ASSESSMENT OF INTEGRATED PV SHADING SYSTEMS FOR ENERGY SAVINGS AND INTERIOR COMFORT CONDITIONS IN MEDITERRANEAN COUNTRIES

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ABSTRACT

Fixed shading systems are saving energy by reducing the cooling loads of the space they shade, but can be a source of energy losses due to the increased need of daylight that they create. Aim of this paper is the comparative assessment of different typologies of buildings' shading systems with integrated photovoltaics. The assessment is focused on their energy efficiency and degree of internal visual comfort conditions that they can ensure. The purpose of the comparison is to optimize the combination of shading systems and their integrated solar cells. Especially for office units, due to the specific demands for visual comfort and the increased needs for quality lighting, balancing the above mentioned facts is more crucial.

Shading systems are grouped and studied according to their energy savings (production and reduction of cooling loads) and to the quality of the visual interior environment. For the study computer simulations are used for the energy loads (needs/production) and both computer simulation and experimental physical models are used for the daylighting assessment. Moreover, through this research, the effect of specific geometrical characteristic of the photovoltaic modules installed is analyzed in relation to the energy produced and to the resulting visual conditions.

KEYWORDS: energy balance, shading systems, BIPV, visual comfort

1. INTRODUCTION

The main objective of this paper is to evaluate fixed shading systems with integrated photovoltaics (PV) facing south in Mediterranean countries according to their ability to save energy and to provide visual comfort. For this purpose we focus the experimental work mainly on three areas: balancing energy consumption with the resulting thermal comfort, daylight quality and energy production for office units.

This research concerns the determination of best performing systems in terms of low energy needs for heating, cooling and electric light needs of the shaded space. We examine both the energy needs for heating the space and the energy needs for cooling the space for yearly-fixed thermostat settings range between 21.6 and 24.1 C, for office hours of 9:00 to 17:00 for five days per week (Sanea & Zedan, 2008). We examine electric light needs when daylight levels fall under 500 lux on the desk level (Boyce & Raynham, 2009)

We mostly compared the two groups of shading systems, the louvers systems and the systems that allow view to outside. Analytically we categorize them to:

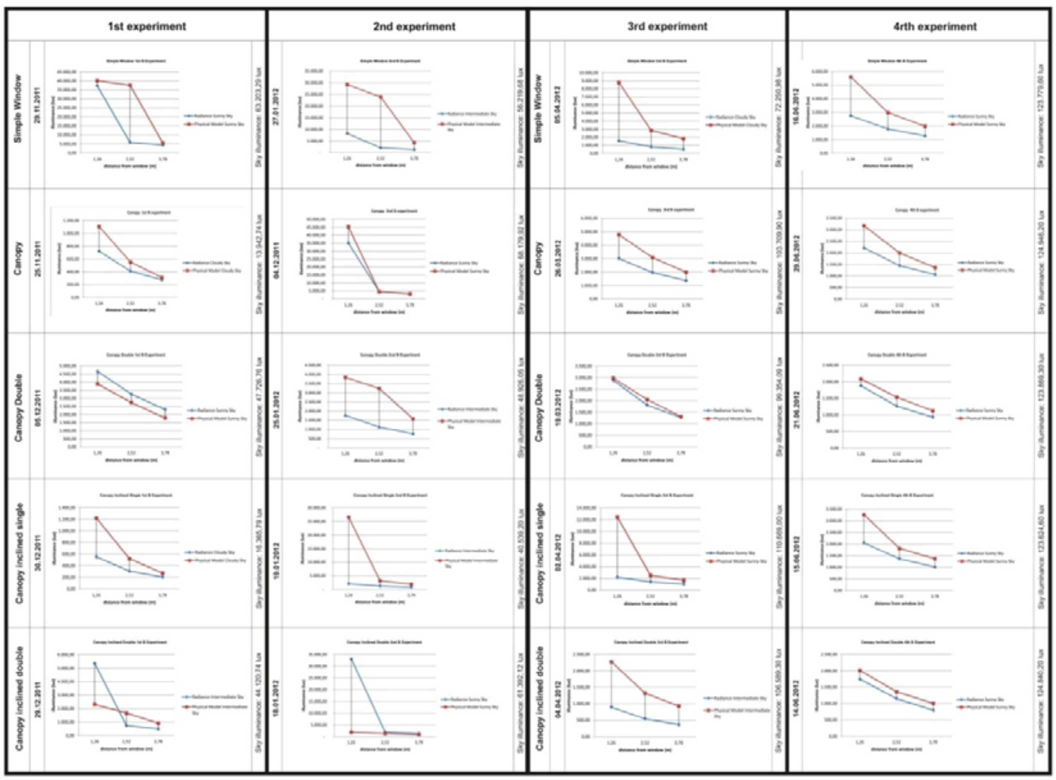
a. Shading systems that allow transparency: Canopy horizontal, Canopy horizontal double, Brise Soleil full façade, Brise Soleil Semi façade, Surrounding Shade, Canopy Louvers, Canopy Inclined Single and

b. Shading systems that obstruct view to outside: Canopy Inclined double, Brise Soleil Semi Façade with Louvers, Louvers Vertical, Louvers Horizontal, Louvers Horizontal inwards inclined, Louvers Horizontal Outwards Inclined.

2. EVALUATING VISUAL COMFORT CONDITIONS
2.1. Comparison of physical model and simulation tools

The comparison between measurements on physical models and simulations can be a complicated task, especially in cases when the physical model has been tested in real sky conditions. For this reason, research has been carried out and we have arrived at some basic conclusions with reference to the measurements from the validated simulation tool used and the measurements from the constructed model. In general the physical model overestimates the values in comparison with the simulation tool (Mardaljevic, 2001). In some cases the overestimation is in the range of 10%.

When the divergence between the two models is in the range of 300% and over this is due to the rapid changeability of the daylight and to the small divergence of positioning the sensor in relation to the simulated model. In cases where the sun is higher in the sky (summer solstice) the divergence is higher. Moreover, in the complicated geometries of Venetian blind systems the divergences become even higher. It is important to mention that in contrast with the reported data by Mardaljevic (2001) the differences between measurements in a physical



model and measurements in simulations are higher in positions near the window and not at the back of the room (Fig. 1).

Figure 1: Comparison of results of simulations and measurements with physical models of 44.92% WWR for Chania Latitude

2.2. Evaluation of Daylight Autonomy Levels

Regarding Daylight Autonomy (DA) for daylight levels above 500lux, systems allowing outside view perform better than louvers systems. From the first group of shading systems (transparent systems) **Canopy louvers** and **Brise soleil** systems perform better while the **Surrounding shade** has the lowest value of DA. In the second group of shading systems **Louvers vertical** and **Louvers horizontal** perform better when compared with **Louvers Horizontal Outwards Inclined** (Fig.2).

The higher the DA the lower the energy needs for electric lighting.

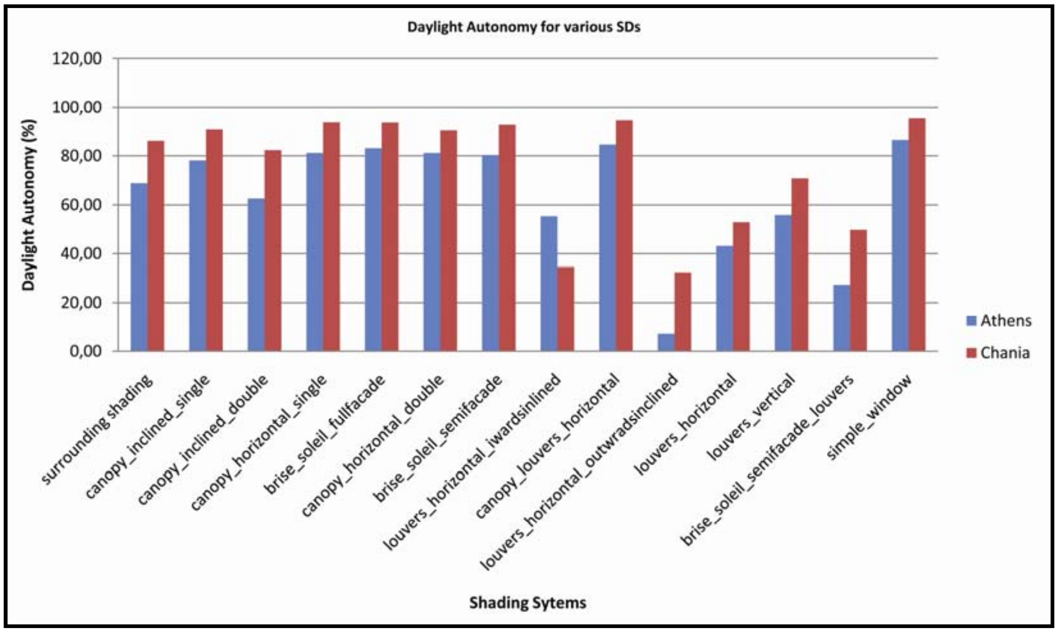


Figure 2: Comparison of Daylight Autonomy for Athens and Chania

2.3. Comparison of Daylight quality in terms of Useful Daylight Illuminance (UDI)

Useful Daylight illuminance (UDI) is defined by Mardaljevic (2001). We assess three basic statistical values: UDI 100 -2000 (the mean value of the UDI), the UDI 100, (the percentage of the time of the year when the space has daylight under 100 lux; this level is considered very low) and the UDI 2000, (the percentage of the time of the year that the space has daylight above 2000lux; these levels of daylight are considered to result in uncomfortable comfort conditions).

Amongst transparent façade systems Surrounding Shade seems to perform well because it has high UDI 100 - 2,000 values, low UDI 100 value and low UDI 2,000 value in comparison to other transparent shading systems. Additionally Canopy Double systems Inclined or not perform well in relation to the three examined UDI values, but lower than Surrounding Shade. Façade shading systems and especially louvers systems perform better in terms of high percentage of UDI 100-2,000. Amongst these systems, Louvers Horizontal has the highest UDI 100 -2,000 and simultaneously the lowest UDI 100 (Fig. 3).

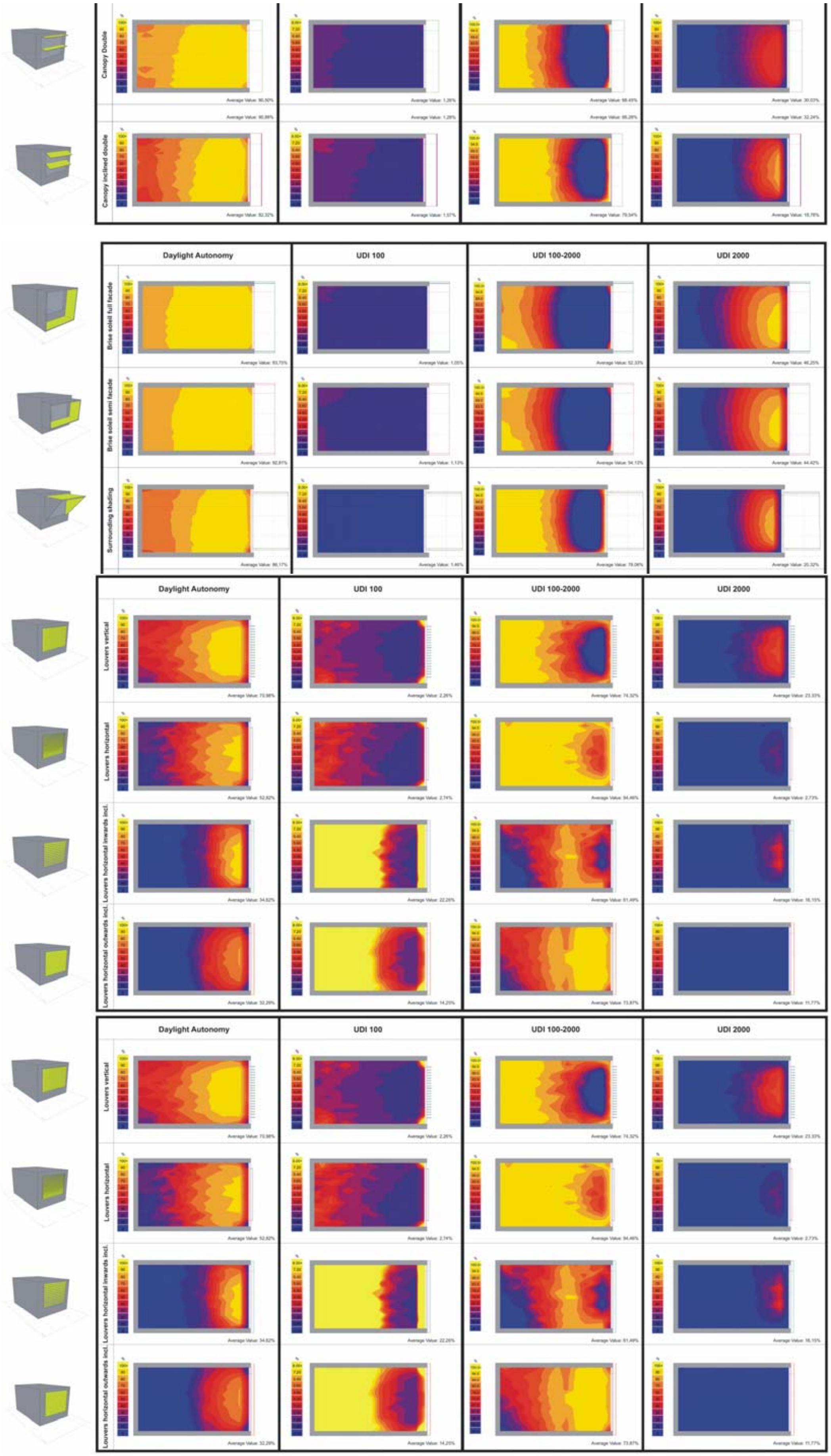


Figure 3: Comparison of UDI values in relation to DA values for all SDs examined for the case of Chania

2.4. Comparison of Daylight quality in terms of Glare

Daylight Glare Index (DGI) is defined by Baker & Steemers (1993). Values below 16 are considered to result in an imperceptible visual environment. Originally we selected the "worst viewing position" for the simulations. In theory, the worst viewing position is the one that has the highest vertical viewing angle of the window that constitutes the main light source of the space in question, and the one with the widest viewing angle onto the surface of the window (Meresi, 2010). Only some systems can result in values below 16 and these are presented here in sequence starting from the best performing: Canopy louvers, Louvers vertical, Brise Soleil Full Façade and Canopy horizontal (Fig. 4).

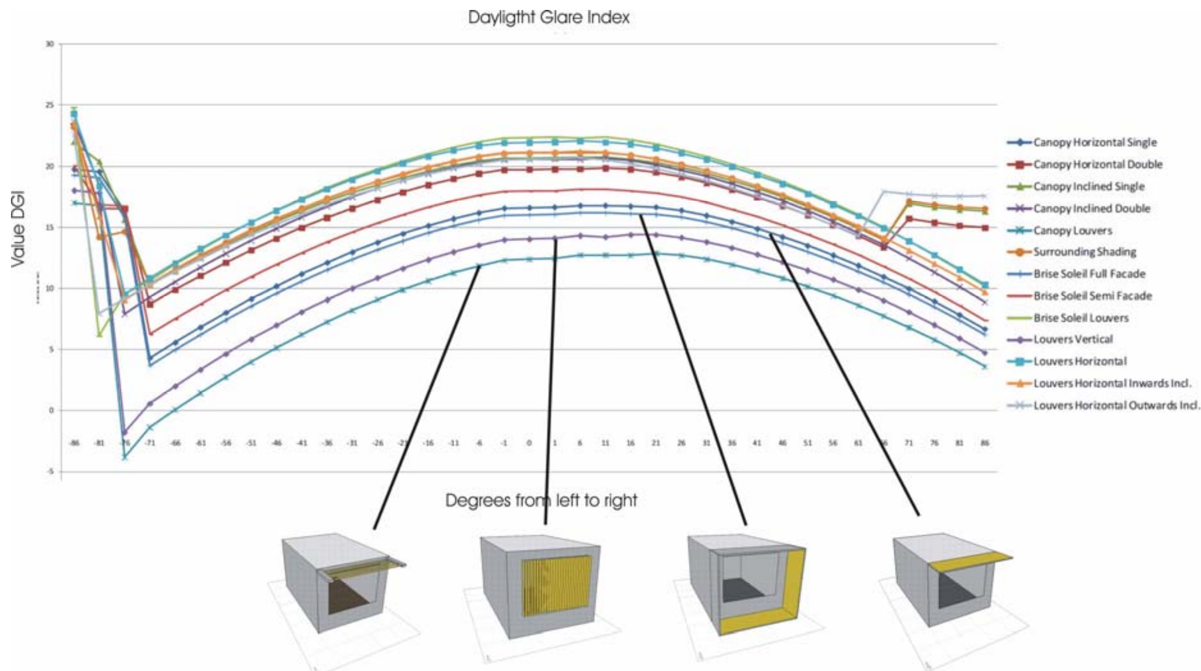


Figure 4: DGI values for the 21 December at 12:00 o'clock for all examined systems in relation to the angle of view for the camera away from window

3. BALANCING ENERGY SAVINGS AND VISUAL COMFORT

The system of Surrounding Shade is performing extremely well in terms of low energy needs, has proved to perform well in terms of daylight quality for positions away from the window and has good performance of UDI values. On the other hand, the System of Brise Soleil full facade that is performing well in terms of energy needs for thermal comfort (but lower than the surrounding shade) performs very well in all daylight quality values examined. Similar results can be extracted for Brise Soleil semi facade system. If we examine the systems in terms of daylight performance the system of Canopy Louvers has very good performance according to energy savings for lighting and according to visual comfort in positions away from window and acceptable visual conditions near the window. At the same time this system performs low in terms of energy savings for heating and cooling the space. Additionally it is important to mention that the systems of Canopy double horizontal or inclined seems to have an acceptable performance for all examined values but cannot be a valuable solution due to the resulting moderate environment in terms of comfort and of energy savings.

4. DISCUSSION AND CONCLUSIONS

In order to evaluate the performance of the examined shading systems a table is being created that incorporates all the examined values related with visual comfort and energy savings (Fig.5). It is obvious that the system of **Surrounding shade** is performing extremely well in terms of low energy needs, has proved to perform well in terms of daylight quality for positions away from the window and has good performance of UDI values. On the other hand, the System of **Brise – Soleil full facade** that is performing well in terms of energy needs for thermal comfort (but lower than the surrounding shade) performs very well in all daylight quality values examined.

We have attempted to combine the different and occasionally contradicting properties of the various shading systems examined in relation to their ability to save energy and to provide high quality of daylight. We have concluded that the systems of Surrounding shade and of Brise Soleil Full and Semi facade can best achieve these two goals. The only disadvantage is that they cannot ensure comfortable daylight conditions away of the window of the examined room.

It is remarkable that the systems of Louvers which have proved to perform very well in office units tare unsuitable for integration of PV, due to the fact that their energy production becomes very low when PVs are integrated.

We recommend that when considering PV integration for shading systems in office buildings Surrounding shade and Brise - Soleil Systems should be considered as a valuable solution.

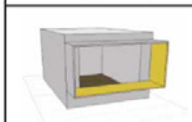
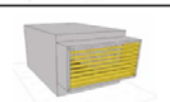
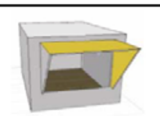
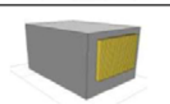
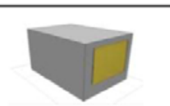
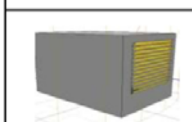
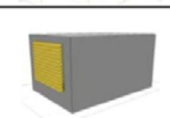
	UDI	DGI Away from window	DA	Energy Needs For H + C
	LOW - 1	BEST - 2	BEST - 2	LOW
	MIDDLE	LOW - 4	BEST - 5	LOW - 3
	MIDDLE	MIDDLE	BEST - 3	MIDDLE
	BEST	MIDDLE	MIDDLE	MIDDLE
	LOW - 2	BEST	BEST	LOW - 1
	MIDDLE	BEST - 3	BEST - 1	BEST - 1
	MIDDLE	MIDDLE	BEST - 1	BEST - 2
	BEST	LOW	LOW - 1	BEST - 3
	BEST	LOW - 3	BEST - 3	BEST
	MIDDLE	BEST - 1	LOW- 2	MIDDLE
	BEST	LOW - 1	LOW- 2	MIDDLE
	LOW	LOW - 2	LOW	LOW - 2
	LOW	LOW -3	LOW	MIDDLE

Figure 7: Comparative assessment of shading systems

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