THE USE OF PHOTOVOLTAIC CELLS AND LED LIGHTING IN THE DESIGN OF FACADES OF SHOPPING MALLS

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Abstract
The use of renewable energy sources, and solar energy in particular, has become an imperative in modern architecture. One of possible approaches are the building integrated photovoltaics, which are architecturally very demanding, since at the current level of development, photovoltaic panels substantially narrow the architect's choice in terms of color and materialization.

Most previous solutions are based on the use of thin-film photovoltaic cells embedded between layers of transparent or colored glass, which forms a semi-transparent layer of the building with a certain freedom in the choice of colors. With the development of energy-efficient LED lighting, its use in combination with photovoltaic panels attracted particular attention on the facade of the GreenPIX Media Wall in Beijing, where the entire facade is turned into a huge screen that creates a coarse-resolution dynamical effects with abstract motifs. However, this facade is opaque and does not leave the possibility for the openings in the facade, which narrows the possibility of its use.

In this paper, the authors suggest how the alignment of transparent surfaces, photovoltaic cells and LED lighting can create a new, dynamic facades of shopping centers that would at night combine the display of illuminated interior spaces filled with people movement and dynamic images of abstract motifs by computer-controlled LED lighting installed at the facade.

Keywords: Solar energy; LED lighting, photovoltaic panels, facade design

INTRODUCTION

The building-integrated photovoltaics and mediatecture are two currently prominent and substantively opposite areas of facade architecture, due to their perceived goals – one of collecting the energy and the other one of media display. However, the disjointness of their application – the photovoltaics collect the solar energy during the day, while the media is displayed during the night – makes these two architectural areas the attracting opposites, the yin and the yang, which follow and support the diurnal cycle of the world and the facade itself.

On one hand, the use of renewable energy sources, and solar energy in particular, has become an imperative in modern architecture. One of feasible approaches is the integration of photovoltaics into the building facade, which is architecturally very demanding, having in mind that at the current level of development, photovoltaic panels still substantially narrow the architect's choice in terms of color and materialization. Most current facade integrations are based on the use of thin-film photovoltaic cells embedded between layers of transparent or colored glass, which forms a semi-transparent layer of the building with a certain freedom in the choice of colors.

On the other hand, mediatecture integrates media into the facade and creates the fusion of both elements into an individual whole, lending the identity to architecture and building the interface between the virtual and the real world. Although there are mediatecture examples using old-fashioned technology, such as the Kunsthaus in Graz by realities:united which uses fluorescent lamps, virtually all current mediatecture realizations are based on energy-efficient LED lighting.

The first, and at the same time very radical, facade that successfully featured a combination of both goals – it uses collected solar energy to power its media technology – is greenPIX, the zero energy media wall in Beijing by Simone Giostra & Partners. The huge attention it attracted in architectural community is setting it as a...
milestone in the goal of reconciliation and simultaneous facade integration of photovoltaics and media display.

Fig. 1. greenPIX, the zero energy media wall in Beijing by Simone Giostra & Partners [7].

However, the greenPIX surface is fully opaque and, as such, has limited application to facades with substantial amount of transparent surfaces. Examples of this type are shopping malls, which are filled with life in evening hours as well, and which feature transparent surfaces in parts of the space with highest communication density (at the entrance and the restaurants, for example). Here we discuss how a careful alignment of transparent surfaces, photovoltaic cells and LED lighting may create new, dynamic facades of shopping malls that would at night combine the display of illuminated interior spaces filled with people movement and dynamic images of abstract motifs by computer-controlled LED lighting installed at the facade.

MODERN LED MEDIA FACADES

Besides greenPIX, a large amount of modern media facades are fully opaque. For example, while the media facade of former Bayer headquarters (Figure 2) is obtained by wrapping it into partially transparent stainless steel mesh with LED profiles mounted on the mesh framework, the interior of the building has still been closed with green core used to gleam off a separate architectural light behind the mesh.

Fig. 2. The exterior of the former Bayer headquarters [3].

Fig. 3. The interior of the former Bayer headquarters [3]. Stainless steel mesh with LED profiles is shown to the right.

On the other hand, the facade of A.APM office building in Singapore (Figures 4 and 5) consists of a high-end LED screen and over 500 full color LED light units. By day, this facade is indeed a conventional glass facade, however for its night activity it uses light reflecting curtains, which are subdued when the offices are emptied. Thus, it also relies on opacity for its work.

Fig. 4. Media facade of A.APM building in Singapore [5].
The majority of modern media facades are still fully opaque, the reason probably being to avoid deterring viewer’s attention to the interior of the building. However, the transparent LED media facades started to appear and they use pretty much the same steel mesh technology with mounted LED profiles as the former Bayer headquarters (Figure 6). The amount of transparency is hereby controlled by a ratio of thickness of single steel ingots to the space between them.

For example, the American Airlines Arena in Miami (Figures 7 and 8) features rather tight mesh ensuring high resolution display, while the facade of the T-mobile headquarters in Bonn (Figure 9 and 10) employs more distant steel ingots to allow for interweaving with the interior views at night and to become almost completely transparent if turned off.
ON THE DESIGN OF SUSTAINABLE MEDIA FACADES FOR SHOPPING MALLS

While the shopping malls usually have smaller height, they cover large areas and have prolonged facades. In order to keep the ware safe from the bleaching effect of sun rays, their facades are opaque with transparent parts present only and necessarily in the spaces of high communication density, such as the entrance halls and the eating areas. As a prominent local example, we shall consider the Mercator shopping mall in Niš, Serbia.

![Fig. 11. The west-southwest facade of the Mercator shopping mall in Niš, Serbia.](image)

![Fig. 12. The south-southeast facade of the Mercator shopping mall in Niš, Serbia.](image)

An important characteristic from the viewpoint of sustainability, the shopping malls in general have large roofs which can certainly be used for the installation of photovoltaic power plants. Moreover, the location of shopping malls is often such that their roofs cannot be substantially shaded by neighboring buildings, making the PV installation even more plausible. In countries with favourable state subventions for the production of renewable energy production subventions, such installations may yield to profits in the long term, with an added benefit of making the image of the shopping mall owner more appealing, more green, to the general public.

However, while the PVs installed on the roof may be tilted to optimum angle for maximum energy production, they are not visible to the mall visitors. Thus, to fully exploit the green image making potential of PVs, they have to be installed at mall facades, either as outdoor facade panels at the highly visible opaque parts of the facades or as the PV glass laminate at the transparent parts of the facades. The first option is illustrated in Figure 13, as applied to the Thyssen Krupp factory in Duisburg.

![Fig. 13. The facade covered with PV panels.](image)

Due to its orientation – the large opaque surfaces of the Mercator shopping mall are facing west, north and east – the second option is more suited to this shopping mall. It has large glass facade facing south-southeast at 80° tilt, and two smaller glass facades opposite to each other – one at the west and another one at the east side of the mall. One should notice here that only the two smaller glass facades are allowing the daylight into the main entrance of the building – at the moment, a number of smaller shops is located behind the larger glass facade, a good deal of them with opaque walls behind this facade – quite some sense of contradiction! Thus, the first architectural action called in here should be for the reorganization of internal space to grant this daylight flooded area to eating and seating space.

Next, a carefully aligned PV modules and LED pixels either laminated in the glass or mounted on the semitransparent steel mesh would create a new, still transparent, but dynamic facade that would at night combine the display of illuminated interior spaces filled with people movement and a suitable media content display. It is superfluous to mention that the moving images on a facade have a decisive advantage on the perception of people outside the mall and will even better attract their attention. Off course, unlike the electronic billboards, the media content display of a facade should be harmonized with the form of the building and the activities inside, since in this situation the mall architecture, activities of a swarm of people inside and the media display are perceived as one, unified, modulating architectural entity by exterior visitors.
Further question is whether such proposal could be sustainable in the sense that it generates as much energy as it uses for the media display? The standard stainless steel mesh with LED profiles sports 320 LEDs per m² and consumes around 20 Wh [5]. Thus, displaying the media content six hours per night would consume around 44 kWh per year per m² of display. On the other hand, the average solar irradiation on horizontal surface in Niš measured from 2005 to 2009 at the Faculty of Science and Mathematics is 1364 kWh/m². At 80% tilt, a simulation run in PVSYST 5.11 [4] reports that the requested 44kWh per year would be generated if PV installation would have nominal output of 53Wp per m² of glass. This is easily achievable: contemporary PV modules of dimensions 0.6 x 1.2m have nominal output of 75Wp. Thus, the necessary energy for 1m² of LED display would be generated by 0.55m² of facade integrated contemporary PV modules (we have taken into account the shading coefficient implied by the presence of steel mesh in front of the facade). Alternatively, one might consider the case of solar cells sandwiched in the glass (which would make it semi-transparent). However, due to the presently low efficiency of such type of PV modules, it turns out that ratio of solar cells to the total area of the glass would have to be larger than 80% (see, e.g., [1,2]).

Therefore, we may conclude that a zero-energy media facade at the Mercator shopping mall in Niš may be achieved with readily available technologies by replacing 55% of glass with glass laminated PV modules and creating an artistic module composition that would still allow plenty of daylight into the space.

CONCLUSION

Media facades bring architecture from static to utterly dynamic form and present an entirely new dimension for creative architectural expression. Modern media facades mostly use LED lighting, whose little energy consumption makes it feasible to create a fully sustainable, self-sufficient, zero-energy media facade even with readily available photovoltaic technologies and skilful design. Such option has been discussed here in the case of a particular shopping mall, whose complex has large enough surfaces exposed to sun. With fast rate of development present both in the fields of LED lighting and photovoltaic technology, the design of zero-energy media facades will become even simpler and it is certain that we will witness increasingly more such facades in near future.

REFERENCES