somfy.com

Comparison of control strategies for shading devices

Sebastian Herkel – Tilmann Kuhn – Jan Wienold

Fraunhofer Institut Solare Energysystem ISE

Fraunhofer Institut Solare Energiesysteme ISE

somfy

Inhalt

Summary

Using a thermal and lighting simulation model of the 14 floor office building ‘Heinemannstraße‘ in Bonn five different control strategies for an external venetian blind were evaluated. The tools used were RADIANCE for the lighting simulation and ESP-r for the thermal building simulation. ESP-r was extended to handle bidirectional data for the solar transmittance and the total solar energy transmittance “g” for the façade. The façade consits of a heat mirror glazing (gDGU = 0.6) in combination with an external metallic-grey venetian blind. The Somfy control strategy used in ANIMEO was implemented.

The five evaluated strategies are

- No shading
- Radiation control (closed at 150 W on the façade)
- Somfy “Performance“ without sun path tracking. This stragegy is referenced in the text as “performance” mode.
- Somfy „Performance“ with sun path tracking. This strategy is referenced in the text as “cut-off” mode
- Manual control

The energy demand for heating is lowest for the case “no shading” and “manual control but at the cost of high cooling loads in summer and uncomfortable visual and thermal conditions. The Primary energy demand for the three strategies with automatic control is in the same range, changing the order depending on given boundary conditions like additional overhangs or the switch on illuminance level for the lighting. The “cut-off” mode leads to a lower energy demand for lighting but to a slightly higher cooling energy demand in summer.

The visual comfort of the simple radiation controlled strategy is lower compared to the cut-off mode, as at most of the office hours the blinds will be closed and no view out is possible. The thermal comfort achieved is reasonable for the radiation control mode and the “performance” mode at the cost of a reduced visual comfort. With the “cut-off” strategy the temperatures are slightly above the comfort level, with the manual control or without a shading device it exceeds the comfort temperatures by far.

2 Goal and Methodology

2.1 Goals

The goal of this simulation study is a comparative analysis of algorithms to control shading devices. The analysis is regarding energy demand, thermal an visual comfort. This study had to be performed using a model of an existing, typical building.

2.2 Calculation method

2.2.1 Heating and indoor climate

The annual heating and cooling energy balance will be calculated by the following tools and standards. The dynamic simulation will be used for room temperature as well:

- Dynamic building simulation environment ESP-r[1].
- Building physical properties according: DIN 4108[2].

2.2.2 Daylight and electrical energy demand

- Daylight Coefficient method using the program RADIANCE[3]. This program is based on raytracing techniques.
- The calculation of daylight autonomy and annual time series of indoor illuminances and the electrical energy demand for lighting is done by the RADIANCE based program DAYSIM[4].

The maximum lighting consumption is calculated with a power of 12 W/m². The lighting is on during office hours. It is switched off when the daylight illuminance level is higher than 300 lux at the workplace.

- The electrical consumption for fans or pumps will not be evaluated.

2.2.3 Calculation of primary energy demand

The primary energy demand respective the primary energy savings are the most important value to characterize the energy efficiency of the different algorithms.

Within this study the following primary energy conversion factors were used, which are most common in Germany:

***Tab. 1** primary energy factors*[5]

Heat	1,1 kWh_{PE}/kWh_{heat}
Electrical energy	3 $kWh_{PE}/kWh_{el.}$

As primary energy supply natural gas is chosen. This has a primary energy factor of 1.1. The electrical energy demand will be valued with a factor of 3. The Coefficient Of Performance (COP) of the cooling unit was assumed to be 3.

The Primary Energy demand is calculated according the following equation: $Q_{PE}=Q_{HEAT}*1.1+Q_{LIGHT}*3+Q_{COOL}*1/3*3$

2.3 Modelling of sun shading devices and shading control

The glazing used is a double glasing unit with a low-e coating on position III (external surface of inner glazing).

The shading devices are metallic grey coated external venetian blinds with 80 mm slat width.

Within this study four different control strategies were analysed:

- no shading (reference case)
- Manual control
- Radiation control
- Somfy "Performance" without sun path tracking. This stragegy is referenced in the text as "performance" mode.
- Somfy "Performance" with sun path tracking. This stragegy is referenced in the text as "cut-off" mode.

The reference case without shading device is not a realistic case. It is only used for comparisons. The control strategies are explained in detail below.

[1] ESP-r, Version 10, 2/2006, University of Strathclyde, ESRU, Glasgow UK
[2] Norm vom März 2001, DIN 4108-4 bis DIN 4108-7
[3] RADIANCE Version 3.1.8, LBL, Berkley CA, USA
[4] DAYSIM Version 1.1 7/2002, Fraunhofer ISE, NRC Canada
[5] source: ENEV / DIN 18599 V

2.3.1 g-value

The thermal and optical properties of the venetian blinds have been calculated with the façade models developed at Fraunhofer ISE[6]. With this models, the gvalue of the DGU was calculated bidirectionally as function of solar azimuth and solar height angle with a step-width of 5°. This means that we used a matrix of 1369 data points for every defined slat angle. We calculated the blind properties for slat angle-steps of 5°.

Within this study the simulation tool ESP-r was extended in that way, that even with this detailed, bidirectional calculation a switching of the optical properties was enabled.

Additionally the code was changed in order to allow to use external control strategies for shading devices like the sophisticated Somfy "Performance" control.

2.3.2 Control-Mode: Solar radiation controlled

A solar incident irradiation based control is a very often used method within thermal building simulation. The shading device is activated at a set point of 150 W vertical global irradiation on the facade, regardless of the office hours or the status of the heating. In this study it is assumed, that the slats have maximum closing angle of 72° and that the slats are closed completely, when they have been activated automatically.

2.3.3 Control-Mode: Somfy "Performance"

The control algorithm of Somfy ANIMEO is implemented as follows: Heating mode: During heating season the shading device will be opened on weekends and non office hours. In heating-off season the shading device will be closed in non working hours. Control by vertical illuminance on the facade: During office hours the shading device will be activated, if a set point of 25.000 lux is exceeded. The shading device will be re-opendend, if the illuminance is below a set point of 15.000 lux. The calculation of the illuminance values is done by the lighting calculation tool RADIANCE and is fed into ESP-r.

Security functions like wind control, frost and rain protection are not used within this study, as they act for all strategies the same way and have minor influence on the energy and comfort performance of the shading control. In this study it is assumed, that the slats have a maximum closing angle of 72° and that the slats are closed completely, when they have been activated automatically.

2.3.4 Control-Mode: Somfy "Performance" with sun path tracking

The control is done with the same criteria regarding heating mode and illuminance as described in 2.3.4 but the slat angle of the lamellas is automatically controlled to be in "cut-off" position according to the actual location of the sun. The angles and times have been calculated externally by ANIMEO and used. The slat angles are classified in steps of 5°. ESP-r was extended in order to enable different slat angles bidirectionally.

2.3.5 Manual control

The manual control of the shading device has been implemented according to the „Lightswitch 2002" algorithm to describe user behaviour regarding blind control[7]. The basic result of ongoing research is, that users tends to close the blinds if direct sun light hit the working desk and accepts higher luminance values if they can achieve a good look out. The algorithm separates two cases:

- Low sun height angle (< 60°): The user closes the blind, if a specific set point for the luminance is exceeded
- High sun height angle (> 60°): The blind remains open

The algorithm was implemented in ESP-r by D. Bourgeois within a newly algorithm to model user behaviour: "SubHourly OCcupancy Control (SHOCC)". In this study it is assumed, that the slats have a maximum closing angle of 72° and that the slats are closed completely, when they have been activated automatically.

[6] [Kuhn 2006a] T. E. Kuhn. "Solar control: A general evaluation method for facades with venetian blinds or other solar control systems" Energy and Buildings, Vol 38, Issue 6, pp 648-660, June 2006. http://dx.doi.org/10.1016/j.enbuild.2005.10.002 [Kuhn 2006b] T. E. Kuhn. "Solar control: Comparison of two new systems with the state of the art on the basis of a new general evaluation method for facades with venetian blinds or other solar control systems", Energy and Buildings, Vol 38, Issue 6, pp 661-672, 2006. http://dx.doi.org/10.1016/j.enbuild.2005.10.001.

[7] C. Reinhart, Lightswitch 2002, NRC Canada

3 Example: Heinemannstrasse Bonn

The "Heinemannstraße" building in Bonn with 14 floors is a real estate of the German government. It was built in 1973 and is under reconstruction. It has a band facade, where within the renovation an external shading device was applied.

3.1 Building description

3.1.1 Building and simulation mode

Fig. 1 *South West corner of the building located in Bonn*

The main data of the building is presented in Tab. 2. For the simulation study a segment of one floor and a typical office room was chosen.

Tab. 2 *Main characteristics of the building*

Volume (gross)	95.270 m³
A/V- ratio	0,29 m²/m³
Heated gross area	ca. 30 000 m²
Heated gross area	appr. 13 900 m²
Main used area (1.-11.OG)	appr. 8 000 m²
Operation time	Mo-Fr from 6^{00} to 19^{00}

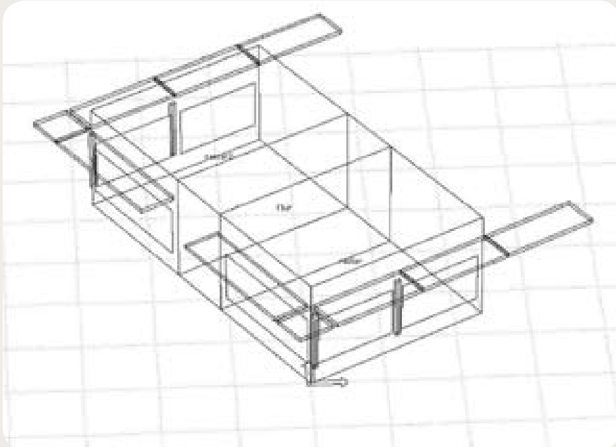
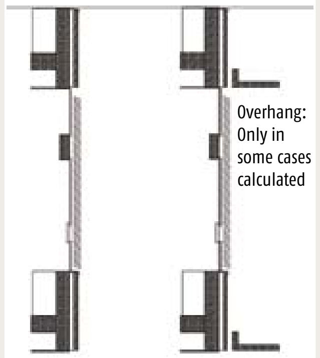


Fig. 2 *Simulation model of the two offices used in the simulations with ESP-r The grid is rectangular to East/South orientation*

3.1.2 Facades

In Tab. 3 the facade is described. There are two cases evaluated, one with a static overhang, one without.

Tab. 3 *Facade: Glazing and shading device*

Description	Low-e double glass unit 75/58 with external venetian blinds
Schematic cross section with and without overhang	
Construction	Concrete wall with external insulation (mineral wool), thermally insulated aluminium frames
U-vaule of façade	1,4-1,6 W/m²K
g-value open/ cut-off/ closed	58% / 15-20% / 7-10%
light transmission	75%

3.1.3 Internal loads

A space of 10 m² is available for each person in the building under consideration. Based on this, the internal loads for equipment (PC, printer etc.) were calculated to be 30 W/m² peak load. The sensible load for persons is 80 W respective 8 W sensibel/m². The daily load curve can be seen in Fig. 3. Weekends are treated as night time.
Loads are given Fig. 3.

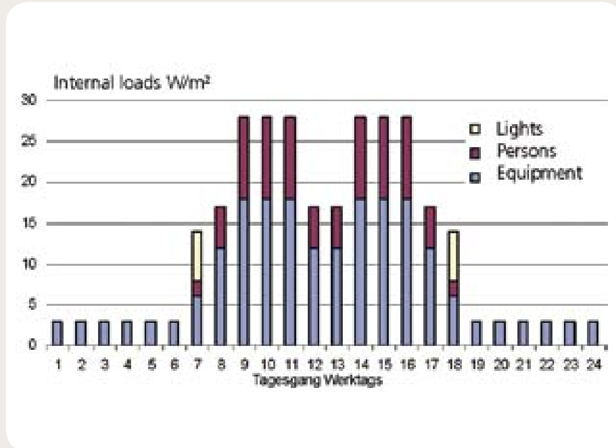


Fig. 3 *Daily load curve on weekdays. The loads due to lighting are evaluated separately and shown here only for illustration.*

3.1.4 Heating and cooling set points and air change rates

The offices have a heating set point of 20°C and a cooling set point of 24°C. During Night time and on weekends the heating set point is 16°C. There is no humidification or dehumidification. In order to evaluate the comfort, the building is calculated as well without a cooling set point. The air change rate in the offices on working days from 6^{00}–19^{00} is 40m³/Person which is equivalent 1.3 AC/hour At room air temperatures >22°C the air change rate is increased to 4 AC/h.

3.1.5 Climate

The basis fort the calculation ist the German Test Reference Year Nr. 13 in the edition of 2005 (Passau), which is a representative German climate. The Test Reference Years (TRY) are developed on the base of measurements from 1960-1990. They are typical years, not extreme ones.

4 Results

4.1 Energy

4.1.1 Relationship between solar control, lighting and energy demand

The control of shading devices effects two parts of the end energy balance of a room or building: The less the shading device is used, the higher are the solar gains and the lower is the energy demand for lighting.
In winter this causes a decreasing energy demand for heating and a decreasing energy demand for lighting. As second order effect the heating energy demand will be less reduced, because the internal loads due to lighting has to be substituted by heating.
In summer the effect is the other way round: The cooling loads are reduced by the use of shading devices as long as the light is not switched on due to lower Iluminance levels.
Due to the relationship between lighting, solar loads on the one hand and the heating and cooling loads on the other, the effect of controlled shading devices on the energy demand is some times counter intuitive and strongly belongs to the given boundary conditions like installed lighting power and given set points.

4.1.2 Typical days

The following figure gives the status of the shading device, the solar loads and the lighting loads for two typical days, one in January and one in April. The plots of the absorbed solar gains for the control mode "without shading device" and "Performance with cut-off" shows on the winter day no activation of the blinds, the lights are switched on in the morning and evening (Fig. 4).
On the spring day, the blinds were activated in the "Performance with cut-off" mode. During the course of the day, the blinds were adjusted resulting in a stepwise change of the absorbed solar gains (Fig.5).

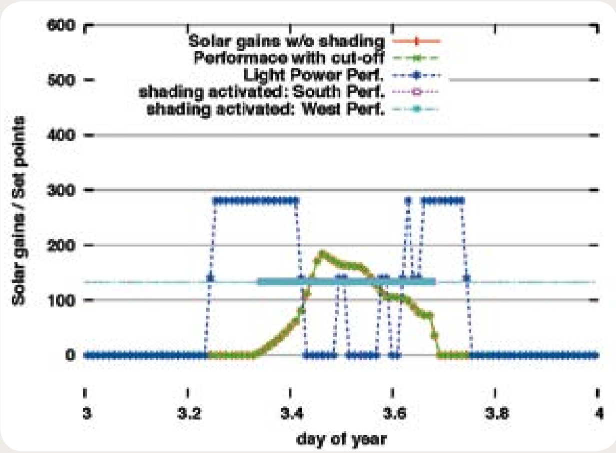


Fig. 4 Typical Winter day with cloudy sky and low irradiation. The "shading activated" curves show the status of the shading control, "130" equals a fully retracted shading and "2000" a fully closed shading.
Intermediate values gives othe positions in the cut-off mode. It is differientiated between South and West orientation.

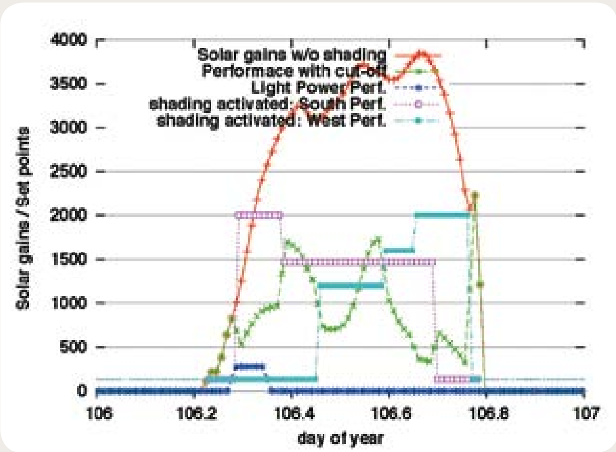


Fig. 5 Typical spring day with sunny sky and high irradiation on the facade. "2000" equals a fully closed shading (72° slat angle)

4.1.3 End Energy balance

The balance of the end energy is given in fig. 6. The manual controlled case and the case without control show a slightly lower heating energy demand and a significant higher cooling energy demand. The lighting energy decreases with the use of the cut-off strategy compared to a simple on-off strategy used by irradiance control or illuminance control with hysteresis. The cooling demand increases with a more user adapted control strategy, which allows a better view out in the sunny periods.

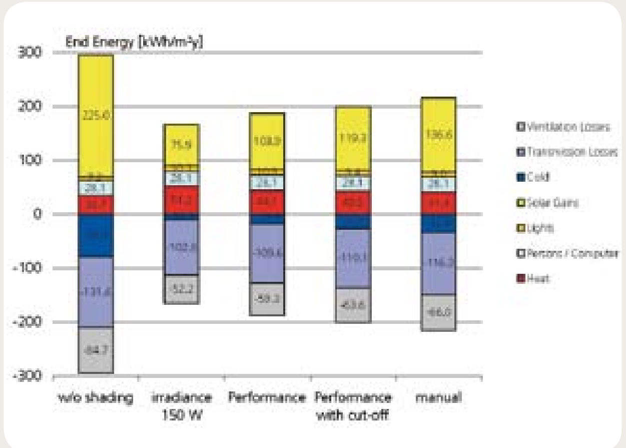


Fig. 6 Comparison of the specific annual end energy balance for different control strategies of the shading device. Here the results for the case without overhang for an requested illuminance level of 300 Lux are shown.The specific energy demand is calculated on the results for the two office rooms and corridor as shown in Fig. 2

The monthly energy distribution for the control strategies "without shading" and "Performance with cut-off" are given in Fig. 7 and Fig. 8.

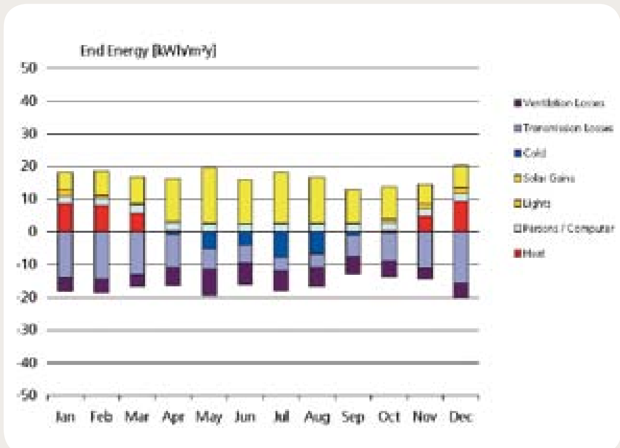


Fig. 7 Specific monthly end energy balance for the control strategy "Performance with cut-off". Here the
results for the case without overhang for an requested an illuminance level of 300 Lux are shown.

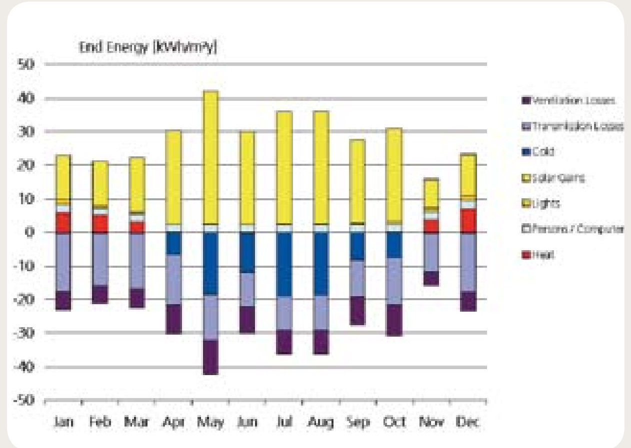


Fig. 8 Specific monthly end energy balance for the case without sun shading. Here the results for the case without overhang for an requested illuminance level of 300 Lux are shown.

If the illuminance level, at which the lights are switched on is reduced to 150 Lux or if an additional overhang is attached to the facade the end energy balance changed (Fig. 9,Fig. 10, Fig. 11). The reduction of the lighting loads results in reduced cooling loads and a slightly increased heating demand.

The overhang reduce the solar loads and reduce the effect of a more sophisticated control like the "Performance cut-off" mode.

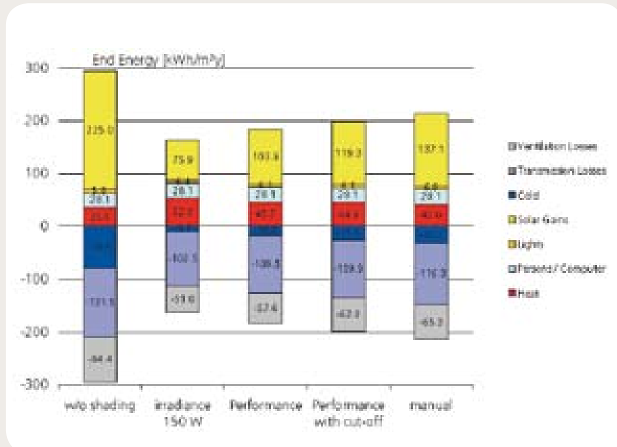


Fig.9 Comparison of the specific annual end energy balance for different control strategies of the shading device. Here the results for the case without overhang for an requested illuminance level of 150 Lux is shown.

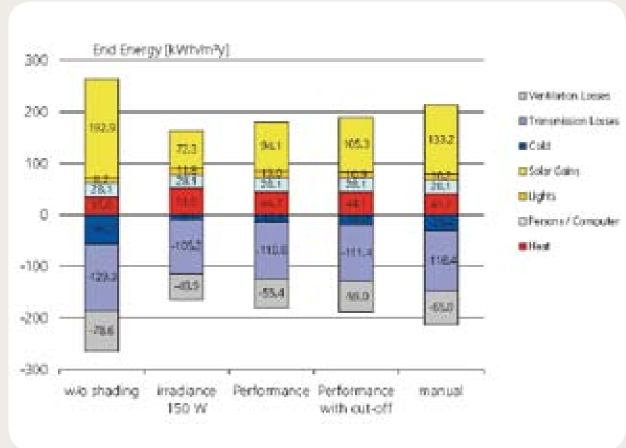


Fig. 10 Comparison of the specific annual end energy balance for different control strategies of the shading device. Here the results for the case with overhang for an requested illuminance level of 300 Lux are shown.

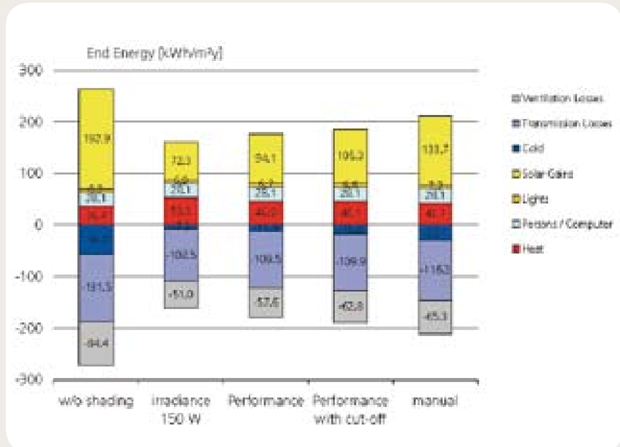


Fig. 11 Comparison of the specific annual end energy balance for different control strategies of the shading device. Here the results for the case with overhang for an requested illuminance level of 150 Lux are shown.

4.1.4 Primary energy demand

In order to evaluate the global influence of the control strategies on the energy balance, the primary energy (PE) is evaluated for the five strategies. The primary energy demand for heat, cold and light is given in Fig. 12.

The highest PE demand is needed using no shading devices, followed by the manual control. The difference between the automatic control modes is small, even though the irradiance control has the lowest PE demand. The comparison between "performance" and "performance with cut-off" mode leads to the following conclusions: The building is summer dominated, so the higher solar load reduction by using the cut-off tracking of the blinds effects the balance more than the reduction of the heating energy and of the lighting energy.

If the boundary conditions changes (overhang, Illuminance level for lighting activation), the order of performance changes between the different control strategies (Fig. 13, Fig. 14, Fig. 15). With the overhang and a illuminance level of 300 lux the cut-off strategy performs best.

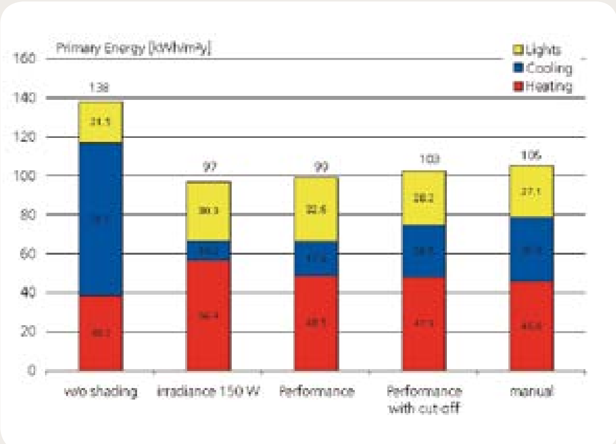


Fig. 12 Comparison of the specific annual primary energy demand for different control strategies of the shading device. Here the results for the case without overhang for an requested illuminance level of 300 Lux are shown. The primary energy demand is calculated on the results for the two office rooms and corridor as shown in Fig. 2

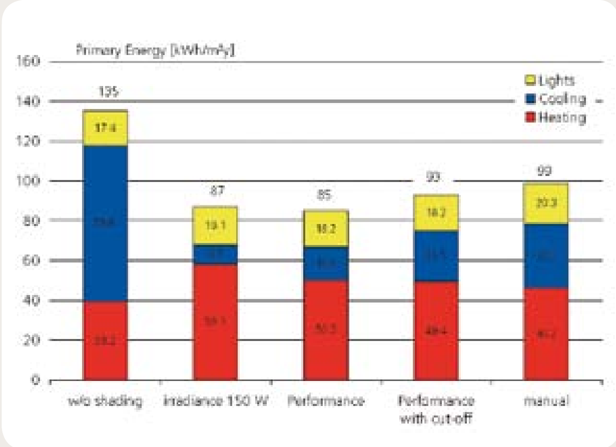


Fig. 13 Comparison of the specific annual primary energy demand for different control strategies of the shading device. Here the results for the case without overhang for an requested illuminance level of 150 Lux are shown.

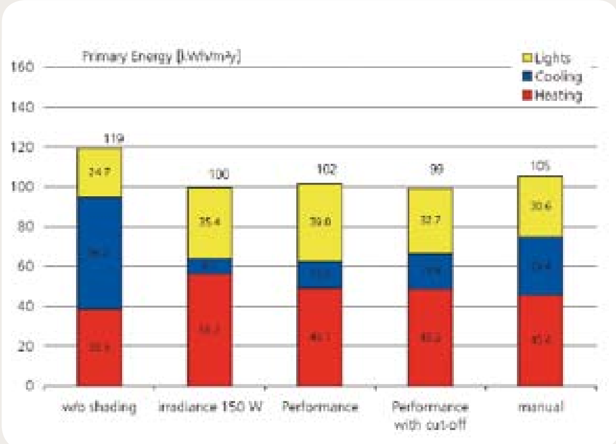


Fig. 14 Comparison of the specific annual primary energy demand for different control strategies of the shading device. Here the results for the case with overhang for an requested illuminance level of 300 Lux are shown.

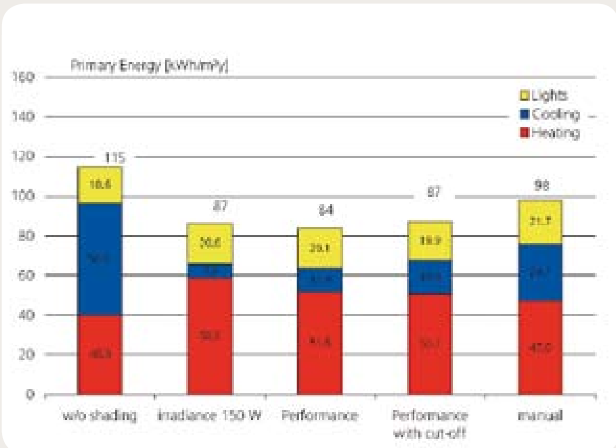


Fig. 15 Comparison of the specific annual primary energy demand for different control strategies of the shading device. Here the results for the case with overhang for an requested illuminance level of 150 Lux are shown.

4.2 Comfort

The comfort for the different control strategies was evaluated in the following way: the visual comfort was evaluated qualitively, the thermal comfort was evaluated for a not actively cooled building.

4.2.1 Visual comfort

Two of the strategies, the "without sun shading" and "Irradiance 150W" result in a reduced visual comfort. Without a shading device no glare control is possible resulting in visually uncomfortable situations. The control strategy "Irradiance 150 W" very often closes fully the blinds. This contradicts the possibility of having a view out and thus results in uncomfortable situations. With manual control and "Perfomance with cut-off" the best results regarding visual comfort are achievable.

4.2.2 Thermal comfort

To evaluate the thermal comfort, the indoor room air temperatures are calculated for the five solar control strategies. They were plotted over the ambient temperature in Fig. 16. Obviously, the highest temperatures occur in case of the unshaded office, exceeding 40°C in summer. The summer indoor climate performance of the three automated control strategies is the best, even though the maximum temperatures are above the comfort level. The "Performance with cut-off" strategies results in ~1.5 K higher temperatures compared to "Performance" due to the higher solar loads.

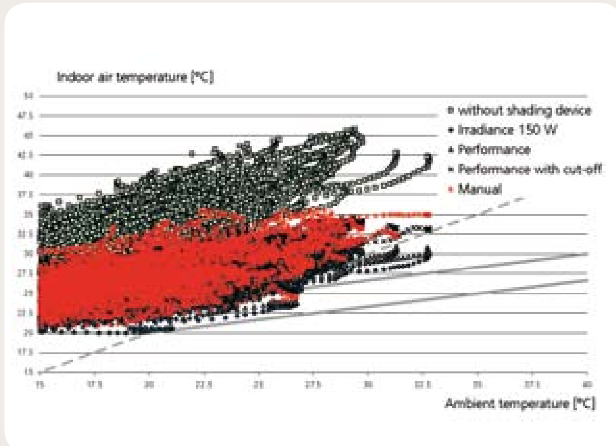


Fig. 16 Indoor temperature versus ambient temperature for five different control strategies. Temperatures above the grey dashed line are above the ambient temperature. The grey lines give the boundary conditions for thermal comfort according to the old German code DIN 1946 part 6. Winter temperatures (<15°C) are not shown .