# VISUAL COMFORT STUDY OF A RETROFITTED BUILDING

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## ABSTRACT

Thermal renovation of buildings has other consequences than energy savings. In this project, a light framed renovation façade with a low U-value was added on existing heavy building envelop, for enhance its energy performance. Beyond energy saving questions we were interested by the impact of this retrofit solution on entering daylight quantity.

The problem was approached experimentally and numerically. The experimental study was conducted in a "PASSYS" test cell; a real sized experimental device with 5 adiabatic façades and one "removable test" wall that was used to represent an opening without shading device. The numerical part was done using Google SketchUp Pro v7 to input the 3D geometry model, and simulations were done using EneryPlus, DAYSIM/Radiance and a free, but commercial code.

The paper presents the confrontation of experimental and numerical data, issue of the cited three codes. A summary of inequalities and discrepancies close this paper.

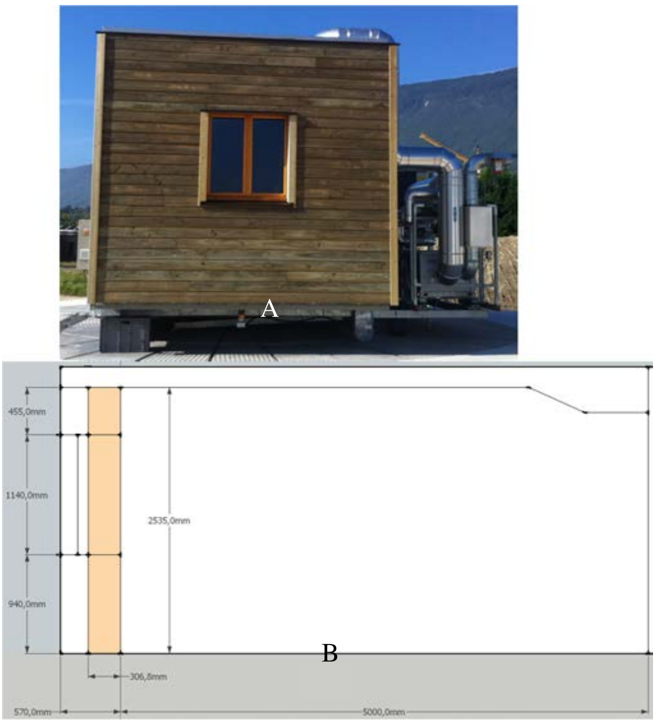
## INTRODUCTION

Our project aims to analyse the potentials of using a light framed structure renovation technique on an existing heavy structured façade of a dwelling. (Questions of energy saving are discussed in the project and are not involved in this paper). In this study we will zooming on daylight availability problems related to this renovation project; In fact stakeholders are not always aware of this question and owners of individual houses are often discouraged enough, by the daylight loss due to added structure on the façade, to abandon the idea of an outside renovation strategy. Thus it happens quite often that they prefer to install heat insulation on the inside as it is less expensive and less time consuming. This decision has consequences on energy saving as external insulation has a better performance as it uses better the building inertia.

It is well known that increasing the section of a building structure (without changing openings' size), leads to a decrease of natural lighting. This fact is a discouraging factor for building owners and it is important to quantify the daylight losses to argument for energy retrofitting. Throughout this study, we will evaluate these losses in order to help convince building owners to renovate their houses.

## MATERIALS/METHODS

For this project, we disposed of two real sized experimental cells. Both of them had the same heavy façade representing structures of 1980s and one has a light frame façade "add on", for improve its energy performance. These test cells are exposed to real meteorological conditions and had a North-East (135°) orientation. The reason of this orientation was to expose the test cells to the highest annual amount of rain (the most unfavourable conditions for wooden renovated structures). Figure 1 presents the studied test cells.




*façade, b) section of the renovated test cell, original structure is at the inside in the façade (colored part).*

Simulations were carried out using three "freeware" software EnergyPlus v6, DAYSIM/Radiance v3.1b and Velux Daylight Visualizer. This choice was voluntary, as authors would like to use tools accessible for everyone.

An EnergyPlus format weather file (.epw) was generated for the simulations with locally measured data. This step is important as around the site there are middle-height mountains (around 1500m) that create distant masks. The file contains weather data with a 60 s time step, using locally measured data helps avoid the need of sky models. The studied test cells are situated at Bourget du Lac, next to the French Alps Mountains. No shading device is considered in this project, as its aim is to analyze internal daylight illuminance variations due to building retrofitting.

The most common characteristic used in daylight analysis is the Daylight Factor (DF). It describes the ratio of outside illuminance to inside illuminance, usually on horizontal plan, expressed in per cent. In this paper, we will also use the annual light exposure. This metric quantifies the daylight availability in the studied space during opening hours (8 am-5 pm) with a level of 500 lux minimum for our case.

According to Clarke (2001) there are two different approaches to calculate internal illuminance distribution: analytical method and numerical method. The first one is implemented in EnergyPlus, the second one in DAYSIM/Radiance. EnergyPlus uses the model of DOE-2 (Winkelmann, 1983) (Winkelmann and Selkowitz, 1984) for illuminance calculation with four sky models. EnergyPlus obtains DF values using the following equation (Clarke, 2001):

$$DF = \sum_{N} TM \times \left( SC + ERC + IRC \right) \qquad (1)$$

where $T$ is the visible transmittance, $M$ is the maintenance factor, $N$ is the total number of windows, $SC$ is the sky factor (light directly from the sky), $ERC$ is the external reflected component and $IRC$ is the internal reflected component. The complete description of the method finds in EnergyPlus (2008) documentation.

## RESULTS

### Daylight Factor (DF)

Despite of its wide use, the application of DF has some inconveniency if one needs more complex data than static daylight simulation. For example DF considers light only from overcast sky (no direct sunlight, no light from non-overcast skies), thus the orientation of openings (building) has no effect on its value. It is not suitable for blinding control for exemple. As one can not separate the effect of natural and artificial lighting in DF, here we ignored all artificial lighting inside test rooms. Due to these disadvantages, for complex cases, UDI (Usefull Daylight Illuminances) is recommended. More information about UDI could be found in Reinhart (2010).

Several DAYSIM simulations were carried out at two different heights (0,85 m and 0,0 m) and for two orientation cases: North-West and South. As expected, results are orientation independent and the choice of height of the reference plan has an important impact in renovated case as we recorded a loss of 12% in DF values while we passed from 0,85 m to 0,0m. This difference was + 0,75% before renovation.

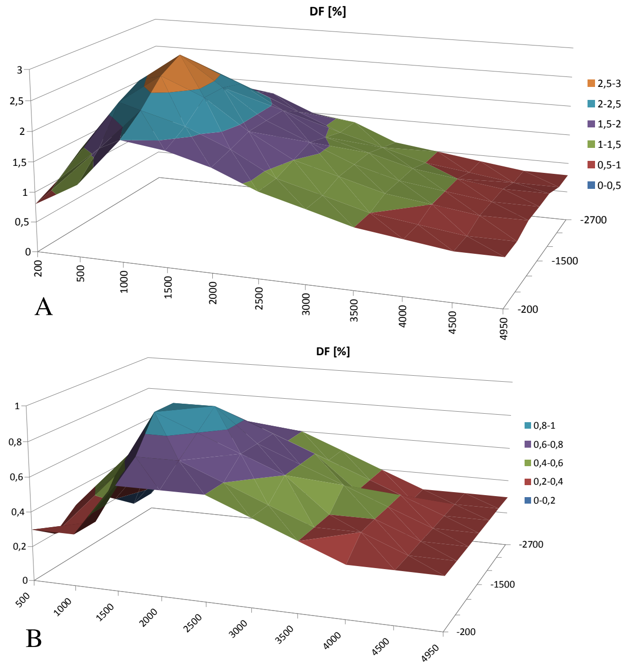
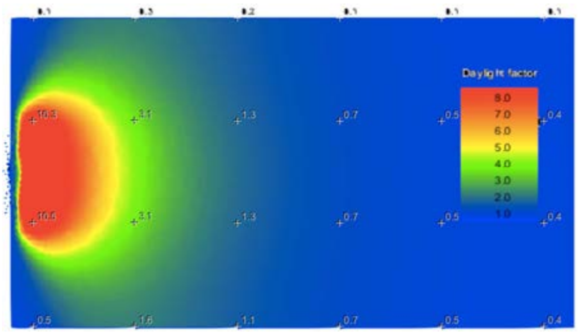


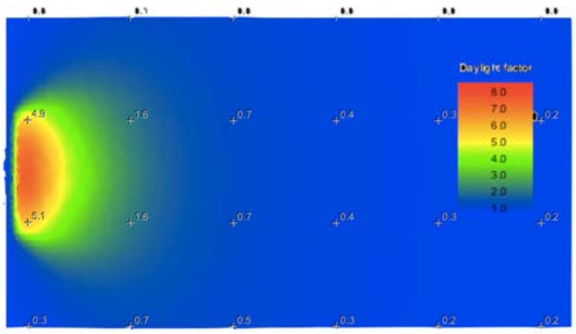

*Figure 2 Daylight factor results for A) non-renovated and B) renovated structure obtained by DAYSIM at 0,0 m height from reference plan. Horizontal axes represent room dimensions.*

Simulations show for both renovated and non-renovated cases a distribution expected in the room: low values adjacent to the window, a peak next to the window and a decreasing tendency with the depth of the room. DF maximum values decrease from 3% to 1% when adding the lightweight structure.

Some simulation with the VELUX software were carried out too. These values are superiors to values obtained by the DAYSIM software. The well illuminated zone is closer to the windows than in the case obtained by Daysim and values are 3 times higher than in the other case. Thus we conclude that it can not serve for comparaison with Daysim simulation.




a)




b)

*Figure 10. Daylight factor results for a) renovated and b) non-renovated structure obtained by VELUX at 0,0 m height from reference plan. Horizontal axe represents room depth.*

The renovation impact on daylight has been analysed experimentally also, using illuminance measurements. Measurements have been carried out in both PASSYS cells and analysed for three short period: one in February, one in July and one in August. An illuminance meter (Delta Ohm HD2021T) has been placed at the midline of the room at 0,85m height. The measurement range is between 0 and 2000 lux. Figure 3, Figure 4 and Figure 5 show the measured data for each period in both test cells.

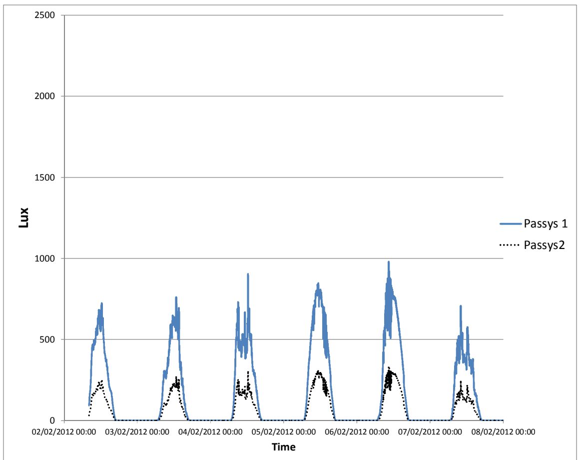



*Figure 3 Illuminance values measured during the 1st campaign in both PASSYS cells*

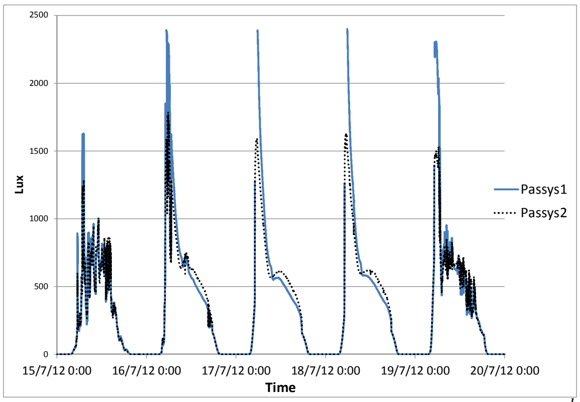



*Figure 4 Illuminance values measured during the 2nd campaign in both PASSYS cells*

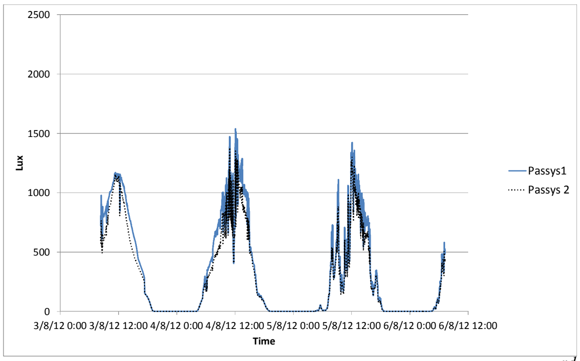



*Figure 5. Illuminance values measured during the 3rd campaign in both PASSYS cells*

During the first measurement campaign (Figure 3), the increase of facade width and the second window added with the renovation structure together drove to less daylight available inside of both the cells. It is in good agreement with the simulated tendencies. During the second measurement campaign, good weather conditions were recorded, with lot of daylight and without clouds. On Figure 4 the measured daylight before 11 AM is more important in PASSYS 1 cell than in PASSYS 2 (renovated) and then during the day it is inversed and we measured more daylight in the renovated cell than in the non-renovated one. It may come for the environment (albedo, surrounding buildings, etc.). Thus a supplementary analysis of received energy on facades gave more information and confirmed that the second (renovated) test cell receives more energy than the first one. So its influence is measured during the daylight measurements. To decrease the influence of the surroundings we decided to change cells orientation and the have direct sunlight on the façades. From the position of North-West we turned the cells in the South direction. We recorded that the second cell receive still more energy than the first one, but the measured values are almost superposed. This measured phenomena can be explained by the presence of a driveway made of light coloured gravel next to the second cell which has a different albedo. On Figure 5 we notice that cells have less daylight than in July (Figure 4) and in PASSYS1 (non-renovated) the available daylight is higher than in the renovated test cell.

These experimental measurements emphasized that the environment of the daylight measurements has a very important part in the data analysis. With the taking into consideration of the environment, we can conclude that the renovation and the presence of the second window decrease the available daylight in the renovated test cell (PASSYS 2).

## Daylight availability

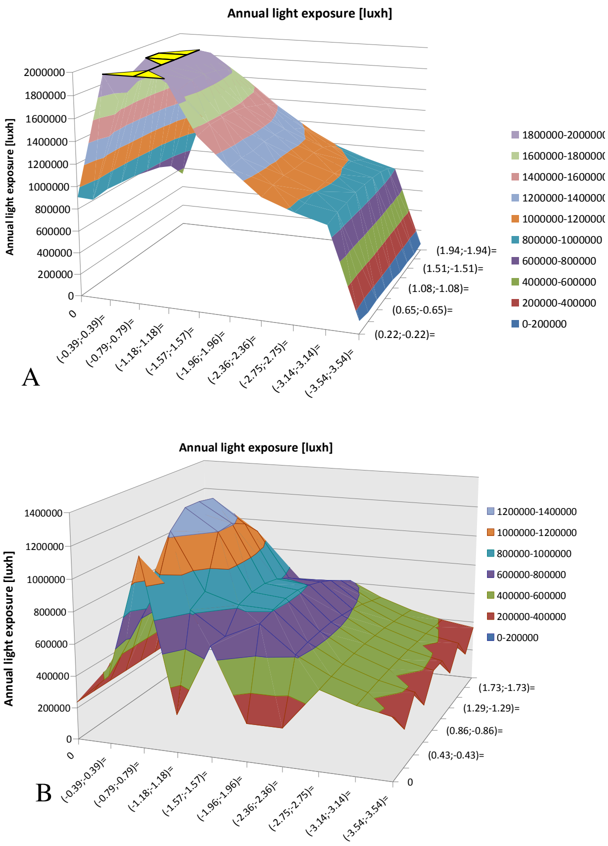



*Figure 6. Results for simulated annual light exposure values for test cell (not renovated) with a North West orientation a) DAYSIM and b) EnergyPlus. Horizontal axes represent room dimensions*

The renovation impact on daylight has been analysed numerically from an annual light exposure point of view. The light exposure is function of orientation, thus will give valuable complementary information to DF study.

For both cases, renovated (PASSYS2) and not renovated (PASSYS1), one simulation with DAYSIM and one simulation with EnergyPlus were performed. For each case, the two numerical results are presented together.

On Figure 6 the non-renovated, North-West oriented case is presented. We noticed big discrepancies between results of the two simulations software. The annual light exposure of North West orientation calculated with DAYSIM exceeds by 20 % the one obtained with EnergyPlus. One can notice that the EnergyPlus results show oscillating results on boundaries, and a second peak in annual light exposure level was found at 3 m depth in the room. This phenomenon was noticed also by Ramos and Ghisi, (2010) and it may come from the internal reflectance treatment of EnergyPlus algorithm. A parametric study of interior surface's influence on these results is planned.

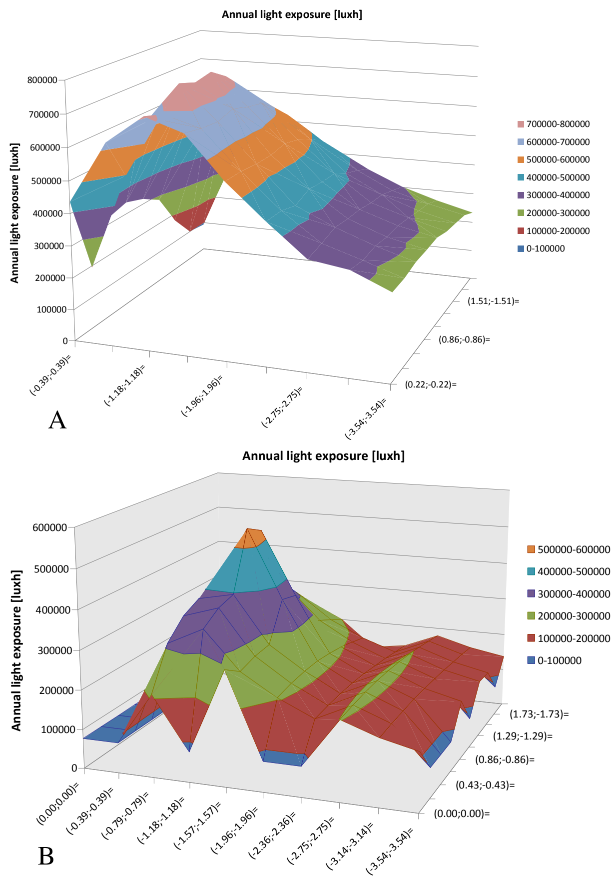



*Figure 7. Results for simulated annual light exposure values for test cell (renovated) with a North West orientation a) DAYSIM and b) EnergyPlus. Horizontal axes represent room dimensions*

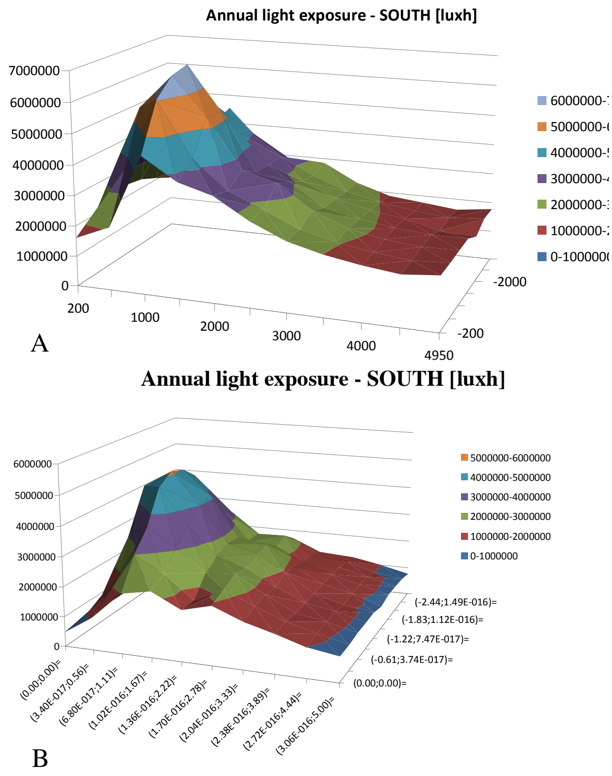



*Figure 8. Results for simulated annual light exposure values for test cell (not renovated) with a South orientation a) DAYSIM and b) EnergyPlus. Horizontal axes represent room dimensions*

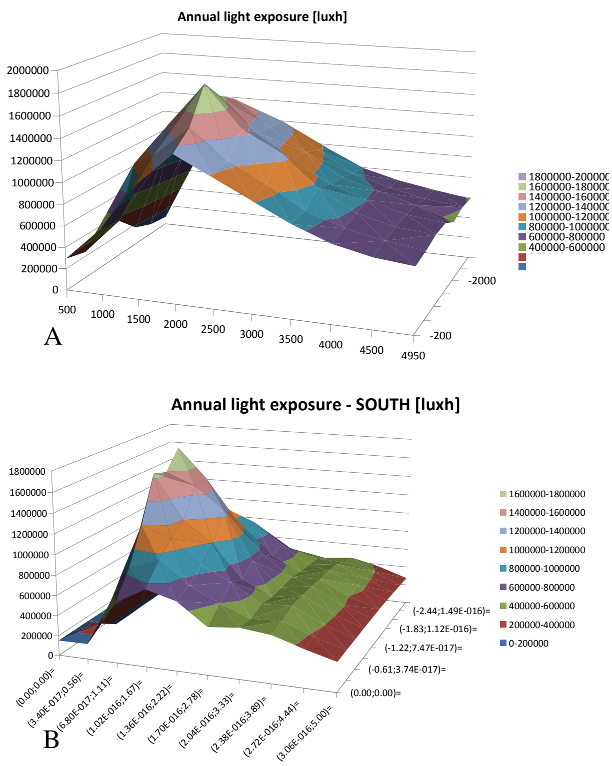



*Figure 9. Results for simulated annual light exposure values for test cell (renovated) with a South orientation a) DAYSIM and b) EnergyPlus. Horizontal axes represent room dimensions*

On Figure 7 the renovated, North-West oriented case is presented.

With South orientation, the same discrepancies between models appear as for North-West orientation. The maximum annual light exposure for the south oriented non renovated facade is three times the value of that of North West orientation. On the other hand, for the renovated case, the maximum annual light exposure value for the southern orientation is about 2.3 times of that of the north-western one.

## DISCUSSION

With daylight availability simulations, a building retrofitting solution was analysed. We obtained a division by three in annual light exposure values between not renovated and renovated solutions. To offset this inconvenience, additional daylight amplifier structures such as light shelves or light reflectors should be used. With these structures, thermal retrofitting can increase daylight inside the room. Simulation results showed that southern orientation let enter as much annual light in the room for a renovated case as a north-eastern orientation for a not renovated case. This could be a good argument for retrofitting, thus outside thermal retrofitting without changing openings' size is recommended for southern facades while for north-eastern ones you should choose other solutions or supplementary daylighting structures.

## CONCLUSION

This paper shows a way to process and give a comparison between two simulation tools available for daylight computations. Their results showed that the discrepancies between results stay around 20 % for annual values and about 30 % for DF simulations. The showed instantaneous measurement data can only give tendencies and highlight the need for annual daylight measurements. In the future, this annual measured value can be confronted with our simulated values for a better numerical simulation adjustment and improvement.

## ACKNOWLEDGEMENT

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