INDOOR CLIMATE IN A DANISH KINDERGARTEN BUILT ACCORDING TO ACTIVE HOUSE PRINCIPLES: MEASURED THERMAL COMFORT AND USE OF ELECTRICAL LIGHT

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ABSTRACT

The Kindergarten Solhuset is built according to the Active House vision with an emphasize of good daylight conditions and fresh air. The house was completed in 2011, and detailed measurements of the indoor environment have been performed since the completion. The daylight performance is evaluated with daylight factor simulations. The main activity rooms have daylight factors of 7%, while the innermost rooms with only roof windows achieve a high daylight factor of 4%. Electrical light is used frequently in daytime during the winter, but much less frequently during summer.

The thermal environment is evaluated according to the Active House specification (based on the adaptive method of EN 15251), and it is found that the house reaches category 1 for the summer situation. Some hours with temperatures below category 1 are observed during winter, and the building achieves category 2 for the winter situation. It is found that ventilative cooling through window openings play a particularly important role in maintaining thermal comfort and that both window openings and external solar shading is used frequently

KEYWORDS

Thermal comfort; daylight; ventilative cooling; solar shading; kindergartens

1. INTRODUCTION

Childcare centres 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.

The vision for Solhuset (The Sunhouse) was to set new standards for future sustainable childcare centres. It rests on the Active House principles (Eriksen, 2011) 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.

Daylight and a healthy indoor climate play a vital role in Solhuset. From the very beginning, the vision was to create a building with a positive impact on its surrounding environment and daily users. There is a particular focus on good daylight conditions and fresh air from natural ventilation

Solhuset was developed in a strategic partnership between Hørsholm Municipality, VKR Holding A/S and Lions Børnehuse, and built by Hellerup Byg A/S in co-operation with Christensen & co arkitekter a/s and Rambøll A/S.It was completed in 2011.

Solhuset is laid out as a small village with streets, lanes, small squares and niches, and is divided into three zones: an arrival zone; a small children's zone with access to group rooms, an outdoor area and an open-air shelter; and a large children's zone with access to group rooms and the outdoor area. Common exercise rooms and eating facilities are placed in the middle of the house for easy access. It has high-ceilinged rooms and strategically placed windows to ensure optimum use of daylight. The sloping roof, with roof windows that open and close automatically, creates varied ceiling heights for good air circulation in the rooms.

Intelligently controlled sun screening and window opening make the house flexible, allowing the flow of daylight and fresh air to adapt continuously to the weather conditions outside and the needs indoors. Solhuset is built of sound materials that have minimal impact on the indoor climate. Vertical windows in the southeast and south-west facades and roof windows let in more than three times as much light as in a traditional house. A weather station on the roof, together with temperature and CO_2 sensors in every room, is used to control the indoor climate – protecting against overheating, ventilating with fresh air, and switching the lights on and off according to needs and weather conditions.

Figure 1. Solhuset (exterior, interior and floor plan).

Solhuset has the following characteristics:

- All rooms get daylight from at least two sides.
- Vertical windows with iron-free glass ensure that up to 85% of the light is transmitted through the windows.
- Plenty of fresh air is ensured by a combination of automatically controlled natural and mechanical ventilation with heat recovery (hybrid ventilation).
- Strategically placed windows ensure optimal use of daylight and adequate air flow.
- The special design and volume of the rooms, together with the use of sound absorbers, ensure a good acoustic climate.
- Use of healthy materials ensures minimal impact on the indoor climate.

Measurements of IEQ include light, thermal conditions, indoor air quality and occupant presence. Measurements of energy performance include space heating, domestic hot water and electricity for appliances, lighting and technical installations.

The present paper describes the performance of the house in relation to light and thermal comfort, particularly the natural ventilation system and the solar shading. Use of natural ventilation for summer comfort is based on ventilative cooling principles (Venticool, 2014). The presented results focus on the use of electrical light and the thermal conditions.

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.
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.

The data from the sensors that are used for the controls of the house is recorded. The IEQ data is recorded for each individual zone as an event log, where a new event is recorded when the value of a parameter has changed beyond a specified increment from the previously recorded value. The event log files are automatically converted to data files with fixed 15-minute time steps, which are used for the data analysis.

The recorded temperature data is evaluated according to the Active House specification (Eriksen, 2012), which is based on the adaptive approach of EN 15251 (CEN, 2007).

2. RESULTS

2.1 Light

Figure 2 presents calculated daylight factors. The building has an average 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. This gives a score of 2 according to the Active House specification. For the Active House parameter of Direct Sunlight Availability, the score is 1.

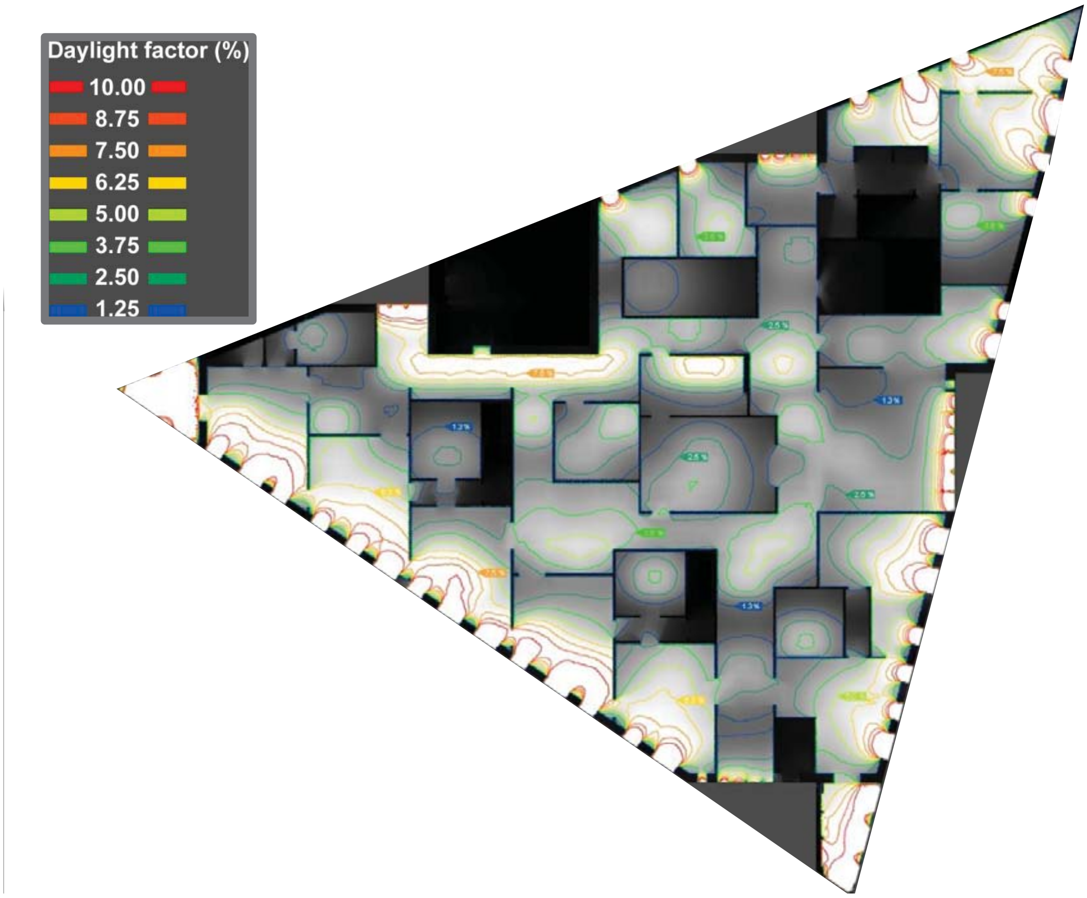

Figure 2. Calculated daylight factors in Solhuset.

The monthly lighting energy consumption varies naturally according to time of year; higher in the winter than summer. The overall lighting energy consumption in 2013 is 6100 kWh, which correspond to 4,7 kWh/m^2 (i.e. Solhuset is 1300 m^2) and only 1/3 of lighting use in commercial-sector buildings for six EU countries (average values of 15 - 18 kWh/m^2 according to Kofod. (Kofod, 2001). See Figure 3.

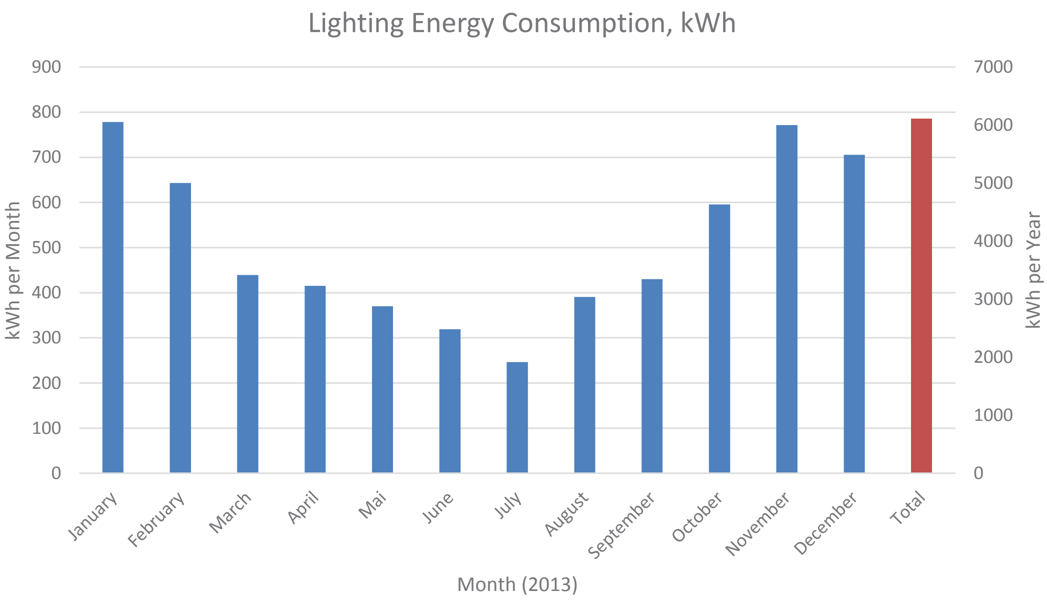

Figure 3. Monthly (blue) and total (red) lighting energy consumption (KNX_EM05_E) in kWh.

Measured lighting energy data (Figure 4) show each day of the year along the X axis and the time of day along the Y axis. In addition, the two curves mark the sunrise (blue) and sunset (red), and the curves are adjusted according to local time and Daylight Saving Time (DST). The colour map show blue colour for lighting energy consumption less than 500 Wh (mostly standby effect; around 60% of the total hours).

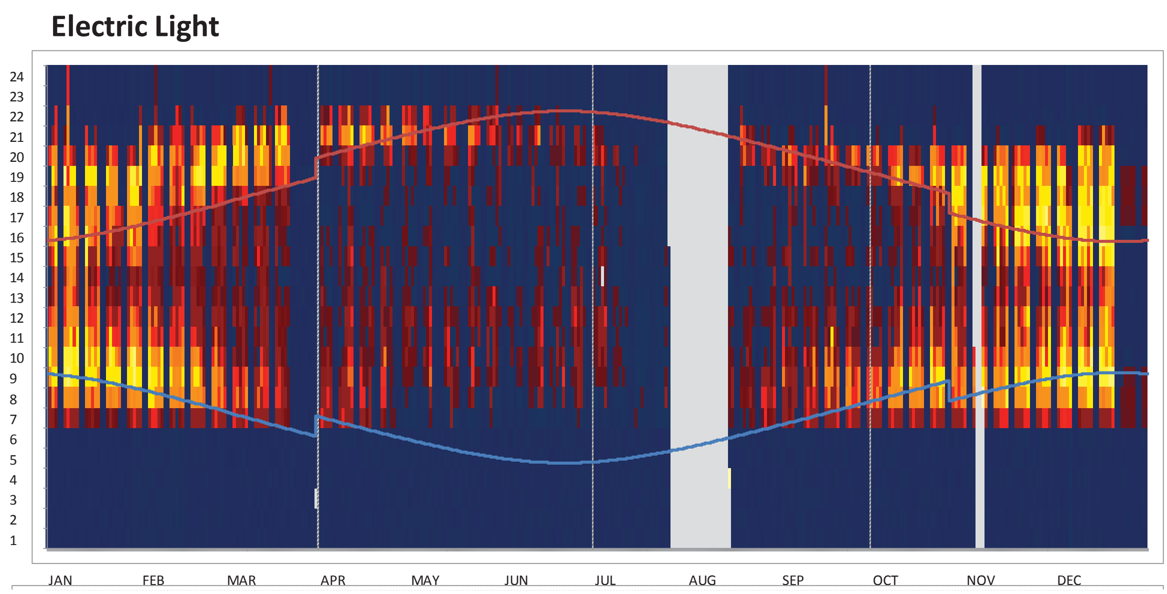

Figure 4. Temporal map of lighting use in Solhuset, 2013, including the sunrise (blue) and sunset (red). Lighting use and sunrise/sunset is according to local time, which account for Daylight Saving Time (DST). Measurements from August is missing.

The yellow and red colours reflect lighting energy use above 500 Wh, while the grey area has no measured data. There is a clear tendency that winter months have lights on most of the days (yellow/red), while the summer months show more frequent switch-off (blue). Furthermore, the switch-off in summer is more frequent in the afternoon than in the morning hours, which could be an indication that the staff of the kindergarten experience significant amount of daylight, while morning lights on is more a behavioural ritual. The results are based on the measurements from January 2013 to December 2013.

2.2 Thermal comfort

Figure 54 shows thermal comfort categories for 15 rooms in Solhuset, which represent the spread of different room types and functions in the building. Solhuset experiences practically no episodes with temperatures above category 1. This demonstrates that overheating has not occurred during the year of 2012.

Temperatures below category 1 are seen in all rooms. All rooms fall in category 2 for this reason, with the exception of two semi-outdoor rooms.

The focus of the present report is on the performance related to ventilative cooling and potential overheating. The further analyses will focus on the performance of group room 3, which is a representative room located at the perimeter of the building oriented towards south-west, which has a higher risk of overheating than other orientations.

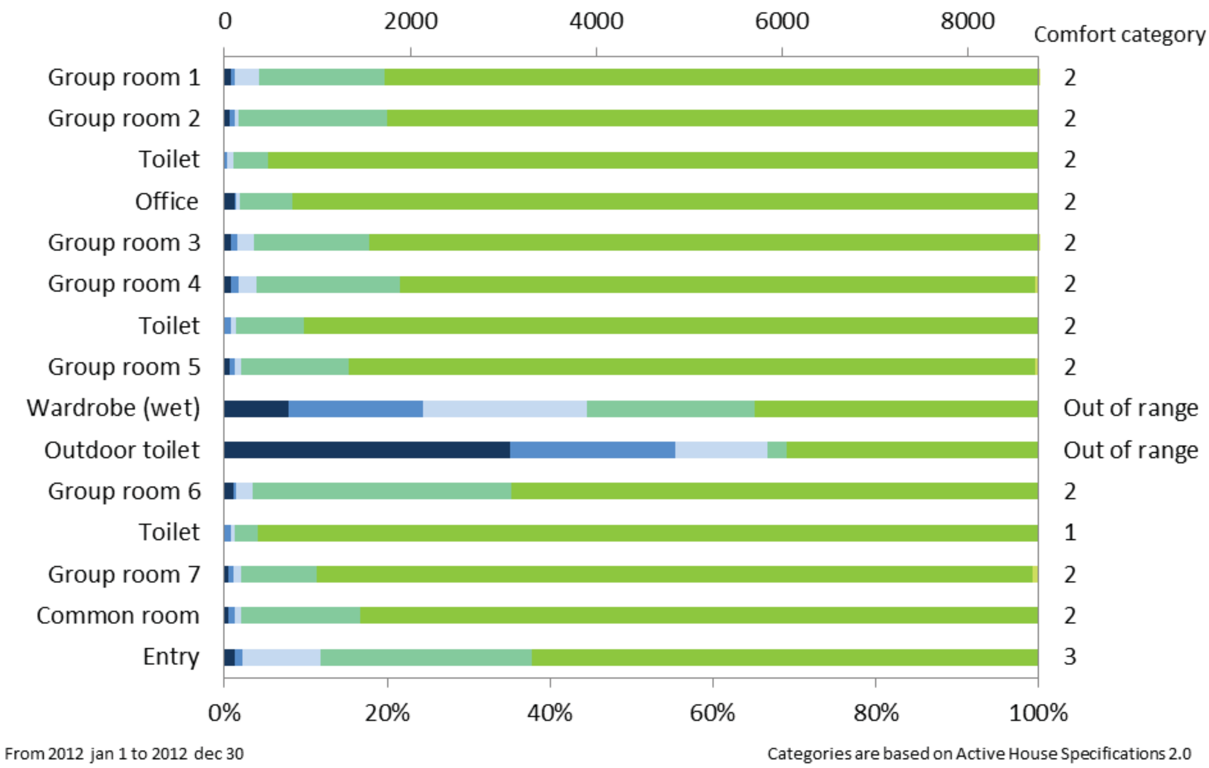

Figure 5. Thermal comfort for 15 representative rooms in Solhuset evaluated according to Active House specification (based on adaptive method of EN 15251). Criteria are differentiated between high and low temperatures.

Figure 6 shows the indoor temperature at each hour of the year plotted against the running mean outdoor temperature as defined in EN 15251. The figure shows Group room 3. The figure clearly shows that there are no hours with temperatures above category 1 (no overheating).

As seen before, the temperature in many hours during winter fall below category 1, with a few episodes with temperatures below category 2. There has been an issue with the heating system in the reported period which is part of the explanation why the temperatures are low.

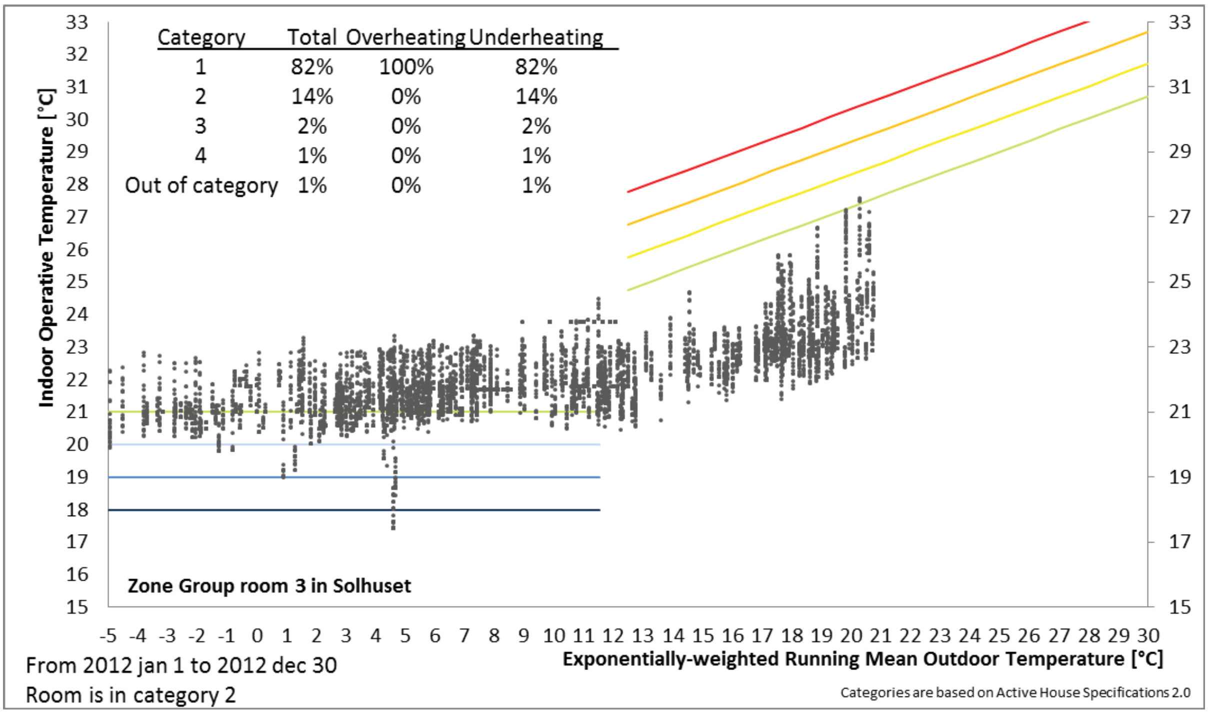

Figure 6. Measured indoor air temperature for Group room 3, plotted against the running mean outdoor temperature. Each dot represent the average temperature for an hour of the year.

The variation over time-of-day and time-of-year is further investigated in Figure 7. It is clear that the episodes with temperatures in category 4 or below are limited to two episodes, each lasting for two to four days. The hours with temperatures in category 2 (low) mainly occur during winter between 24:00 and 12:00, which indicates that the solar gains contribute to heating up the room from midday.

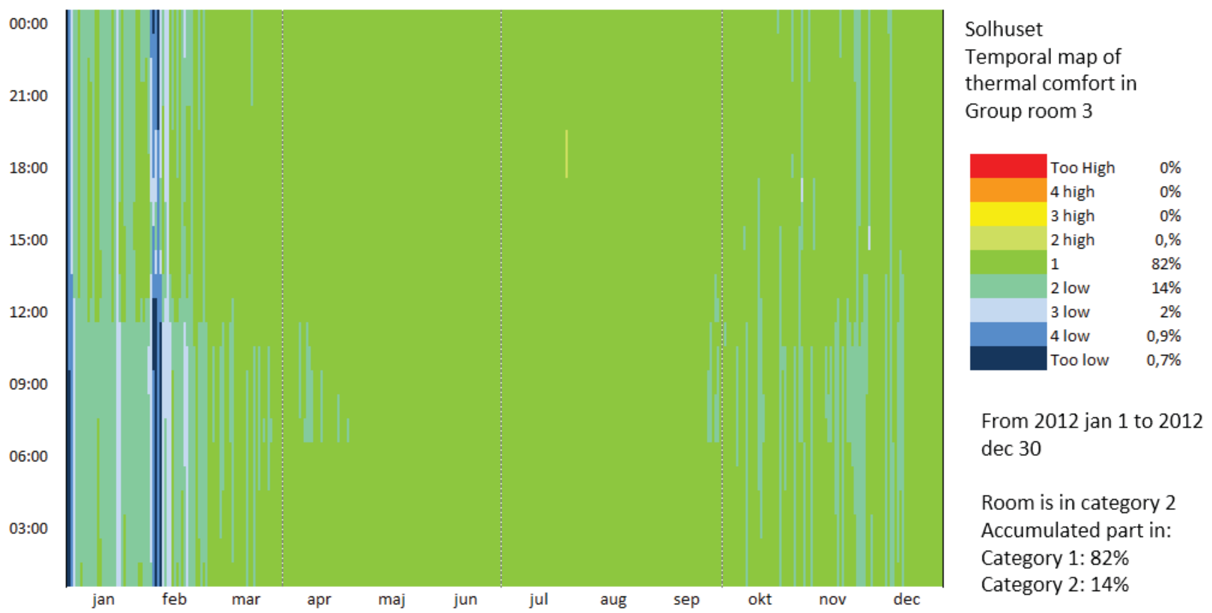

Figure 7. Group room 3. The comfort category of each hour of the year is plotted as a temporal map

Figure 8 Presents a temporal map of the same room as Figure 56, but Figure 57 also shows the use of windows in the room. Green or light green indicates that the temperature is within category 1 or 2, which is the case almost all the year. Light green indicates that windows are open in the room, dark green that they are closed. The figure shows that in the warmest period from June to the end of August, windows are open continuously from 07:00 to 19:00. Windows are also open during the night in this period, not constantly, but with airings at 22:00, 24:00 and 04:00 every day.

During almost all days of the year an airing at 07:00 seen, activated by the automatic control system. In the spring/autumn seasons, windows are used frequently during the day.
The combination of frequent use of windows and thermal comfort in the two best categories, underlines that windows have been important in maintaining good thermal comfort.

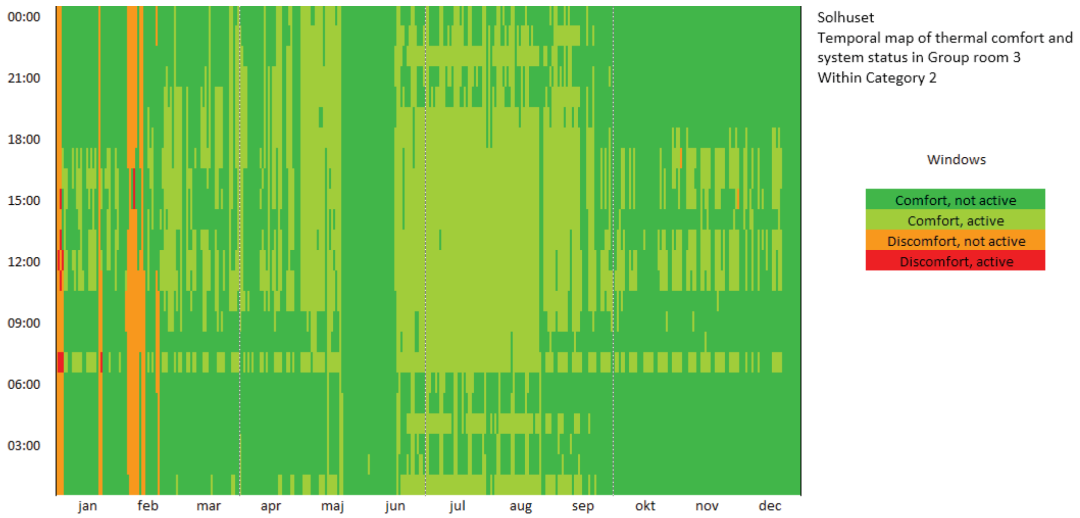

Figure 8 Temporal map for Group room 3 showing open or closed window in combination with thermal comfort category. Windows are marked as open, if one or more windows in the room are open For the sake of the illustration, category 1 and 2 are called “comfort”, category 3 and 4 are “discomfort”.

Figure 9 is similar to Figure 8, except that the use of awning blinds and not windows is shown. The figure shows that awning blinds are used almost constantly from January to May, which cannot be explained from the data alone. There is little or no risk of overheating during winter, so the use in this period must be caused by something else than prevention of overheating.

Figure 9 Temporal map for Group room 3 showing active or inactive awnings blinds in combination with thermal comfort category. Awning blinds are marked as active, if one or more awning blinds in the room are open For the sake of the illustration, category 1 and 2 are called "comfort", category 3 and 4 are "discomfort".

From June until December, the use of awning blinds is as could be expected to prevent overheating, with frequent, but not constant, use during daytime.

The frequent use of awning blinds underlines, that the awning blinds in combination with window openings were important for maintaining good thermal comfort.

3 CONCLUSIONS

Solhusets lighting energy use is low, and clear tendency of natural switch-on probability when outdoor light levels are low in the winter months. The summer months show less lighting energy use and more frequent switch-off probability due to plenty of daylight.

Daylight factors are 7% for the rooms near the facade, and 4% for the inner-most rooms, which is remarkable high for this type of building. The analysis shows Active House category 2, when the innermost part of the rooms are included, while direct sunlight availability is category 1 due to insignificant outdoor obstructions.

Solhuset is characterised with having no problems with overheating in summer. Temperatures do not exceed Active House category 1 for summer. Windows and awning blinds play an important role in maintaining good thermal comfort.

In winter, the temperatures in most main rooms are between 20°C and 21°C, which corresponds to Active House category 2. Category 2 is the standard category for normal, new buildings and considered as good performance.

4 REFERENCES

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