Oliver Ebert[1], Bert Junghans[1], David Geisler-Moroder², Matthias Werner³
Zumtobel Lighting GmbH (1), Bartenbach GmbH (2), University of Innsbruck (3)

DALEC – energy calculation for day- and artificial lighting systems and their impact on energy demand of heating and cooling systems considering control strategies in different clime zones

***Abstract**. DALEC is a new free web tool (www.dalec.net). Based on climate files DALEC allows energy calculation for artificial and daylight systems and their impact on heat and cooling loads in real-time. In this paper case studies are presented which demonstrate the impact of different control strategies for artificial and daylight systems in varying geographic climate zones on energy demand for lighting, heating and cooling.*

Keywords: Day- and artificial light, Control strategy, Energy calculation tool

Introduction

The facade has great influence on the energy consumption of a building. Above all, the transparent or translucent part of the facade system determines the daylight entry and the solar entry into a building. Depending on the daylight entry in the interior artificial lighting must be switched on or added. The necessary need for artificial light generates a higher power requirement on the one hand and an additional internal load on the other hand which has to be cooled down in case of overheating phases. Thus, only with a coupled photometric and thermal simulation a realistic assessment of façade and artificial lighting systems is possible. There is a variety of different façade systems available on the market as e. g. external venetian blinds, screens or daylight-redirection blinds. Each of them has different influence on the aspects mentioned above. Each system is controlled by different strategies to fulfill its purpose properly. Venetian blind e.g. are closed to avoid glare or protect against solar entry in summer time which has a strong impact on the energy need for artificial light and cooling. To combine and to evaluate these aspects is the challenge for a concept analyses tool for façade and artificial light systems.

In this paper the freely accessible online tool DALEC (screenshot see figure 1) is presented, which allows to evaluate façade and artificial light systems within seconds without intensive simulation times and without deep expert knowledge.

With the help of this tool several parameter studies were carried out to investigate the complexities of facade and artificial lighting system and various control strategies. In this paper, results are presented, showing the energetic effects of various facade systems and control strategies in different climatic locations. The study attempts to establish a catalog system, which allows in early design phases to assess the energetic effect of the façade- and control system without detailed calculations.

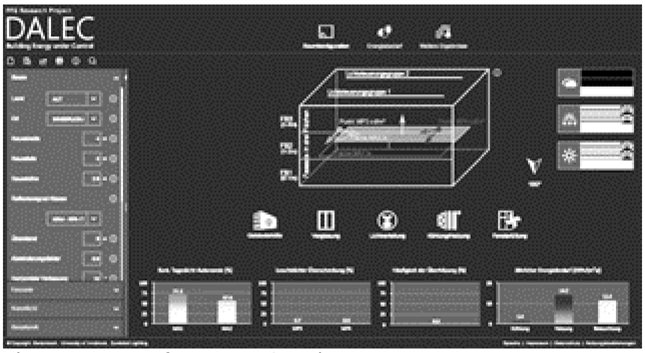

Fig. 1: User-Interface DALEC-tool

Structure of the tool

In order to map the interaction of solar entry, daylight entry and artificial lighting needs considering a control strategy, the program structure of the tool was divided into several modules. The simplified program flow is shown in figure 2.

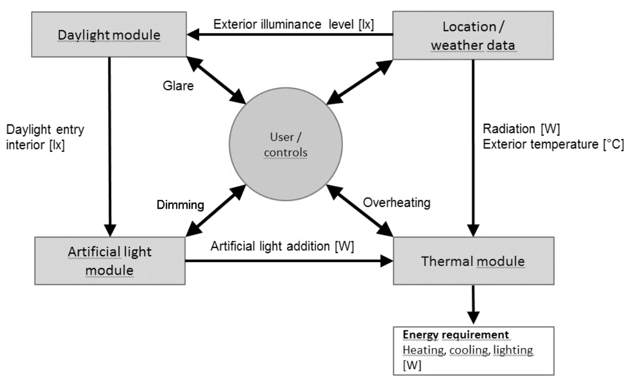

Fig. 2: Program flow through the different modules

On the basis of hourly weather data the climate can be defined for each location. By means of the daylight module the hourly daylight entry in the interior is calculated depending on various factors (e.g. room dimension, window area ratio, protrusion, etc.).

A variety of different artificial lighting solutions can be considered. Different light distribution for direct and indirect light can be chosen. Also the luminaire efficiency can be determined by setting connecting power and luminous flux per luminaire. Depending on the entry of daylight and the selected artificial light solution the additionally needed power for artificial light can be calculated. Three different control states are available (daylight-dependent dimming, daylight dependent ON/OFF switching, continuous operation during occupancy). The artificial light addition is used for further calculation in the thermal module. Additionally the thermal module receives climate data from the weather-files. With help of a dynamic building model (based on EN 13790 [2]) energy requirements for heating and cooling are calculated.

The control module describes a user behavior (in case of glare) respectively sun protection system of the facade (in case of overheating). For each time step it is checked, if a luminance exceedance or solar radiation exceedance is present. If this is true, a shaded façade configuration is selected (e.g. sun protection is moving down). The reduced solar input and the reduced daylight entry are then determined and subsequently affect the energy requirement for heating, cooling and artificial lighting.

Parameter study

At first locations on the northern hemisphere were defined based in different climate zones [3]. Prerequisite for selection was the availability of hourly weather data and a position within the climate zone that can be considered as representatively. In climate zones that are very broad several sites were selected, for example, a central location and two in the marginal position of each zone (Figure 4).

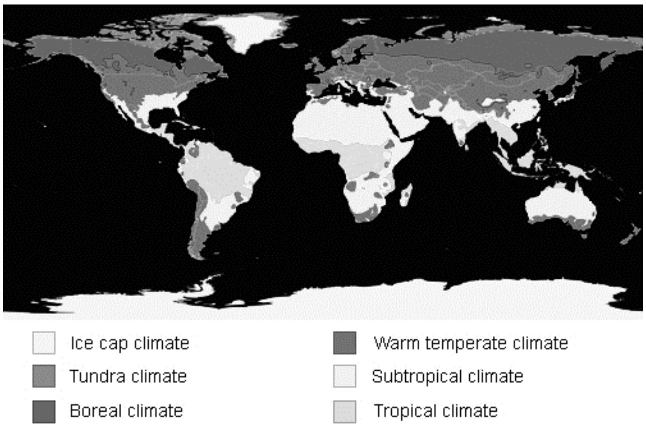

Fig. 3: climate zone map [3]

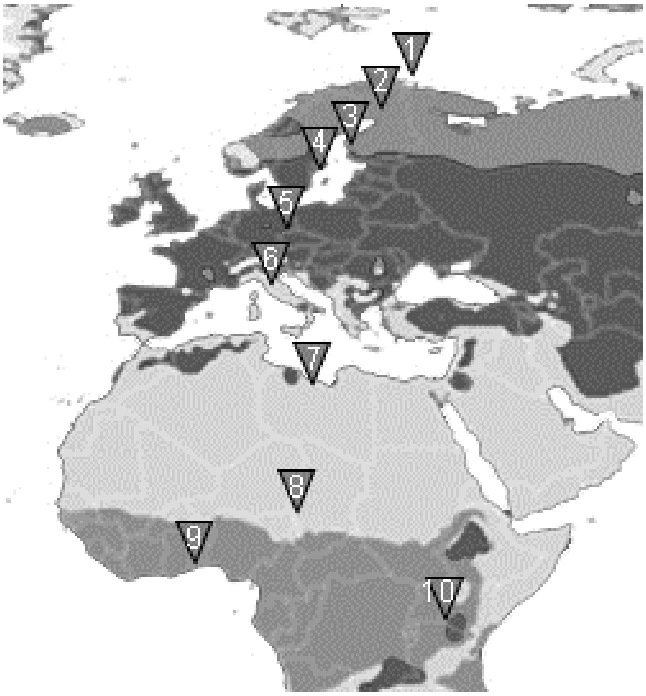

Fig. 4: Position of selected locations

Number	Climate zone	Location	Coordinates	Cooling periode (day of the year)
	Ice cap climate	not available		
1	Tundra climate	Vardo, NOR	70° 22′ N 31° 6′ E	181- 182
2	Boreal climate	Rovaniemi, FIN	66°30′N 025°44′E	150 - 221
3	Boreal climate	Vasa, FIN	63°06′N 021°37′E	148 - 230
4	Warm temperate climate	Stockholm, SWE	59°19′N 18°4′E	120 - 250
5	Warm temperate climate	Dresden, DEU	51°2′N 13°44′E	108 - 280
6	Subtropical climate	Firenze, ITA	43°47′N 11°15′E	100 - 300
7	Subtropical climate	Sirte, LBY	31°12′N 16°35′E	40 - 334
8	Subtropical climate	N'Djamena, TCD	12°6′N 15°2′E	1 - 365
9	Tropical climate	Lome, TGO	6°7′N 1°13′E	1 - 365
10	Tropical climate	Kisumu, KEN	0°6′S 34°45′E	1 - 365

Fig. 5: Additional data of selected locations

For all locations, a reference room was defined, which serves as base solution for comparison with other systems. The parameter setting for the reference solution is available in figure 6. As reference setting for the basic façade solution there was chosen an opaque system for the lower sill area and a triple-glazing without additional systems for the window and skylight area.

Parameter	Setting
Country / Location	**Varying**
Room W D H [m]	4.0; 5.0; 2.8
Reflectance class	80/50/30
Protusion [m]	0
Reduction factor	0.9
Horizontal obstruction [°]	15
Orientation [°]	180
Occupancy time [h]	8.00 - 18.00
Working days / week	5
Cooling period	**Varying**
Glazing	3-pane-glazing
Tau	FA1=0; FA2=0.72; FA3=0.72
g-value	FA1=0; FA2=0.5; FA3=0.5
Active window area	FA1=0; FA2=075; FA3=0.75
Facade system unshaded	FA1=Opaque; FA2=Glazing; FA3=Glazing
Luminance limit [cd/sqm]	3000
Radiation limit [W/sqm]	150
Facade system heating periode	FA1=Opaque; FA2=Glazing; FA3=Glazing
Facade system cooling periode	FA1=Opaque; FA2=Glazing; FA3=Glazing
Req. Illuminance near window [lx]	500
Req. Illuminance far window [lx]	500
Flux per luminaire [lm]	4000
Maintenance factor	0.67
Light distribution	DI=Narrow; IND=Wide; ratio=0.7
Power per luminaire [W]	40
Lamp dimming characteristic	Linear LED
Switching status	Dimmable
Building Physics	New building
Window ventilation	No
Internal temperature [°]	20 - 26
Other internal loads [W/sqm]	7
Cooling	ON
Heating	ON

Fig. 6: Parameter settings reference room

In a further simulation step the available façade systems with their control strategy (Figure 7) were used in calculations for all selected locations.

Facade system	Control strategy
Glazing only	No controls
Clear screen (external)	moving down (up), if threshold is exeeded (undercut)
Clear screen (internal)	moving down (up), if threshold is exeeded (undercut)
Diffuse screen (external)	moving down (up), if threshold is exeeded (undercut)
Diffuse screen (internal)	moving down (up), if threshold is exeeded (undercut)
External venetian blinds	moving down (up), if threshold is exeeded (undercut); blind position: fixed 0°
External venetian blinds	moving down (up), if threshold is exeeded (undercut); blind position: fixed 45°
External venetian blinds	moving down (up), if threshold is exeeded (undercut); blind position: Cut-Off
Daylight redirection blinds	moving down (up), if threshold is exeeded (undercut); blind position: fixed 0°
Daylight redirection blinds	moving down (up), if threshold is exeeded (undercut); blind position: Cut-Off
Daylight redirection blinds	moving down (up), if threshold is exeeded (undercut); blind position: Retro

Fig. 7: Considered façade systems

To obtain information about the energy impact of each strategy in the winter and summer months, one calculation war carried out with active system in the heating period while the system was inactive in the cooling period. The inactive system correlates with the basic façade system of the reference room. A second calculation was carried out with inactive system in the heating period and active system in the cooling period and a third one with active system over the entire year. The thresholds for luminance exceeded and the solar radiation limit on the facade were set for all variants to 3000 cd / sqm and 150 W / sqm. Calculated was the annual energy demand for artificial lighting, heating and cooling.
The results of the calculation with year-round active system were compared with the calculation of the reference system without façade system and control strategy. The deviation was documented (Figure 9 – deviation for venetian blinds, fix 0°).

The results of the calculation with active system in heating period only respectively in cooling period only were compared to the results of the calculation with year-round active system. The deviation was documented as well (Figure 10 and Figure 11).

Results

Hereinafter selected results of the parametric study are presented. Figure 8 shows the annual energy demand for artificial lighting, heating and cooling of the reference room at the selected locations.

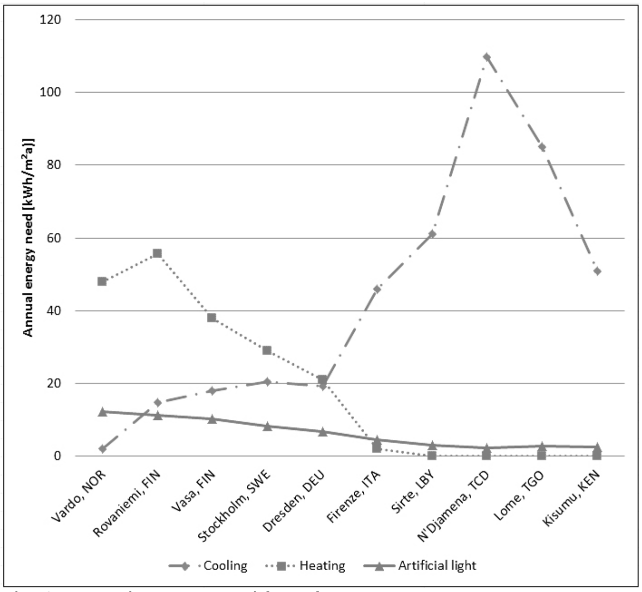

Fig. 8: Annual energy need for reference room

Figure 9 shows the deviation of the annual energy demand for artificial lighting, heating and cooling compared to the reference system when an external venetian blind is used with fixed slat position of 0 ° (system all year ac tive when threshold is exceeded).

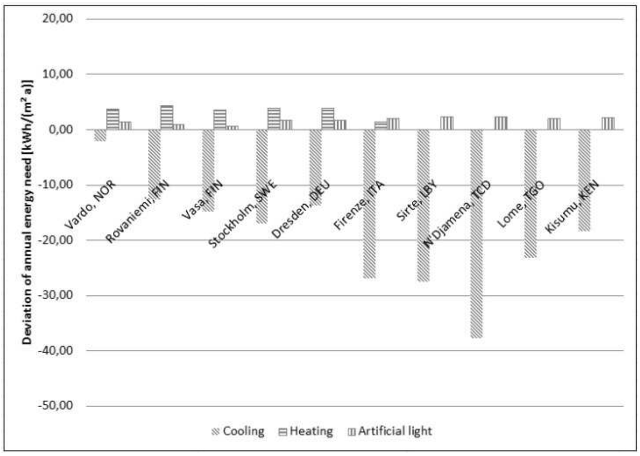

Fig. 9: Deviation of annual energy need – system: venetian blinds 0°fix

Hereinafter a comparison of the calculation results for the location Dresden is presented exemplarily. Figure 10 shows the deviation when the façade system is only active during the cooling period, while figure 11 is showing the deviation when the system is only active during the heating period. As a basis for the comparison a reference calculation was performed using the same system which is active all year in the selected location.

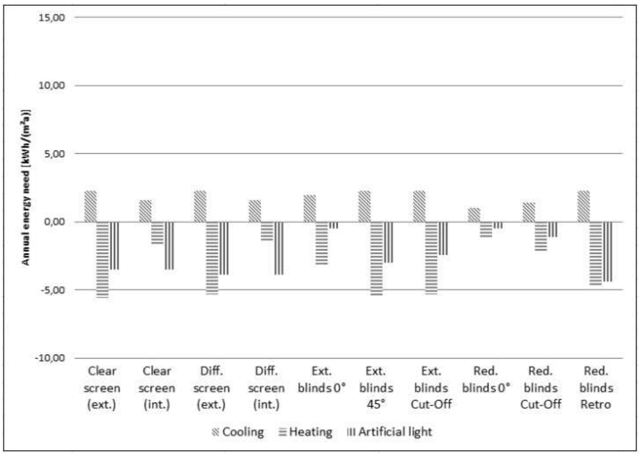

Fig. 10: Deviation of annual energy need for Dresden – System only active in cooling period

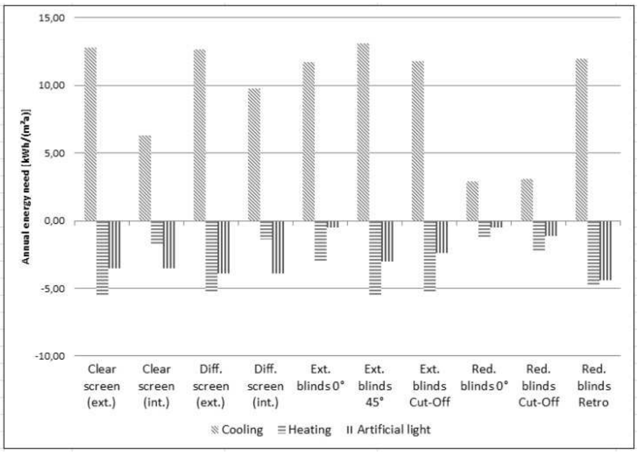

Fig. 11: Deviation of annual energy need for Dresden – System only active in heating period

Conclusion

With help of the DALEC online tool it is possible to demonstrate the effects of various facade systems and control strategies at over 2000 (number of implemented weather-files) locations worldwide. The systems can be evaluated separately for the heating and cooling period and can be combined with each other along different areas of the façade. In addition to the energy need for heating, cooling and artificial lighting, comfort criteria can be considered. The need for artificial light can be influenced by the choice of daylight-dependent dimming or daylight-dependent ON / OFF switching. Already in the early planning phase day- and artificial lighting systems can be evaluated and analyzed holistically with low expenditure of time.

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***Authors' contact**: Dipl.-Ing. (FH) M.A. Oliver Ebert, Zumtobel Lighting GmbH, Schweizerstrasse 30, 6850 Dornbirn, Austria, email: Oliver.Ebert@zumtobelgroup.com*