sunset, which suggests that the daylight level affect the switching probability, while outside weather, day of the week has less impact. Similar switching patterns for the electric lighting use is found in the other houses. In addition, the residents in the houses support this key point by stating that they turn the electric light on “less often” (100%) than in their former home, and they evaluate the interior light levels as “appropriate” (>72%) in the main rooms.

The relatively large window area in the buildings is key to achieving these levels of natural daylight. However, it also raises the concern of excessive heating due to solar gain in the warmer seasons (see section Thermal Comfort), which is conveyed into key point 2.



Key point 1: Plenty of daylight eliminates your need for artificial lighting during the day

Key point 2: Having many large windows doesn’t necessarily lead to overheating

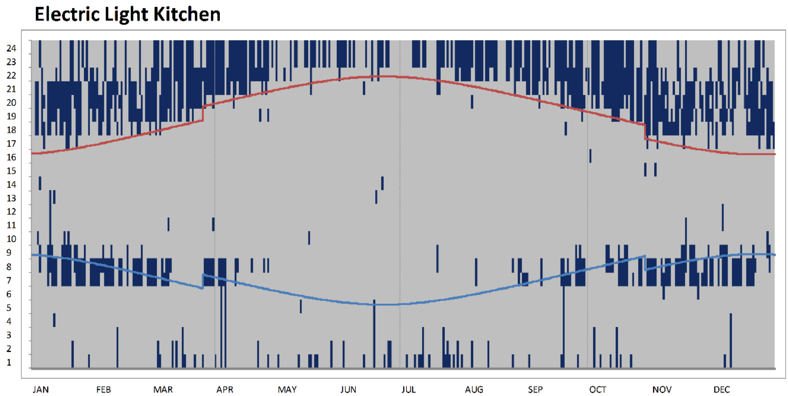


Fig. 2 Temporal map of measured lighting use, as dark blue colours, to support key point 2 (LichtAktiv Haus, kithcen). It show the day of the year mapped along the x-axis (January to December) and the time of day along the y-axis (0 to 24h). In the morning, lights is switched on in the winter months, when it is dark outside, while sufficient daylight in the summer months, limit lighting use. For the evening lighting use, the behavioral pattern show a clear tendency of light switched on after sunset, which suggests that the daylight level affect the switching probability, while outside weather, day of the week has less impact. Similar switching patterns for the electric lighting use is found in the other houses.

Thermal comfort

All buildings were fitted with awning blinds to control the incoming solar energy and maintain good thermal comfort. The awning blinds were mostly activated during the summer, but also during spring and autumn. The use of window openings follow the seasons; during spring and autumn windows are used on most days for approx. 50% of the time during daytime. During summer, windows are used more systematically during daytime hours, and also during the night.

Key point 3: Moderate bedroom temperatures ensure a good night's sleep

Key point 4: Good ventilation lowers the temperature during the night

Key point 5: Solar screening protects your home from overheating

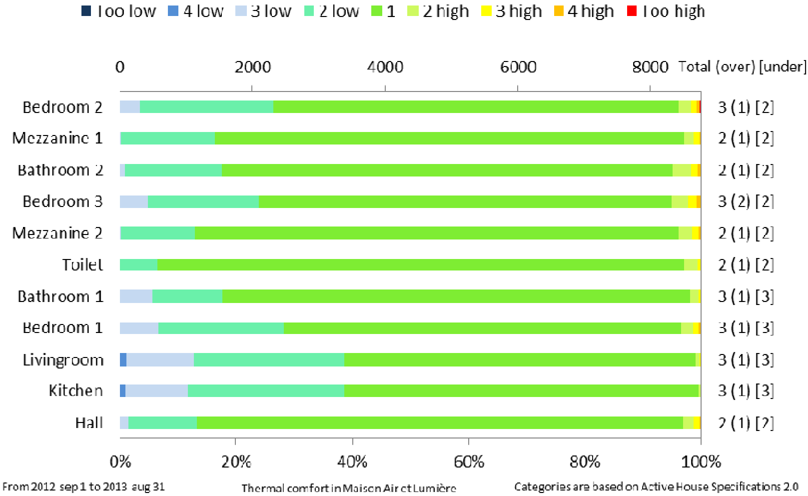


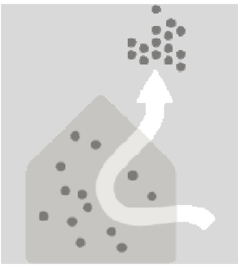
Fig. 3 Thermal comfort of Maison air et Lumiére support key point 3, 4 and 5, for each of the rooms evaluated according to Active House specification (based on adaptive method of EN 15251). Criteria are differentiated between high and low temperatures. Similar patterns for thermal comfort is found in the other houses.

Similar to window operation, the position of the blinds was registered throughout the day, monitoring the correlation between acceptable temperatures and the position of the awning blind. Combining those information together, there is a clear link that window opening and exterior solar screening is important to obtain good thermal comfort, and it consistently show that overheating has been prevented efficiently (see fig. 3). It is demonstrated by the fact that the buildings achieve category 1 according to the Active House specification for thermal comfort during summer (in less than 5% of the hours of the year is the temperature above category 1), which is based on adaptive method of [4].

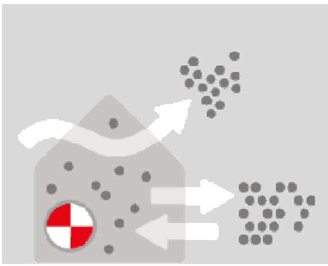
Ventilation

A healthy indoor climate relies on continuous ventilation to replace humid and CO_2 saturated air with clean, fresh outside air. The houses use natural ventilation for summer comfort and it is based on ventilative cooling principles. Ventilative cooling refers to the use of natural or mechanical ventilation strategies to cool indoor spaces. This effective use of outside air reduces the energy consumption of cooling systems while maintaining thermal comfort. The most common technique is the use of increased ventilation airflow rates and night ventilation [5]. The houses used natural ventilation in the warm season, while most houses used mechanical ventilation with heat recovery during cold periods.

The CO_2 levels in remained low during spring, summer and autumn due to heavy use of natural ventilation (key point 6). A mechanical ventilation with heat recovery will reduce the level of CO_2 and comply with the existing building codes. However, CO_2 levels may exceed 1,150 ppm and influence sleep quality in the bedroom, but the achieved CO_2 levels in the houses are reasonable low (see fig. 4).



Key point 6: Natural ventilation provides good indoor air quality during large parts of the year



Key point 7: Mechanical ventilation meets CO_2 level standards, but doesn't satisfy the increased demands for clean air in the bedroom

Key point 8: Good air quality in the bedroom can require targeted measures

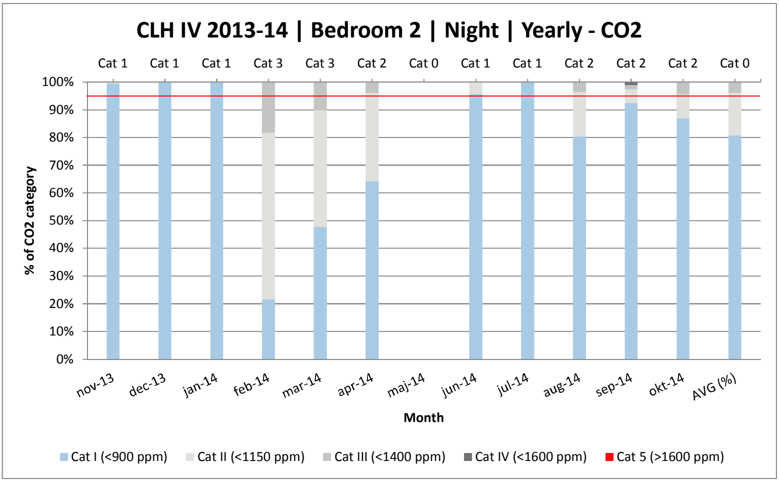


Fig. 4 Bedroom 2 in CarbonLight Homes. Monthly distribution of *night time* hours in each of five categories for CO_2 level, based on Active House specification. The CO_2-level is lower (better) during the summer than in winter. Similar patterns for thermal comfort is found in the other houses.

Automation important

Automated control of window openings, solar shading and mechanical ventilation were used in all the investigated buildings. The results show that the automated solar shading and window openings were used frequently during work-hours on weekdays, and during the night, e.g. at times when the families cannot be expected to be able to operate the products themselves (see fig. 5). The same use of products could not have been achieved with only manual products.

Key point 9: To get the full effect, you need intelligent automation

Fig. 5 Automated control of window openings, solar shading and mechanical ventilation were used in all the investigated buildings.

The families responded in the POE survey that they were generally "very satisfied" or "satisfied" (>85%) with the way the automated house system operated the facade and roof windows, the indoor temperature, internal and external screen, and ventilation system (one house used natural ventilation only). They had a clear feeling that the way the control unit operated the house supported their needs, and it was "easy" or "very easy" to use.

Improved sleep & reduced no of sick days

The room temperature when falling asleep has an influence on sleep quality and research suggests that it is preferable to have a lower room temperature during times of sleep than when awake. The families stated that they subjectively experienced sleep quality as being "better" (50%) or "almost the same" (39%), and when rating their children's sleep quality, the tendency was a bit higher ("better" 56%; "almost the same" 44%) compared to their former home. Furthermore, they experienced "less" sick days (83%) than in their former homes and they stated that their general health, all in all, was "good" or "very good".

4. Conclusions

All houses have good daylight conditions, and the results show that electric light under these conditions was not used between sunrise and sunset. The measurements show that good daylight conditions can be obtained without causing overheating, when solar shading and window openings are included in the building design and controlled automatically. Night cooling is a particular important aspect. It was found that high ventilation rates can be achieved also during summer with limited temperature difference is available as driving force.

The use of ventilative cooling during summer also meant that the ventilation rates were high in this period, and as a consequence the measured CO2-levels were low. The POE survey indicated that the families show high satisfaction with the indoor environment, that their expectations often are fulfilled, and that house automation is acceptable. Furthermore, combining excellent indoor environment with high quality homes, give clear indication that the residents experience better health and better sleep quality, as well as having less sick days than when living in their former homes.

References

[1] Alliance, A. H. (2011). Active House. Retrieved from Active House Specification: activehouse.info.
[2] Hammershøj Olesen, G. (2014). A Model for Enquiry of Sustainable Homes of Model Home 2020. PhD Thesis, Aalborg University. PhD Thesis, Aalborg University.
[3] CIBSE (2007). Code for Lighting, Oxford: Chartered Institution of Building Services Engineers.

[4] CEN Standard EN 15251:2007. Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.
[5] Venticool, the European platform for ventilative cooling. Published by Venticool. http://venticool.eu/faqs/.