Integration strategies of Luminescent Solar Concentrators panels: a case study in Florence - Italy

Ali Sayigh *Editor*

Sustainable Energy for all

Selected Papers from the World Renewable Energy Congress WREC 2016

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Ali Sayigh (Ed.)

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Integration strategies of Luminescent Solar Concentrators panels: a case study in Florence - Italy

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Topic: renewable energies in building & cities

Keyword: LSCs, Urban Lighting, Green power, Concentrator Photovoltaics

Topic: renewable energies in building & cities

Abstract

The paper deals with few solution for the integration of a luminescent solar concentrator (LSC) realized with color dye-sensitized solar cells, some of them produced by ENI Donegani Institute and analyzed by Politecnico di Milano. By this paper, we want to show the versatility of LSC panel either on the facade of a building and on urban lighting.

The Luminescent Solar Concentrators have the capability to produce electricity on transparent surfaces, to use in architecture and to be integrated into the building envelope, such as in vertical walls. These panels do not need to have south oriented surfaces because LSCs panels are perfect in the presence of diffused light and their performance does not decrease during this condition. The visual effects of the dyed LSC integration are analyzed to find the potential use of such a component in the built environment.

A typical LSC panel consists of three elements: a layer containing fluorophores (fluorescent molecules), a waveguide plate in PMMA or similar and lastly solar cells along the edges of the plate. The peculiarity of these panels are: a colorful coloration, transparency, lightweight system (so they are good for building integrated photovoltaics), use of direct or diffuse light, no heat production, decrease in the quantification of solar cells, use of low-cost materials, 10% efficient and they also glow during the night with their own colorful light.

It is also a feasible alternative to the classic PV solar panels. LSCs panels can show identity value, sense of belonging and iconography which is so much needed in an iconic building like University residence “M. Luzi”, in Florence. By four project ideas we demonstrated the versatile usage of these panels, furthermore, we made a comparison, for equal dimensions, between same efficiency LSC panels and Si- polycrystalline PV panels. In a similar context, like the service industry, even an industrial building can evolve by changing the nature of a sad and empty suburb. The LSC panels can be adapted for public urban lighting and also traffic lights which can either lead more light and be able to be self-sufficient.

The LSC panel integration in the building envelope can contribute greatly to produce electricity and characterize the envelope through transparency and color. However, during the planning stage, it is necessary to focus on the internal and external context of the building. This is because LSCs panels are characterized by very bright colors such as yellow and red (which have been commonly used up until nowadays). The usage of these colors can occur into a visual discomfort and dazzling light if they are not used correctly.

Objectives

Through the explanation of the LSCs (Luminescent Solar Concentrators) and their positive or negative aspects, we want to prove that these are better than the classic PV panels. Sometimes specific local conditions or just common sense, lead us to prefer the LSCs.
There are two different examples proposed in this paper: firstly, the M. Luzi student hall. It is situated just outside Florence city center, towards the north. In this case, if we used classic PV panels, we would have low energy performances due to the local natural conditions. Using LSCs panels could be a valid aesthetical alternative, probably more appropriate to represent a dorm iconography. Actually, LSCs panels could give a significant improvement to the quality and performance of the energy.

Secondly, urban lighting in Florence. The aim is to improve the urban lighting through road signs integrated from LSC Technology. The primary goal is to increase the urban and extra-urban nighttime visibility (during rain, fog or snow).
Therefore, the objective is to establish a link between squares, parks, gardens, and roads. Urban and extra-urban lighting management is also an area that is seeing energy-saving innovations and develops three categories which will be discussed later on.
Every brought example serves to confirm that LSCs panels are versatile and repeatable in different contexts despite low energy performances. LSCs panels have a very low or void cost, so these devices have become the object of deepened studies in different parts of the world.

Concentration technology & LSCs

LSCs panels belong to the family of the systems to concentration, which use optical systems as mirrors or lenses to focus the solar radiation into high efficient PV cells.
The ability to produce energy from sunrise to sunset is the greatest characteristic of these devices. This solves the problem of the panel's disposition to a certain inclination and orientation.
Initially, it seemed that the problem linked with the classical PV system by using concentration technology was solved (cost and bigger spaces). However, it soon became clear that these also had other problems.
The heat produced from such devices was difficult to reduce and every mechanical issue of the solar pursuer would have been able to decrease the efficiency of the whole system.
In 1970 LSCs panels were considered an evolution of existing concentration system for the lack of the solar pursuer and were not able to produce heat.

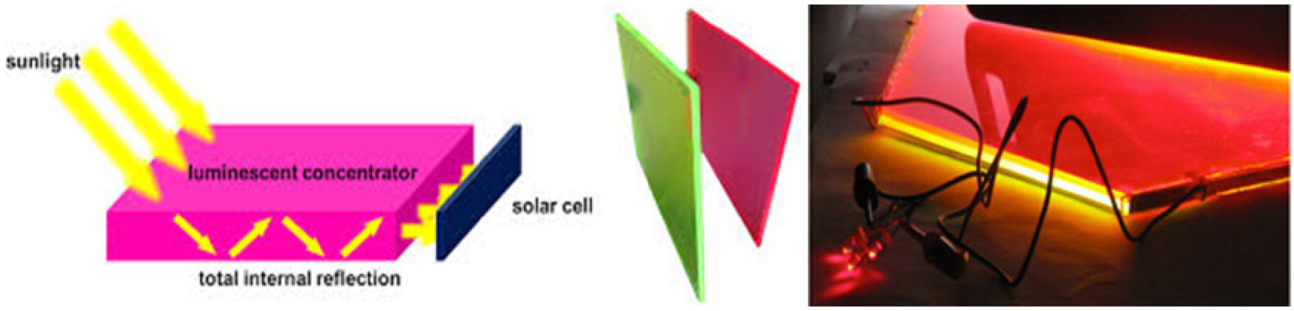

Fig1. Luminescent LSC panel. A typical LSC panel during the night with its fluorescence.

Generally, the LSC panel is composed of flat plate waveguide (in plexiglass, glass or similar), which has high optical quality. The flat plate is a matrix of this system and it is covered with a desired thickness of fluorophores. These are particular chromophores, which are colorful and are able to light up in particular situations. Presence of such particles makes the system photoactive; it means that the panel can convert the incidental photons on the surface into energy. Along the edges of the plate, there are PV cells that absorb the solar radiation, which is turned into electricity.
The most important characteristic of LSCs panels is the ability to convert the solar radiation into more efficient wavelengths: ultraviolet radiation (UV).
The matrix material of the LSC panel is transparent, colorful and very light so it is perfect to use in different architectural contexts.
A typical LSC panel is divided into only three parts: a thin layer containing organic molecules, a flat plate, and transparent plate waveguide and finally a small Si-monocrystalline PV cell along the edge of the plate.
For the University of Science and Technology in China, the ideal LSC panel must have the following characteristics:

1) grid parity with form of energy currently used;
2) ample range of absorption, to absorb more efficiently light energy within the sunlight range;
3) 100% quantum fluorescence yield;
4) large Stock Shift to minimize the overlap between absorption and emission spectrum;
5) simple in functioning;
6) able not to get overheated;
7) realizable in more colors and shapes;
8) low cost;

9) long-term stability (over twenty years).

The second important characteristic of LSC panel is the matrix in polymeric material like PMMA or glass. Part of the UV radiation is absorbed from LSC panel so during summer time the energy demand for indoor cooling decreases and hence savings on costs. The remaining part of sunlight range goes unchanged through the plate illuminating indoor areas.

Methodology

This paper presents a case study of the integration of the Luzi University student hall with LSC colored modules.
Before designing a PV installation, it is important to understand the local project and global conditions.
If the building was unfavorably directed and the shadow factor was too raised and it was not possible to integrate classic PV cells on the rooftops for aesthetic or urbanistic reasons, then it could be necessary to integrate LSCs panels. That is exactly the case of M. Luzi student hall.

Fig2. Luzi university student house, Florence.

This building is like a rectangular and white parallelepiped divided on its surface from vertical, narrow and long elements. The dorm has six stories and it is surrounded by other buildings (2-3 stories), and there is a square around it.
If we integrated classic PV panels in front of this building then we would have a low performance because of limited solar energy accident (the front of the building has North-Western exposure), because of shading factor and albedo existing in this place. Actually, surrounding buildings shadows hinder the sunlight on its front. Because of this, we would have an increase of costs and times of return of the initial investment.
In effect, the shading coefficient, calculated on “Solarius-PV” ACCA software, is equal to 0.25, while reflectance values are equal to 0.26 (monthly average albedo value).
However using classic PV cells in Si-Polycrystalline on M. Luzi dorm, we would have a return greater than using LSCs panels. Nevertheless, we prefer these second categories because the first type produces an overheating on the skin of the building and because they are more appropriate to represent the iconography of a university dorm.
We have then drawn, four different dispositions of panels on dorm surface and for every possible scenario; we have designed a daily and night time view.

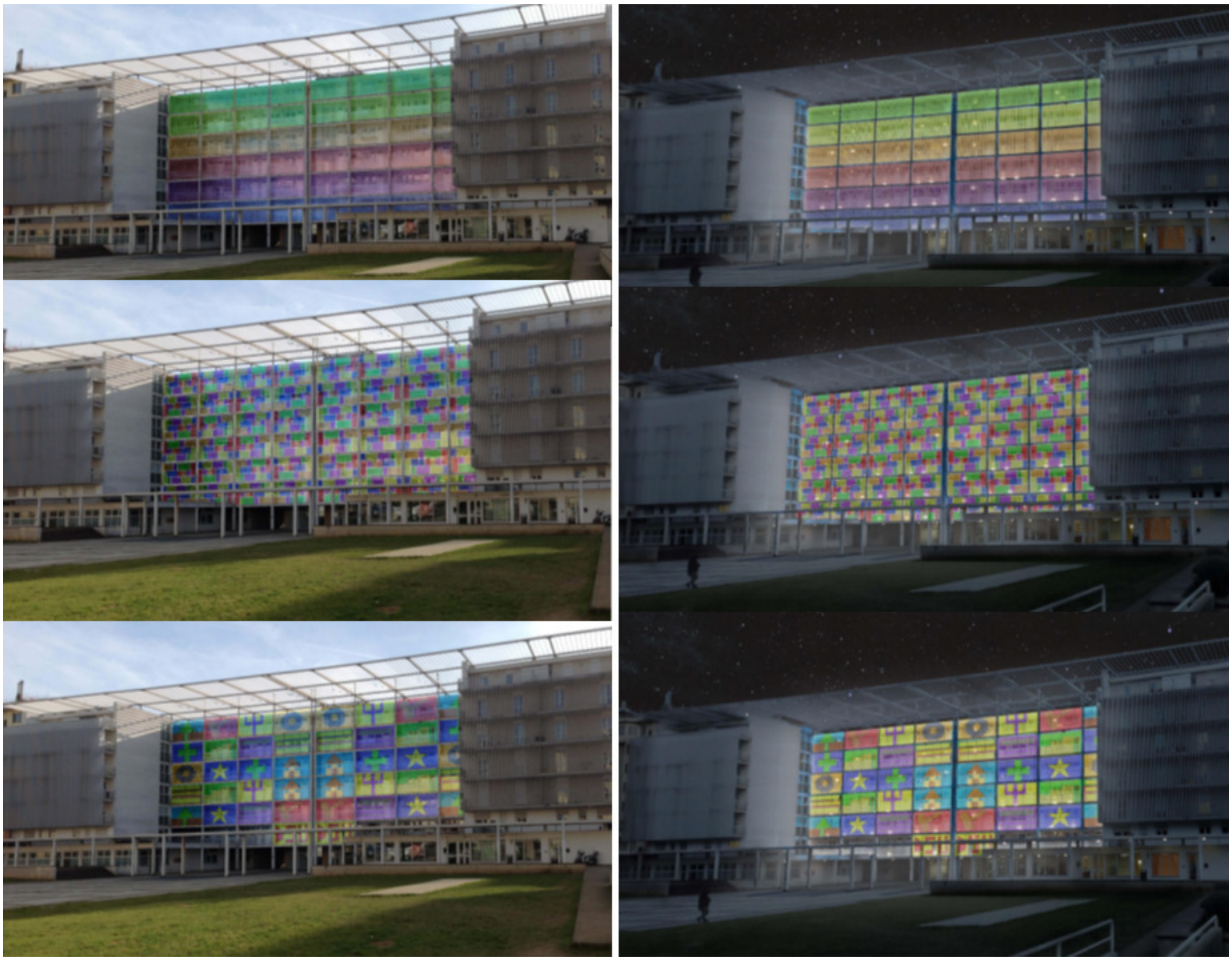

Fig.3 Luzi university student house. First daily and night time view it is about the rainbow color project idea, second, view it is about form and size actually on the market; third, it is about Florence University logos.

The second case study is about efforts to improve urban lighting and safety on the streets by integration of LSC technology to the roads system of signs.

Putting totems near benches in parks or along avenues can generate electric production usable in common services and contributes to improving nighttime visibility of these areas. In this way, it is possible to stay there after sunset.

Fig4. Totem in green LSC panels, “Parco delle Cascine”, Firenze

In urban areas, for example, in one of the most famous streets of Florence “via dei Calzaiuoli”, we have thought about making more visible advertising shop signs using LSC technology along the edges of roadside billboards. This could effectively be used inside open-air shopping malls, by illuminating, regulating and identifying the shop signs.

Fig.5 LSC frame with red dye, “Via dei Calzaiuoli”, Firenze

Scientific literature has agreed that improving the visibility of roadway can decrease the number of accidents. So, we thought we’d integrate LSCs panels in road signs like traffic lights, visible lane marking (means delineators on the borderline on the lane that are visible by the driver), danger, give way signs, obligation or prohibition signs. Despite small energy power, this system is effective and functional in different situations and contexts.

Fig.6 Pictures show the different visibility in the same place between hairpin during the night with fog and during the night with fog but with LSCs panels integration.

Results

Through the study of existing, examples about LSC panels like Eni’s bike sharing shelter in Rome (500 Wp from 60 mq of transparent photoactive yellow plates), and studies of Sergio Brovelli from University Milano-Bicocca it is deduced that these panels have about 10% efficiency.
Sergio Brovelli’s team studies are based on the use of particular plates die chromophores, which can propagate sun light for long distances without energy dispersing (because concentrators are incorporated of particular colloidal crystals, nanomaterials). Therefore, fluorescence can propagate for long distances without losses and then it is possible to make LSC panels hundreds of centimeters in width. If directly used in buildings (windows for example), they do not do not increase costs.
For Eindhoven University, the color of LSC panel influences yield of panels, in effect a blue dye is more efficient than red dye (21,9% ± 1,6% versus 10,83% ± 1,4%), for example.
Using colorful (red, blue, yellow, violet and green), LSCs panels with 10% efficiency on M. Luzi dorm we would have only 50 KW (by 770 modules for 1000 mq).

Similarly in “Parco delle Cascine” we calculated that every totem can generate around 12 watts, so if we put a totem along boulevards every 5m (for 160 ha), we will get about 20 kW of electric production.
While if we put a frame in LSC panel on every shop sign in “via dei Calzaiuoli” street, we would get 270 watts (10 watts for every frame of size 10 x 200 cm).
Lastly, for urban and extra-urban lighting case study, the energy power of every road sign depends on the greatness of signs. In effect, for the small sign (40 cm in diameter), we will have 6 watts, for the middle sign (60 cm in diameter), we will have about 14 watts and for the large sign (90 cm in diameter), we will have 30 watts.

Conclusions

The present work allowed assessing daylighting performances of a series of innovative Smart Windows developed in Italy by Eni and the Politecnico of Milano, based on configurations realized with LSC plates characterized by different colors.
Nowadays, 10% performance for LSC panels is too low to persuade the public administration to finance such far-sighted projects, but scientific research offers prototypes that are more and more powerful and durable every day (Quantum-Dots, EuTT with organic binders like Thenoyl Trifluoroacetone, etc.).
In effect, if we had LSC panels with 30% performance, surely classic PV panels would disappear from the market because LSC panel does not produce heat, for low costs and weight and for great building integration. Think of many application fields is a good way to encourage research.

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