DIAL+*Suite* : a new suite of tools to optimize the global energy performance of room design

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Zusammenfassung Résumé Abstract

Estia SA in collaboration with the Laboratory of Urban Architecture and Energy Reflexion (LAURE/EPFL) has developed a suite of software tools aiming to simultaneously assess:
- Daylighting: Dial+Lighting,
- Natural window ventilation: **DIAL+*Ventilation***,
- Thermal dynamic behaviour for winter or summer conditions: **DIAL+*Cooling***.

The possibility to combine natural and artificial lighting analysis with natural ventilation and dynamic indoor temperature analysis existed in the past, but it was a privilege for researchers, or building physics experts. The corresponding tools did require a high level of expertise, many weeks of training and many working hours to build credible models able to calculate correctly a given reality. Thanks to its intuitive interface, DIAL+ innovates and gives to non-expert users the opportunity to quickly model a complex room and to calculate the following results:

- Daylight factor values (BREEAM, CERTIVEA)
- Daylighting autonomy (MINERGIE ECO, SMEO, LEED)
- Annual energy consumption due to artificial lighting (SIA 380/4, MINERGIE)
- Dynamic indoor temperature (ISO 13791)
- Number of overheating hours (SIA 382/1, EN 15251)
- Annual energy needs for heating and cooling (EN 15255, EN 15265)

The three software modules are designed with a particular focus on user-friendliness. User data input is simple and straightforward and thus allows planners to correctly model the room and quickly analyse lighting and thermal indoor comfort, even without profound knowledge of building physics.

The software suite DIAL+ therefore represents a simple and efficient professional tool, ideal not only for proving the conformity to various norms and building labels, but also for optimising building design, especially in early planning phases.

The paper presents the main features of the software on the basis of illustrated examples.

1. Scope

If we look to the building market evolution during the last decade, we can see that «Very low energy » buildings are no longer considered as «pilot projects». For instance, in Switzerland, the performance of «Low Energy » buildings corresponds to the minimal requirements of the national standard and the label «Very Low Energy» building (passive house) becomes mandatory for most public buildings. In this context the optimization of the thermal behaviour of buildings for winter conditions is the main target, but very often, the questions of lighting and summer comfort are neglected in the design process.

However, if we want to make buildings consuming less than 50 kWh.m^2.year (primary energy), lighting and cooling strategies have to relay on the optimal use of daylight and natural ventilation.

1.1 Lighting

Let's consider an office room (500 lux requested on the work plane), equipped with high efficiency luminaires fitted with fluorescent tubes (average power = 10 W/m^2) and standard opening hours (8 AM to 6 PM, 5 days/week). An average daylighting autonomy of 50%, corresponds to an annual final energy consumption of 13 kWh/m^2.y (final energy), which means 32.5 kWh/m^2.y (primary energy, conversion factor 2.5 for electricity).

1.2 Overheating

To prevent the same office room from summer overheating, mechanical ventilation based on cross-flow heat exchanger will not be enough to extract the energy accumulated during the day, and the number of overheating hours is higher than 100 h/y.
Thus, a fine-tuning of the blinds system and windows openings, coupled with the use oft he indoor thermal mass, is the only way to promote thermal comfort without an explosion of the energy consumption.

However most of time, due to a lack of design/simulation tools dedicated to building designers, these parameters are not taken into account in the early design stage.

The new **DIAL+*Suite*** software gives the opportunity to overcome this barrier and to estimate very quickly the daylighting potential as well as the number of overheating hours as a function of the room characteristics and the control strategies of both windows and shading devices.

2. Methods

2.1 DIAL+*Lighting*

DIAL+*Lighting* is a continuation of the software DIAL-Europe [1] conceived, designed and realized at the beginning of 2000s within the framework of the "European Integrated Daylighting Design Tool, DIAL-Europe Project" by the following partners:
- Cambridge University Technical Services Limited,
- Ecole Polytechnique Féderale de Lausanne,
- ESTIA SA,
- Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung c.v.d
- The Netherlands Organisation for Applied Scientific Research

When launched in 2003, DIAL-Europe was the first daylighting software dedicated to "non specialists" and it had been very welcomed either by academic institutions and architects, with a particular success in France where it is still in use to fulfil the requirements of the Certivea® [2][3], method (daylight factor calculations). The simplicity of use was certainly one of the main reasons of the success.

The first challenge of the new DIAL+*Lighting* module was to allow the description of more complex shapes (DIAL-Europe was only available for shoe-box room shapes) so as to be able to solve 95% of the "real life" situations.

The second challenge was to keep the input procedure as “fluid” and intuitive as possible in order to satisfy non-specialists and/or occasional users.

We first made the choice to maintain a “path” description mode as it was originally developed for DIAL-Europe. It means that instead of relying on a classic menu approach (the user has to search into popup menus to discover all the software possibilities), we guide him through successive windows focusing on each of the key design parameters.
We think that this way offers good guarantees regarding the accuracy of the description (less input errors) and also enables the user to improve his understanding on what is important.

2.1.1 Room geometry

To describe most of usual geometries, the user can choose between generic plan shapes such as Rectangle, L-Shape and Trapeze.

Each room can be fitted with a single or double-sloped roof.

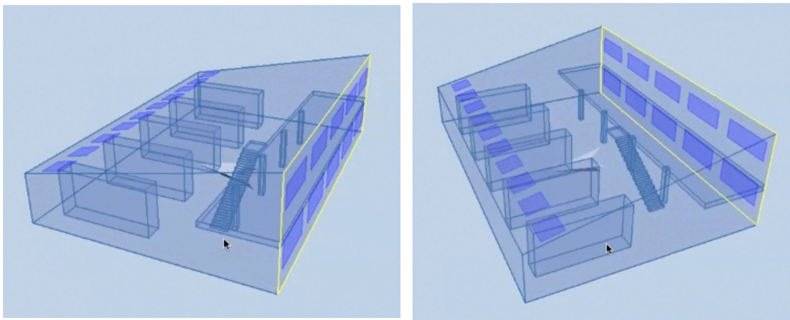


Figure 1 : example of complex room than can be handled with DIAL+

Finally, parallelepipedic obstacles can be placed inside the room in order to represent rough furniture, vertical partitions, intermediate floors or even “blind zones”. These obstacles can be either opaque or transparent so as to allow the user to describe indoor glazed partitions.

This combination allows the user to describe 95% of the rooms with an appropriate level of precision (See fig. 1)

2.1.2 External obstructions

Outdoor fins and blind systems can be described to take into account the light absorption and/or reflection of fixed shading devices.

Moreover, the outdoor environment such as ills and mountains or existing buildings can be easily described as shown in figure 2 hereafter.
These elements are taken into account to calculate the daylighting contribution as well as the solar gains.

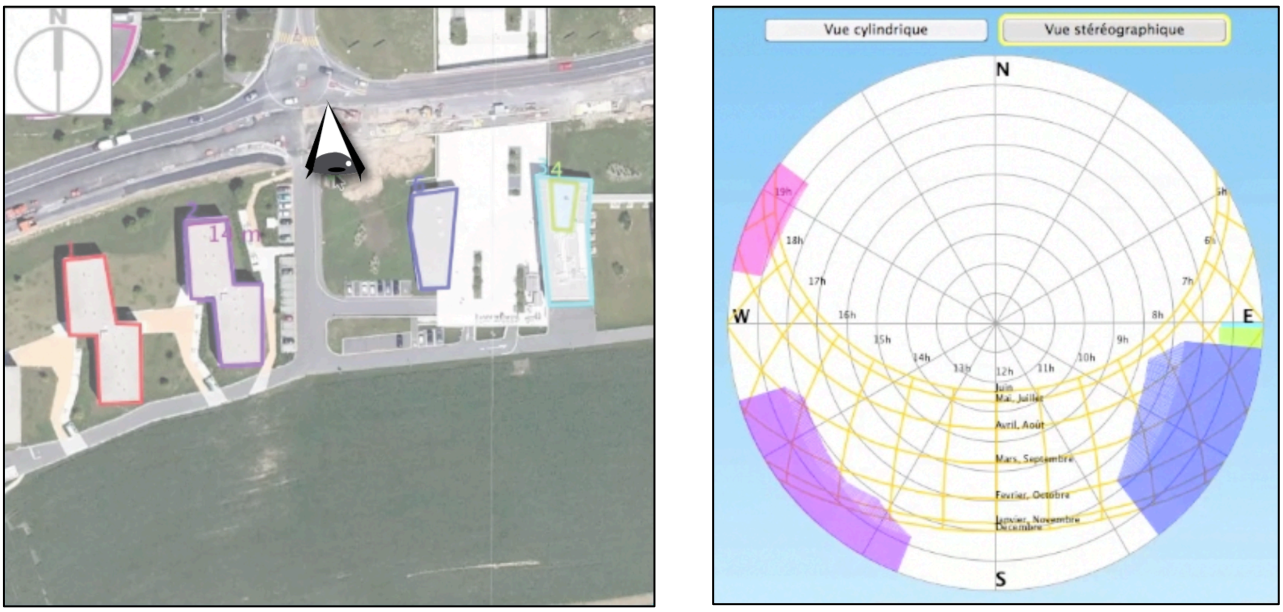


Figure 2 : Example of consideration of the masks of the outside environment.

2.1.3 Calculations

Daylight factor are calculated with Radiance [4][5] under CIE overcast sky conditions.

Daylighting autonomy values are derivate from the cumulative distribution of outdoor diffuse illuminances of the selected location (Meteonorm data) [6]. In addition orientation factors are used to take into account the dissymmetry of the sky vault.

To illustrate this notion of daylighting autonomy, let's consider an office room located in Geneva (500 lux required on the work plane). If, at a given point, the daylight factor is 4%, then the indoor required illuminance will be achieved as soon as the outdoor diffuse illuminance exceed 12'500 lux.

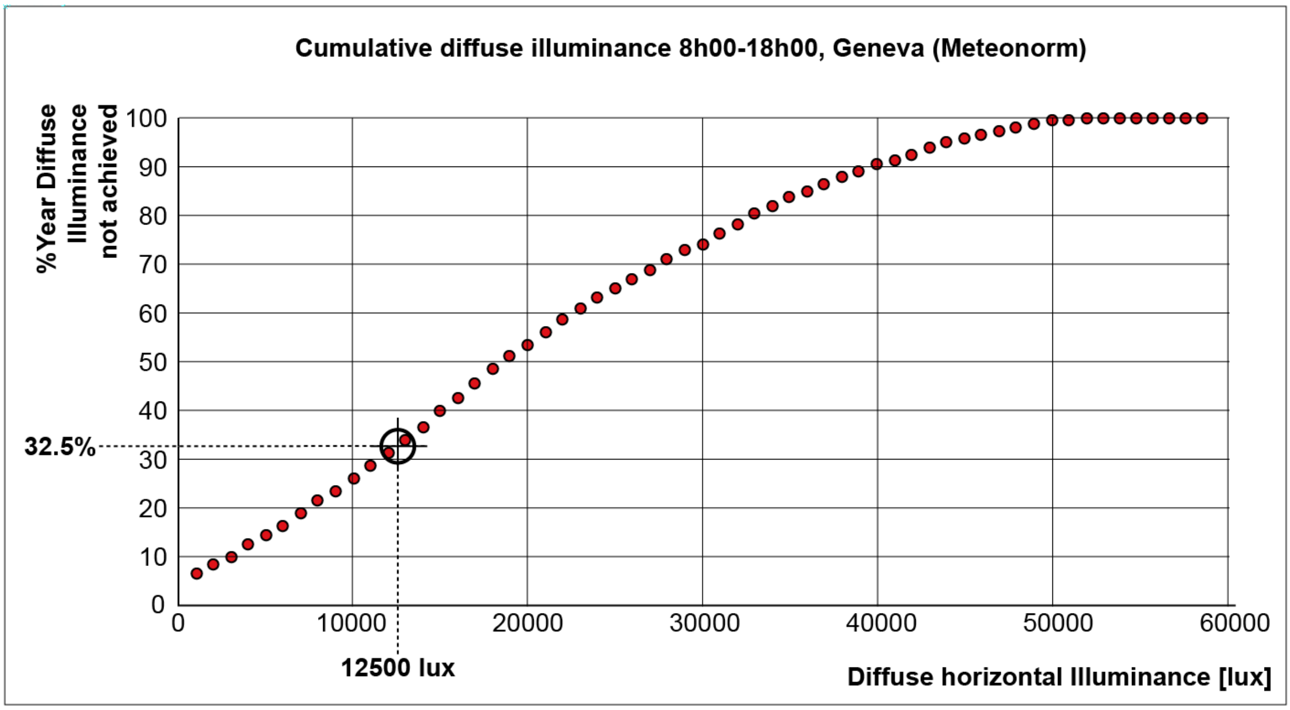


Figure 3 : Cumulative diffuse horizontal illuminance (Geneva : 8:00-18:00, Metenorm data).

Figure 3 shows that on a yearly basis, the probability for the outdoor illuminance to be lower than 12'500 lux is 32.5%. Then, the percentage of time during which there will be no need to switch on the artificial lighting represent 67.5% (100 – 32.5) of the hours between 8:00 and 18:00.

This process implies that climatic data are pre-processed for representative locations.

We choose to develop and apply this procedure in the 2000's within the framework of the DIAL-Europe project because it is the fastest way to switch from daylight factor to daylighting autonomy. Other methods were investigated but they all leads to longer computation time (i.e. Hourly simulation).

The value for daylighting autonomy calculated with DIAL+Lighting is much more precise than the one given by the SIA 380/4 as far as this norm only takes into account parallelepipedic rooms with a single opening. So the software can be used to promote the efforts of the designer regarding the use of daylighting and thus the reduction of full charge hours of artificial lighting use

2.1.4 Results / Display

As show in figure 4 hereafter, we have made the choice not to provide 3D images but to focus on the results (work-plane or any other room surface) in order to go straight to what is really useful to fulfil standards and norms. This leads to fasten the simulations and allows this software to be used as real "production tool" for both design and control purposes.

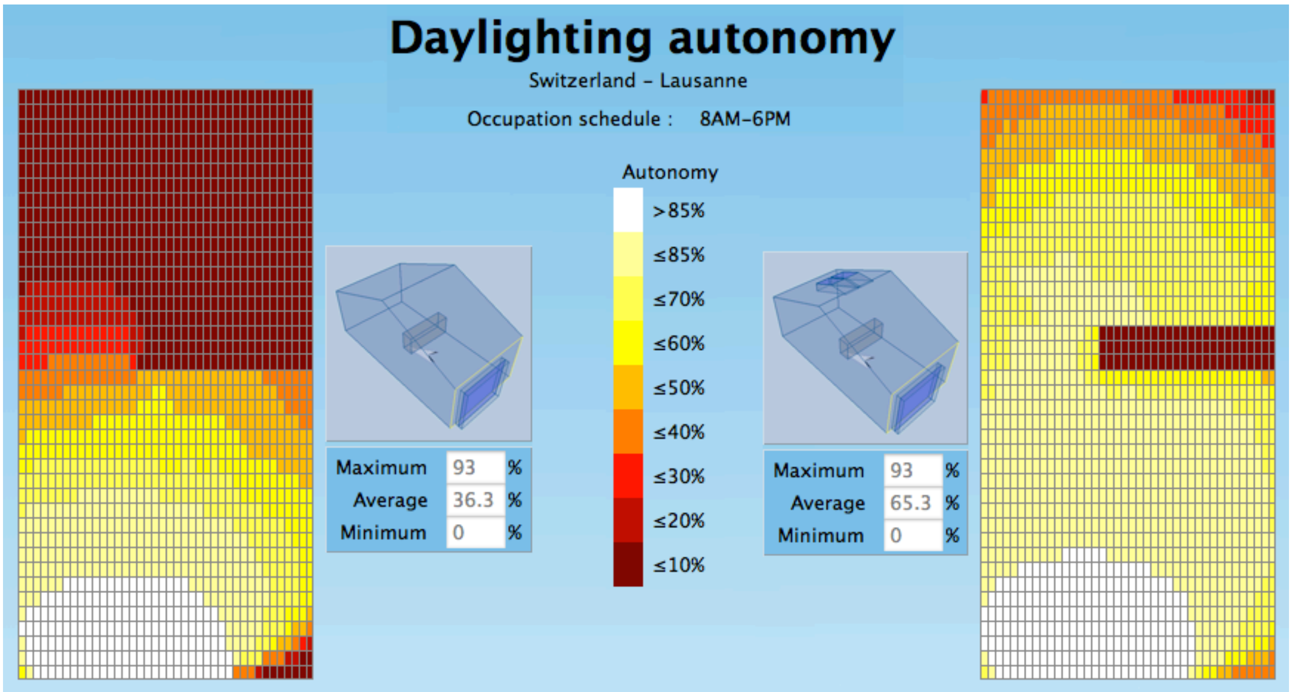


Figure 4 : daylighting autonomy on the floor of for 2 configurations of a same room (with and without roof openings on the back side of the room).

2.2 Artificial lighting

The annual energy consumption due to artificial lighting is calculated according to SIA 380/4. It takes into account the room function (occupancy periods), the type of light sources (luminous efficacy), the type of luminaires (direction and yield), and the command/ regulation of the luminaires.

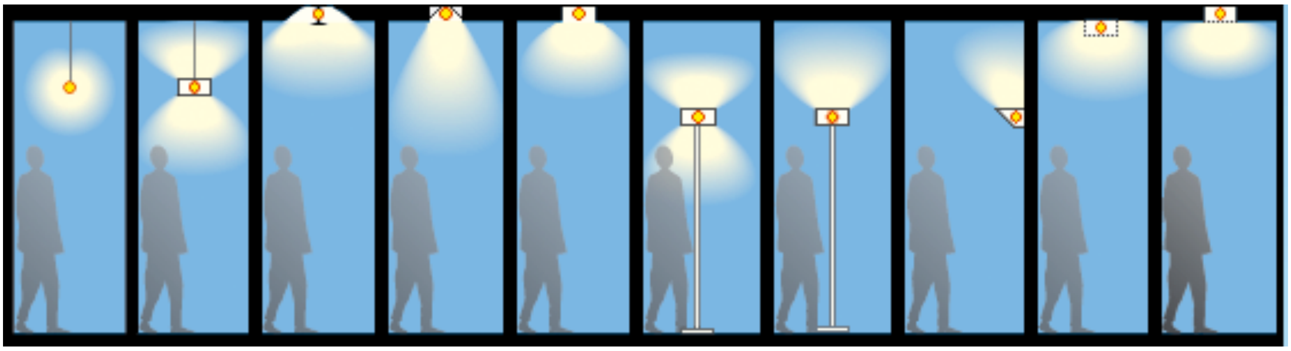


Figure 5 : Selection oft he luminaires

2.2.1 Results

DIAL+ calculates the equivalent number of "full charge" hours during which the lamps have to be switched on and shows the performance of the room according to the "Target" "Limit" and "Minergie" values as shown in figure 6 besides.

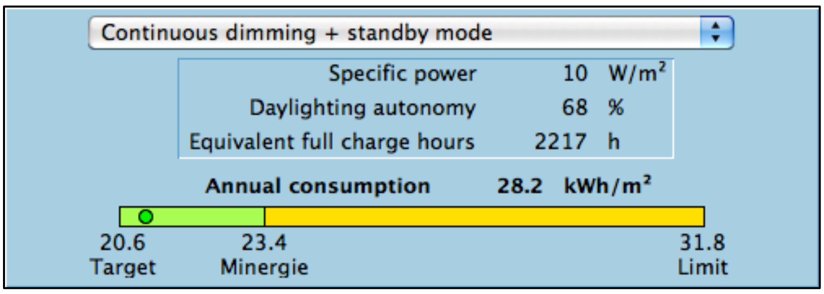


Figure 6 : Artificial lighting calculation according to SIA380/4

2.3 DIAL+*Ventilation (Air flow through the openings)*

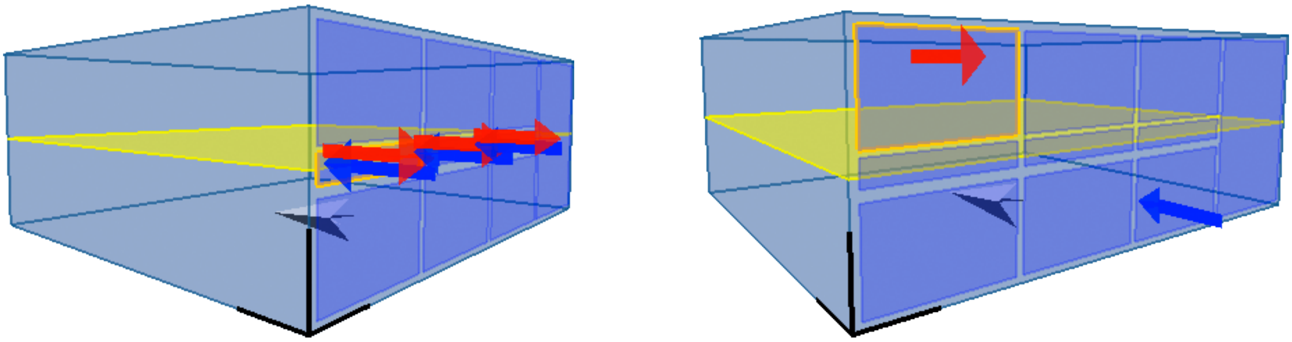
DIAL-Ventilation is a module that allows the user to calculate the air-change potential due to natural ventilation. Calculations are made by iterative resolution of stack pressure flow for all openings (Cockroft) [7].

Depending on the opening characteristics and, the indoor and outdoor temperatures, the software calculates the neutral level and gives the instantaneous air-flow crossing the opening.

Furthermore, it calculates, for a given condition, the time requested to renew the indoor air (based on exponential decay of pollutant), which indicates the natural ventilation potential of the window. This feature is very useful to make a sound design of the openings and can be particularly interesting for school and educational rooms.

2.3.1 Results / Display

Figure 8 shows that for a given room with two different opening modes, the ventilation potential can be multiplied by 10 (vol/h) and symmetrically, the time to change the used air is divided by 10. DIAL+V*entilation* is one of the few tools that can provide designers with that kind of results in the early design stage.



Case 1 :
Air change rate due to natural ventilation : 0.4 vol/h
Time to change 80% of the air : 250 minutes

Case 2 :
Air change rate due to natural ventilation : 4.1 vol/h
Time to change 80% of the air : 24 minutes

Figure 8 : Examples of a natural ventilation analysis for a given room fitted with 2 different openings. (outdoor temp : 15°, Indoor temp = 20°)

2.4 DIAL+*Cooling* (Dynamic thermal simulation)

The thermal simulations are made on the basis of a multinodal model (time step : 1h).
It takes into account the composition of the walls, floor and ceiling, their respective covers, the insulation thickness and position as well as their contact with the exterior.
The walls composition and thus the thermal mass in the room are taken into account in a physical based aspect (multiple nodes for each wall).
The user can define easy-to-understand strategies to optimise the thermal comfort:

1) A max radiative power on the window from which the shading devices will be closed
2) A min inside temperature from which the shading devices will be opened
3) A natural or mechanical night cooling ventilation during the hot season
4) A reduced ventilation during unoccupied periods

2.4.1 Internal gains

Standard profiles of more than 40 rooms categories are stored in the software. The user selects the category and then the qualitative description for "Occupation", "Electrical power" (excluding lighting) and "Lighting power". The total internal gains are then calculated and split into radiative and convective components.

2.4.2 Solar gains

Depending of the localisation of the project, the sun position is calculated for each time step. The software calculates the radiative power on each wall and roof as a function of the horizontal diffuse radiation and the normal direct radiation corresponding to the climate conditions. Overhangs and fins as well as horizon (cf. figure 2) are taken into account for the calculations.

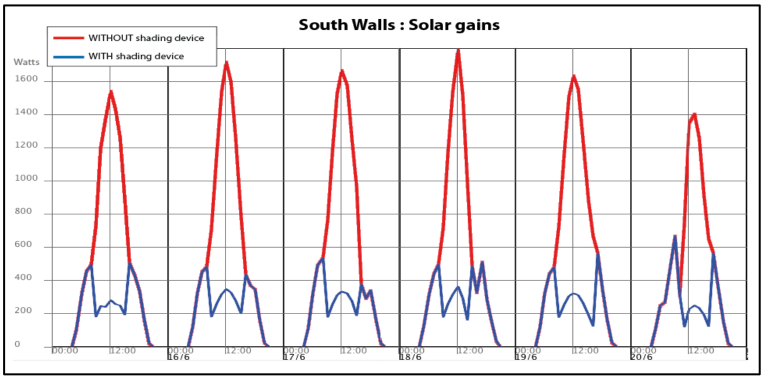


Figure 9 : illustration of the solar gains calculation with and without shading devices for 6 consecutive sunny days.

2.4.3 Ventilation.

The potential air flow is calculated at each time step with the difference between inside and outside temperature. This allows the user to calculate real natural ventilation air-flows which can be useful for night-cooling

2.4.4 Results / Display

The user can view the results for each hour of the simulation. The available outputs are:

- Operative temperature of the room
- Air temperature of the room
- Surface temperature for each wall, roof and floor
- Solar gains through each wall and roof
- Internal gains
- Air flows
- Heating power extracted by air flow
- Heating power
- Cooling power

One of the main results is the number of overheating hours according to SIA 382/1.The user can also define the comfort zone according to EN 15251 and the software calculates the number of hours during which the indoor air temperature is over or under this zone.

Figure 10 shows an example of dynamic thermal calculation of the indoor surfaces temperature for 2 configurations of a given office room located in Zürich. In that case, the combination of night ventilation and automated shading device, leads to reduce the number of overheating hours from 968h/year to 67h/year, which makes a strong difference regarding the thermal comfort of the room.

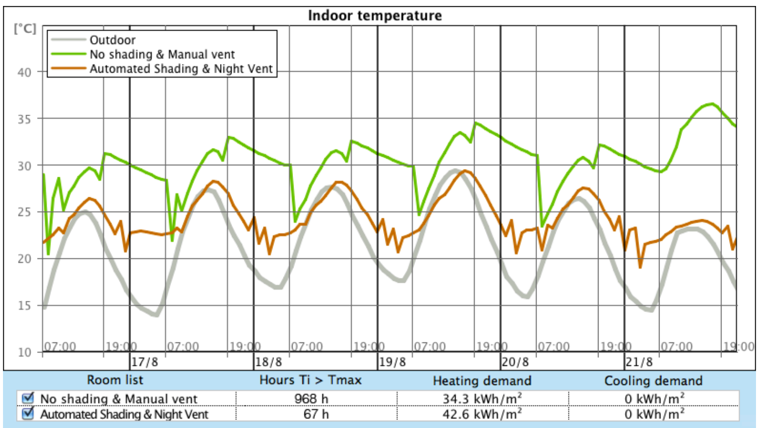


Figure 10 : Comparison of 3 variants of a given room showing, on a yearly base, the evolution of the indoor temperature depending on the night ventilation strategy and the thermal mass of the floor.

The energy demand for heating and cooling (if there is an active cooling system) is also calculated and displayed and allows to compare the different configuration [kWh/m^2]. One can see that with automated shading, the heating demand is increased due to the reduction solar gains. This example illustrates the necessity of finding compromises between the various parameters of the comfort and the energy performance

Figure 11 displays the comfort zone corresponding to both configurations (with and without shading and night ventilation). Each red spot corresponds to a situation where the indoor temperature exceeds the limit value. This example emphasizes the influence of an appropriate shading and ventilation strategy.

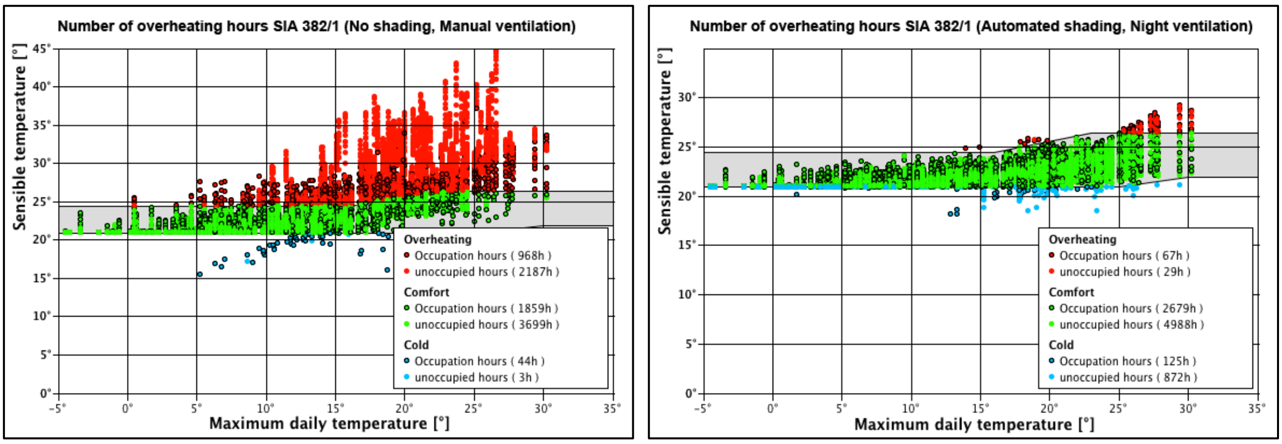


Figure 11 : Overheating hours according to SIA 382/1. DIAL+Cooling displays the number of overheating hours during occupied and unoccupied hours. The comparison of the 2 rooms configuration show the potential for summer comfort optimization.

3. Conclusions / Perspectives

These few examples illustrate the possibilities to optimize the design of room openings and emphasize the necessity to have a global look at the different parameters.

As this new DIAL+Suite is one of the first tool dealing with the evaluation of the overall energy flows crossing the windows (gains and losses), we are persuaded that it opens new possibilities regarding the design of high performance buildings as far as it can be used simultaneously by architects and HVAC engineer in the early design stages.

Until now, architects and building physics consultants used to work separately, working either with architectural references and products on one side (architects) or with figures and formulas on the other side (HVAC engineers). The confrontation of these two cultures, which often leads to misunderstanding and unproductive loops, should be facilitated by the use of a common tool.

4. Literature/references

[1] E. de Groot, L.-Z. Zoneveldt, B. Paule : "DIAL-Europe : A decision support tool for early Lighting design", 8th International IBPSA Conference, Eindhoven, Netherlands, August 2003

[2] Certivéa, "Référentiel pour la qualité environnementale des bâtiments, Bureau / Enseignement"“, Déc 2008.

[3] Certivéa : "Référentiel pour la qualité environnementale des bâtiments, Etablissements de santé", Juillet 2008.

[4] R. Compagnon : "The RADIANCE simulation software in the architecture teaching context", Proceedings oft he 2nd Florence International Conference for Teachers of Architecture, Firenze (Italy), October 1997.

[5] Ward, Gregory J., "The RADIANCE Lighting Simulation and Rendering System," *Computer Graphics* (Proceedings of '94 SIGGRAPH conference), July 1994.

[6] B. Paule, F. Bouvier, G. Courret : « Eclairage naturel », Techniques de l'Ingénieur, CC 3315, Fév. 2008.

[7] J.-P. Cockroft, Heat transfer and air flow in buildings, Ph.D Thesis, University of Glasgow, March 1979.