Solar Shading in Active House

Daylight is a central element in the Active House vision. In this article we show that solar shading is an essential building block that enables the Active House daylighting ambition. In a lot of practical cases, the daylighting requirements will necessitate substantial window size. Combined with the high thermal insulation needed to achieve a sufficiently low energy demand for heating, solar heat gain needs to be harnessed in order to meet the summer thermal comfort criteria of Active House.

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Daylight and view out

Daylight is a central element in Active House. Today, there is ample evidence for the importance of daylight for our health and well-being. Besides that, it is a freely available source of high quality light of high luminous efficacy (visible flux as a proportion of radiant flux, lm/W).

There are two objective metrics for the quality of daylight in the Active House specification. The first is the well known daylight factor, DF. The daylight factor measures the ratio between the interior horizontal illuminance and the unobstructed exterior horizontal illuminance under overcast sky conditions. An adequate daylight factor ensures that under worst case conditions (overcast sky) there still is adequate daylight. The specifications require a DF > 5% for the highest rating on this aspect or a DF > 3% for the second highest rating (averaged over the area of the space). It is clear that a high DF is directly related to large window size and is further influenced by obstacles in the immediate environment of the building. **Figure 1** shows a living room with an area averaged DF > 5.

The second metric applies to at least one of the main habitable rooms and requires that between the fall and spring equinox this room receives at least 10% of the probable sunlight hours for the highest rating on this aspect and at least 7.5% for the second highest rating. This second metric is clearly related to orientation – favoring south orientations – and takes obstructions in the environment into account. The specifications recommend that a shading device should allow for direct sunlight to be excluded if desired.

Energy Demand

At a ventilation regime of 0.2 ACH during the night and 2 ACH during occupancy (conforming to the Active House specifications), the annual energy requirement of the model living room for heating is only 3 kWh/m².a when heat recovery with an efficiency of 76% is used. The materialization of the living room is medium heavy and consists of R = 5.0 m²K/W external walls and triple glazing with U = 0.74 W/m²K, g = 0.51 and a visual transmittance of 0.69. The house is assumed to be located in Amsterdam and the glazed façade is facing south. Our living room is occupied between 7 and 22 h.

Thermal comfort

The daylight requirements above clearly have their consequences when it comes to thermal comfort. From the specifications: "Buildings should minimize overheating in summer and optimize indoor temperatures in winter without unnecessary energy use. Where possible use good building physics and clever solar shading instead of overcomplicated and energy intensive mechanical systems." The Active House specifications look at the operative temperature at room level and give requirements for the maximum in summer and the minimum in winter. In summer, the maximum operative temperature is related to a running mean outdoor temperature T_{rm} as defined in EN 15251. Summer is defined as the time of year when T_{rm} > 12°C. In the climate data used in our simulations there were 150 summer days according to this definition. The summer requirement for the operative temperature reads: $T_{op} < 0.33 \times T_{rm} + T_c$, with $T_c = 20.8°C$ for the highest category (Class 1) and 21.8°C for the second highest category (Class 2). These requirements are to be met during 95% of the occupied time, which in our case translates to a maximum of 113 h during which the requirement may be exceeded. **Figure 2** shows the operative temperature for our south oriented living room. From **Figure 2** it is clear that a DF > 5 and good thermal comfort are conflicting requirements without any further measures.

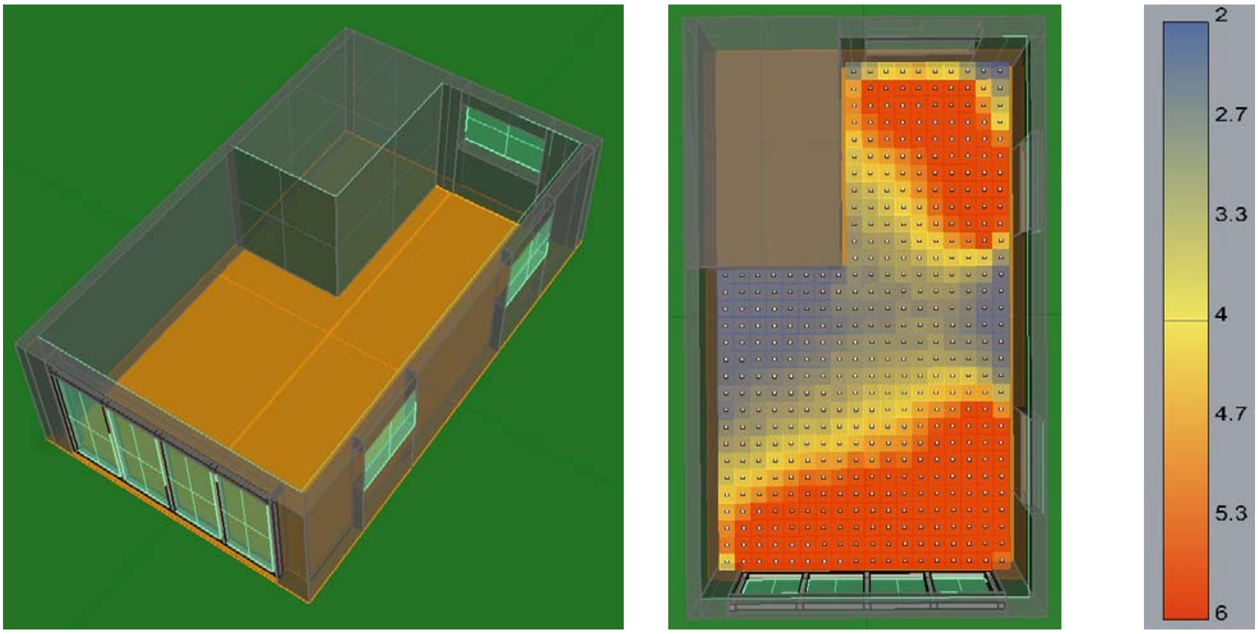

Figure 1. Model living room having an average daylight factor DF of 5.3% at a height of 0.85 m above the floor. From the model it is clear that a daylight factor > 5% requires a fair amount of glazing. The window to wall ratio in this case is 17%. It is also clear that there is quite some variation over the surface of the room: 49% of the area has 2% < DF < 5%, 42% of the area has DF > 6% and 9% of the area has DF < 2%. Without the two windows at the right, the DF drops to 3.7%.

Since our living room is thermally well insulated, accumulated heat will not easily escape. That is desirable in winter, but not so in summer. Ventilation obviously helps to cool the building mass when ambient temperatures are lower than the operative temperature. Therefore, we increase the ventilation rate to 2 ACH at all times during the summer season.

Exterior shading is the passive solution that can reconcile the daylight and thermal requirements. **Figure 3** shows the operative temperature of the living room fitted with external Venetian blinds. These blinds are lowered whenever the vertical irradiance on the façade exceeds 140 W. When deployed, the slat angle of this blind is continuously kept in block beam solar mode. This means that the slat angle is such that just prevents direct sunlight to pass between slats. Whereas this mode of operation may not be the one keeping out the maximum amount of heat, it does allow daylight to enter as much as possible, both as diffuse radiation from the environment and as reflected radiation from the sun. In this respect it is interesting to look at the slat angle over the year. On a south façade, there are a lot of hours that the blind will prevent the entrance of direct solar radiation when fully open. Under these circumstances the view of the outdoors is unimpeded. **Figure 4** shows the block beam slat angle for the south facing window. Here, the slat angle is defined as the angle between the normal of the glazing and the normal vector of the slat, i.e. 90 is fully open, 0 is fully closed.

Besides preventing unwanted solar heat gain, the shading also has a significant effect on the temperature of the window pane. Without shading surface temperatures get as high as 43.5°C. The same window fitted with an external Venetian blind has substantially lower surface temperatures, down to 32.5°C. This is of course reflected in the operative temperature of the room.

Active controls

If one considers the variability of solar radiation during the day and over the year, the challenge of using sunlight and daylight is control.

Active House encourages the application of active and integrated controls: "Through an easy and user friendly interface, a building management system (BMS) may control an Active House." For the blind described in the previous section to function, the basic controls or actors are readily available. Further integration of these controls has advantages and is in fact needed. **Figure 4** shows when the blind is deployed according to an irradiance set point of 140 W/m^2. It is quite clear that such a static set point is not desirable in winter because the blind will block valuable solar energy useful for passive heating. A more advanced strategy to deploy the blind is needed.

It was already stated that block beam solar is not necessarily the most effective mode to control solar heat gain. When coupled to a BMS, it is easy to detect temperature

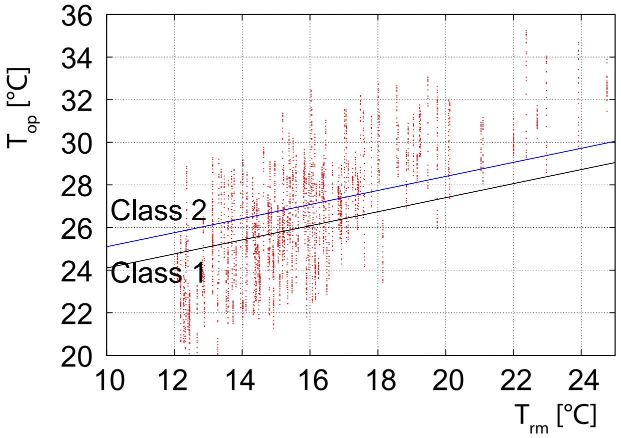

Figure 2. Operative temperature in the living room without solar shading. The Class 1 requirement is exceeded during 2067 h (57% of time), for Class 2 this is 1544 h (43% of time).

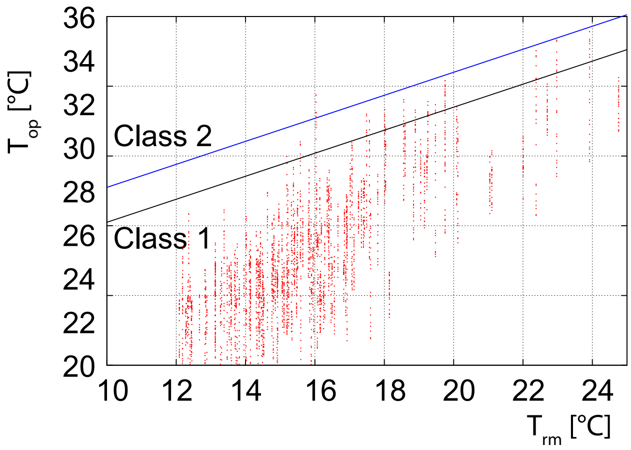

Figure 3. Operative temperature in the living room fitted with external Venetian blinds. The Class 1 requirement is exceeded during 76 h (2.1% of time), for Class 2 this is 7 h (0.2% of time).

exceedance in the space and override the standard slat angle control to a more closed state of the blind, thus further reducing solar heat gain. Likewise, it is possible to use the signal of an occupancy sensor. If there's no one in the room, daylight is not an issue and fully closing the blind will maximally keep out solar heat and keep the room cooler. Whenever the user enters the space, the management system sends a message to the blind controller to revert to daylighting mode. Active and integrated control of a blind clearly has both comfort and energy benefits. Individual control – the ability of the occupants to directly influence their environment from a comfort perspective – is an important requirement within Active House. This translates to the BMS and underlying controllers. Firstly, they should facilitate such interventions. Secondly, the logic should be robust and be able to deal with them. Thirdly, there should be a mechanism that returns the system to its energy-comfort optimal routine after a predefined time or user action.

There are numerous other possibilities to use an active blind. Reducing thermal heat loss during winter by closing a blind at night is a possibility. This will also reduce condensation at the exterior pane of triple pane glazing during cold nights. Although not really an energy or comfort aspect, it is nonetheless valued by home owners.

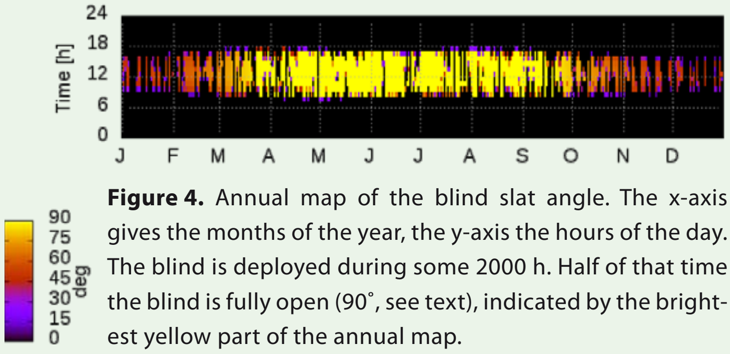

Figure 4. Annual map of the blind slat angle. The x-axis gives the months of the year, the y-axis the hours of the day. The blind is deployed during some 2000 h. Half of that time the blind is fully open (90˚, see text), indicated by the brightest yellow part of the annual map.

Hunter Douglas and Active House

Hunter Douglas has been a contributor to the Active House Alliance since its inception. Our philosophy of Sustainable Comfort seamlessly integrates with the Active House vision.

We are currently working on the practical application of solar shading and the control strategies touched upon in the previous sections in a research project called Active Reuse House. Participants in this project are amongst others the Rotterdam University of Applied Sciences, the city of Rotterdam and the housing cooperative Woonbron. In this project a consortium aims to design, construct and evaluate an Active House in a reuse context for building materials.

The Hunter Douglas Energy Tool

Hunter Douglas developed a tool can be used to make analyses similar to the one presented in this article. This tool is available for download at: tools.hde.nl/energytool2/index.html. It contains the characteristics of our shading solutions and allows the comparative evaluation of different designs and shading strategies.

Conclusion

In this article we've explored the role of solar shading in Active House. In practice, the daylighting requirements will often necessitate substantial window size. High thermal insulation and air tightness are needed to achieve a sufficiently low energy demand for heating. In order to meet the summer thermal comfort criteria of Active House, an active shading strategy is essential if mechanical cooling is to be avoided. Building physical simulation is an essential tool for engineering an Active House. Integration of the shading and ventilation strategy in the context of a building management system appears to be essential. ■