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**Selected Papers from the
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List of Mediterranean Green Buildings and Renewable Energy Forum – 4

31 July –2 August 2017 – University of Florence, Department of Architecture, Florence, Italy

41- Proposing a new method for fenestration shading design in prefabricated modular buildings

Seyedehmamak Salavatian¹ salavatian@iaurasht.ac.ir

42- EFFECTIVENESS OF OCCUPANT BEHAVIORAL VENTILATION STRATEGIES ON INDOOR THERMAL COMFORT IN HOT-ARID CLIMATE

Ali Sedki¹, Neveen Hamza², Theo Zaffagnini

¹ *Beirut Arab University, Faculty of Architecture, Lebanon, egylord@hotmail.com*

² *Newcastle University, Department of Architecture, Newcastle, UK*

³ *Ferrara University, Department of Architecture, Ferrara, Italy*

43- Effectiveness of materials, technologies and renewable energy in educational buildings through cluster analysis of energy retrofiting

Francesco Asdrubali*, Laura Calcagnini**, Luca Evangelisti*, Maria Claudia Guattari*, Paola Marrone**

*Roma Tre University, Department of Engineering, Via Vito Volterra 62, 00146 Rome, Italy

**Roma Tre University, Department of Architecture, Via della Madonna dei Monti 40, 00184 Rome, Italy

laura.calcagnini@uniroma3.it

44- Renewable Energy in Argentina (PDF)

Prof. Carlos Labriola

Faculty of Engineering - Universidad Nacional del Comahue – Buenos Aires 1400 (8300) Argentina

carloslabriola54@yahoo.com.ar

45- Wind energy potential research in a low building within an urban environment (PDF)

Jorge Lassig, Claudia Palese, Juan Valle Sosa, Ubaldo Jara y Carlos Labriola

Faculty of Engineering - Universidad Nacional del Comahue – Buenos Aires 1400 (8300) Argentina

lassig@uncoma.edu.ar - carloslabriola54@yahoo.com.ar - Te:54-299-4490322

46- The natural light in Architecture. The use inspired by the constructive tradition.

Fabio G.S. Giucastro

SDS of Architecture of Siracusa, University of Catania, Italy

fabiogiu@gmail.com

47- The cost of building to the near Zero Energy Building standard – a financial case study

Shane Colclough^{1#}, John Mernagh², Derek Sinnott², Neil J Hewitt¹, Philip Griffiths¹

¹ Ulster University, Newtownabbey, Co Antrim, BT370QB, Northern Ireland

² Waterford Institute of Technology, Cork Road, Waterford, X91 K0EK, Republic of Ireland

#Corresponding author: Dr. Shane Colclough, S.Colclough@Ulster.ac.uk

48- POLICY OF INTENSIFICATION, DIVERSIFICATION, CONSERVATION, AND INDEXATION IN PURSUING THE SUSTAINABLE TRANSPORT

Koesmawan¹

1).Prof.Dr.Koesmawan, DBA, Commissioner of Ffaireness Indonesia Daya (FID), former Rector and The Head of Quality Assurance of Ahmad Dahlan School of Economics,

.mkoesmawanas@gmail.com

49- PROBLEM OF EDUCATION IN DEVELOPING RENEWABLE OF ENERGY

By: EllyamarlianaYudapraja, B.Sc, Edu. M.M 1)

1). EllyamarlianaYudapraja, Faculty of Teaching and Education Science

Pasundan University-Bandung Indonesia.

Ellya.Marliana2010@gmail.com

50- Winter performance of certified passive houses In a Temperate Maritime Climate – nZEB Compliant?

Dr Shane Colclough[#], Prof Philip Griffiths, Prof Neil J Hewitt

Ulster University, Newtownabbey, Co Antrim, BT370QB, Northern Ireland

#- corresponding author: S.Colclough@Ulster.ac.uk

51- A parametric tool for assessing optimal location of buildings according to environmental Criteria (PDF)

Giacomo Chiesa*, Mario Grosso

Politecnico di Torino, Dipartimento di Architettura e Design, Viale Mattioli 39, 10125 Torino, Italy.

*Corresponding author: giacomo.chiesa@polito.it

Forum topic: *sustainable architecture*

Keywords:*parametric morphology; site design; environmental design; bioclimatic architecture*

52- Methodology of Solar Project Managing Through All Stages of Development

Andrejs Snegirjovs 1, Peteris Shipkovs 1, Kristina Lebedeva 1, Galina Kashkarova 1,

Dimitry Sergeev 2

1 Energy resources laboratory, Institute of Physical Energetics
Krivu Street 11, Riga, Latvia, LV-1006, shipkovs@edi.lv

2 PVStream, MZ Consulting

Lenka Street 9, Riga, Latvia, LV-1006, info@pvstream.com

53- Computational BIPV Design: An energy optimization tool for solar facades

Omid Bakhshaei, independent researcher and co-founder of Novin Tarh Studio, 2nd floor, 193, Molla Sadra Street, Tehran, Iran.

bakhshaei.omid@gmail.com

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Arman Saberi, doctorate researcher at the Department of Architecture (DIDA), Università degli Studi di Firenze, via della Mattonaia n.14, Florence, FI, Italy.

arman.saberi@unifi.it

54- Feasibility Study of a Low Carbon House in the UK

Timothy Aird, Hossein Mirzaii

School of Aerospace & Aircraft Engineering, Kingston University London SW15 3DW, UK

H.Mirzaii@kingston.ac.uk

55- Why Do We Need To Reduce The Carbon Footprint In UAE?

Prof. Riadh AL-Dabbagh

University of Ajman, UAE, riadhdabbagh@yahoo.com

56- URBAN FARMING IN THE ERA OF CRISIS IN GREECE: THE CASE STUDY OF THE URBAN GARDEN OF AGIOI ANARGIROI –KAMATERO AND FILI

Konstadinos Abeliotis and Konstadinos Doudoumopoulos

Harokopio University, Department of Home Economics and Ecology, El. Venizelou 70, 17671

Athens, Greece. Tel +302109549363, email: kabeli@hua.gr

57- RESILIENT URBAN DESIGN. BEOGRAD AND FLORENCE: RECONNECT THE WATERS TO THE CITY

Prof.PhD Arch.Chiara Odolini

UNIFI-DIDA, Florence, Italy – chiara.odolini@gmail.com

58- Strategic Sustainable and Smart Development Based on User Behavior

Shahryar HABIBI* and Theo ZAFFAGNINI**

* *PhD, Department of Architecture, University of Ferrara, Italy*

email: shahryar_habibi@yahoo.com (corresponding author)

** *Associate Professor, PhD, Department of Architecture, University of Ferrara, Italy*

email: theo.zaffagnini@unife.it. ORCID: orcid.org/0000-0002-9693-809X

59- High | Bombastic adaptive skin conceptual prototype for mediterranean climate (PDF)

Giuseppe Ridolfi
University of Florence
giuseppe.ridolfi@unifi.it

60- QUALITY OF HEALTHCARE: A REVIEW OF THE IMPACT OF HOSPITAL PHYSICAL ENVIRONMENT ON IMPROVING QUALITY OF CARE (PDF)

Dr. Jazla Fadda
American University in the Emirates- Block 7- Dubai International Academic City- Dubai – United Arab Emirates- P.O.Box: 503000 |Email: Jazla.fadda@aeu.ae

61- Enhancing Indoor Air Quality for Residential Building in Hot Arid Regions

Ghanim Kadhem Abdul Sada,^a , Tawfeeq Wasmi M. Salih^{b,a} Mechanical Engineering Dept. / Al Mustansiriyah University, Baghdad Iraq, Email; ghanimkadhim@yahoo.com
^{**}Materials Engineering Dept. / Al Mustansiriyah University, Baghdad Iraq
Email; tawfeeq1978@yahoo.com

**62- Performance of Solar Window Film With Reference to Energy Rationalizing in Buildings
Dr .Kamil M .Yousif [1] and, Alan Ibrahim Saeed [2]**

[1] Dept of Environmental Sciences, Zakho University, Zakho, Iraq.
Email: kamy22002@yahoo.co.uk
[2] Dept of Physics, Zakho University, Zakho, Iraq.

63- Visualizing the infrared response of an urban canyon throughout a sunny day

Benoit Beckers¹, José Pedro Aguerre², Gonzalo Besuievsky³, Eduardo Fernández², Elena García Nevado⁴, Christian Laborderie¹, Raphaël Nahon⁵

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³ Universidad de Gerona (Spain)

⁴ Universidad Politécnica de Cataluña (Spain)

⁵ Université de Lille 1 (France)

64- Ventilation effectiveness of residential ventilation systems and its energy saving potential

Mohammad Reza Adili^{1*}, Michael Schmidt²

^{1,2} University of Stuttgart, Institute for Building Energetics, Stuttgart, Germany

*Corresponding email: reza.adili@ige.uni-stuttgart.de

65- Meta-design approach to Environmental building programming for passive cooling of Buildings (PDF)

Giacomo Chiesa^{*}, Mario Grosso

Politecnico di Torino, Dipartimento di Architettura e Design, Viale Mattioli 39, 10125 Torino, Italy.

* corresponding author - giacomo.chiesa@polito.it

Forum topic: *sustainable architecture*

Keywords: *meta-design; environmental design; building programming; passive cooling*

66- Urban and Architectural Sustainability in Restoration of Iranian cities (Strategy and Challenges), Case study of Soltaniyeh

Arch. Nazila Khaghani, Ph.D University of Florence

nazilakhaghaniarchitect@gmail.com

67- INFLUENCE OF THE PERIOD OF MEASUREMENTS ON WIND POTENTIAL ASSESSMENT FOR A GIVEN SITE

H. Nfaoui* & A. Sayigh**

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** Chairman of WREC & Director General WREN, Editor-in-chief Renewable Energy
P O Box 362, Brighton BN2 1YH, UK

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

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69- Photovoltaic and Thermal solar concentrator integrated into a dynamic shading device

Giulia Chieli, Lucia Ceccherini Nelli

Department of Architecture DIDA – Centro ABITA, University of Florence, via San Niccolò 93 Firenze, Italy, lucia.ceccherininelli@unifi.it, chieli.g@gmail.com

70- A University Master Course and training program for energy managers and expert in environmental design in Italy

Marco Sala¹, Lucia Ceccherini Nelli², Alessandra Donato²

Department of Architecture DIDA – Centro ABITA, University of Florence, via San Niccolò 93 Firenze, Italy, marco.sala@unifi.it, lucia.ceccherininelli@unifi.it, alessandra.donato@unifi.it

¹ Ordinary professor, ² PhD and contract professor

71- A project for the NZERO-Foundation in the south of Italy

Lucia Ceccherini Nelli¹, Vincenzo Donato², Danilo Rinaldi¹

¹ Department of Architecture DIDA – Centro ABITA, University of Florence, via San Niccolò 93 Firenze, Italy lucia.ceccherininelli@unifi.it, arch.rinaldi@hotmail.com

² DISEG - Department of Structural, Geotechnical and Building Engineering, Corso Duca degli Abruzzi, 24 - 10129 Torino (TO), Italy – Vincenzo.donato@polito.it

72- Planning without waste. (PDF)

Adolfo F. L. Baratta*, Laura Calcagnini*, Fabrizio Finucci*, Antonio Magarò*

*Roma Tre University, Department of Architecture, Via della Madonna dei Monti 40, 00184 Rome, Italy

adolfo.baratta@uniroma3.it

73- Policy Of Intensification, Diversification, Conservation, And Indexation In Pursuing The Sustainable Transport(PDF)

Koesmawan1

1).Prof.Dr.Koesmawan, DBA, Commissioner of Ffaireness Indonesia Daya (FID), former Rector andThe Head of Quality Assurance of Ahmad Dahlan School of Economics,
mkoesmawanas@gmail.com

74- Problem Of Education In Developing Renewable Of Energy(PDF)

By: EllyMarlianaYudapraja, B.Sc, Edu. M.M 1)

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Pasundan University-Bandung Indonesia.
Elly.Marliana2010@gmail.com

75- Production of ZnO Cauliflowers Using the Spray Pyrolysis Method

Shadia J. Ikhmayies

Al Isra University, Faculty of Science, Department of Physics, Amman 11622, Jordan. E-mail:
shadia_ikhmayies@yahoo.com

76- RESILIENT URBAN DESIGN. BEOGRAD AND FLORENCE: RECONNECT THE WATERS TO THE CITY (PDF)

Prof.PhD Arch.Chiara Odolini

UNIFI-DIDA, Florence, Italy – Chiara.odolini@gmail.com

77 - Adaptive skin conceptual prototype for Mediterranean climate.(PDF)

Omid Bakhshaei, independent researcher and co-founder of Novin Tarh Studio, 2nd floor, 193,
Molla Sadra street Tehran, Iran. Bakhshaei.omid@gmail.com

Giuseppe Ridolfi, professor at the Department of Architecture (DIDA), Università degli Studi di
Firenze,

via della Mattonaia n.14, Florence, FI, Italy. giuseppe.ridolfi@unifi.it

Arman Saberi, doctorate researcher at the Department of Architecture (DIDA), Università degli Studi
di Firenze, via della Mattonaia n.14, Florence, FI, Italy. arman.saberi@unifi.it

78- EVALUATING DEEP RETROFIT STRATEGIES FOR BUILDINGS IN URBAN WATERFRONTS

Nicola Strazza^{1*}, Piero Sdrigotti¹, Carlo Antonio Stival², Raul Berto¹

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e-mail: carloantonio.stival@dicea.unipd.it, web: <http://www.dicea.unipd.it>

79- Enhancing the Thermo-physical Properties of Rammed Earth by Stabilizing with Corn Husk Ash (PDF)

Batagarawa Amina L., Abodunrin Joshua A., Sagada Musa L.
Department of Architecture, Ahmadu Bello University, Zaria, Kaduna, Nigeria.
Aminab@hotmail.com

80- THERMAL MONITORING OF LOW INCOME HOUSINGS BUILT WITH AUTOCLAVED AERATED CONCRETE IN A HOT-DRY CLIMATE

Ramona Romero-Moreno, Gonzalo Bojórquez-Morales, Aníbal Luna-León, César Hernández
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ramonaromero@uabc.edu.mx, gonzalobojorquez@uabc.edu.mx, anibal@uabc.edu.mx

81- RENEWABLES ARE COMMERCIALY JUSTIFIED TO SAVE FUEL AND NOT FOR STORAGE

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Secretary, WREN and Visiting Prof, Kingston University,
Woking, Surrey GU21 4XX
United Kingdom
email: donald@swift.hook.com

82- Developing Sustainable Energy and Climate Action for Local Governments: Baseline Emission Inventory - Case studies of City of Luxor and City of Hurghada, Egypt

Mohsen Abounaga¹, Bruno Rebelle², Emilie Essono³, Naguib Amin⁴ and Sara Ali⁵
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(Full Paper WILL BE RECEIVED LATER)

83- Climate Change Assessment, Simulation and Adaptation for Hot-Arid Urban Settlements: The Case Study of Asmara Project, Cairo, Egypt

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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.

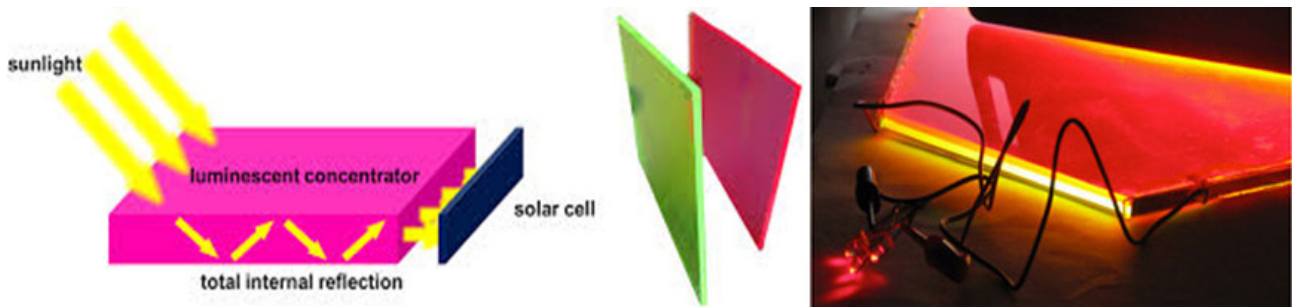


Fig1. Luminescent LSC panel. A typical LSC panel during the night with its fluorescence.

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.

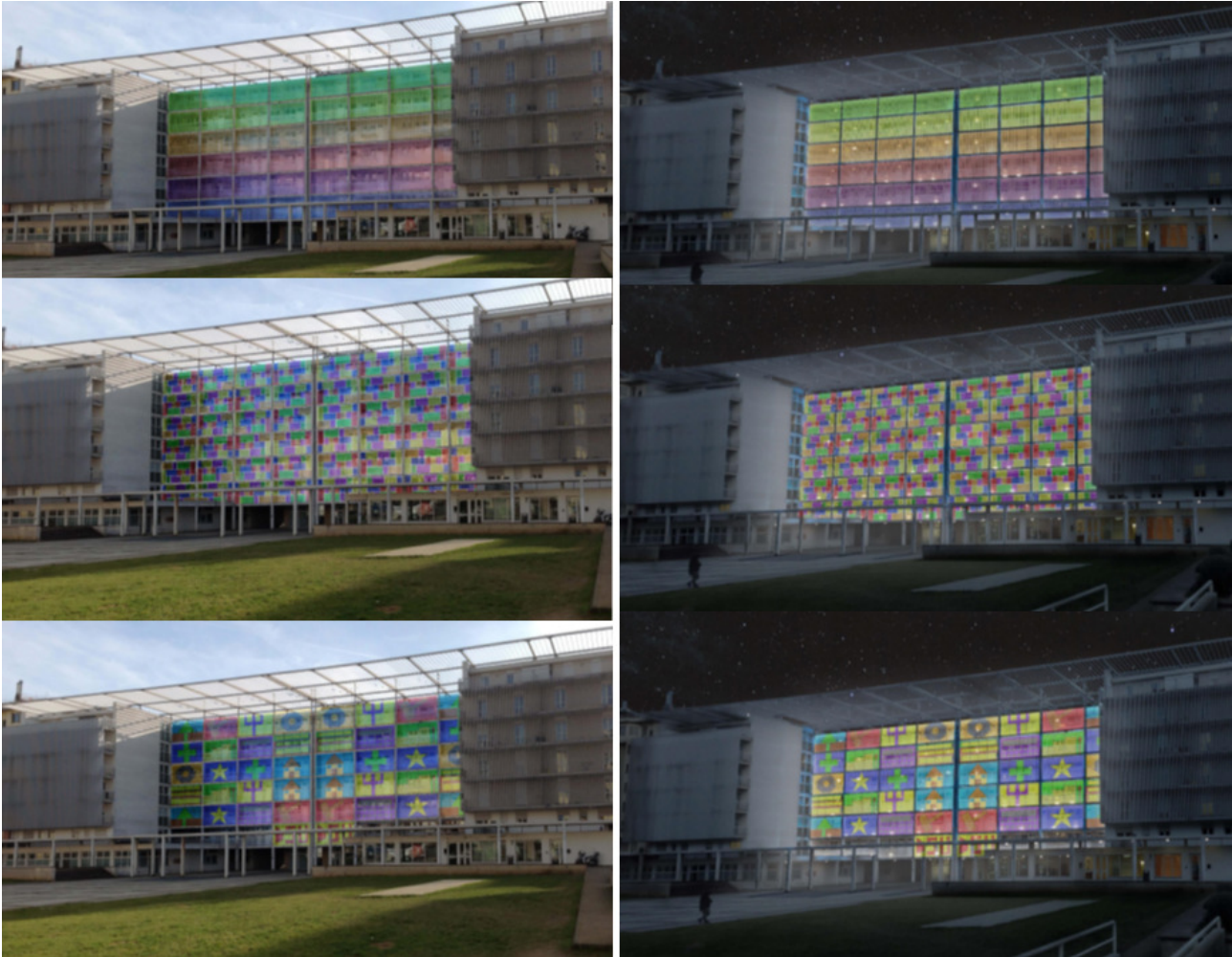


Fig.3 Luzi university student house. First daily and night time view it is about the rainbow color project idea, second, view it is about form and size actually on the market; third, it is about Florence University logos.

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.

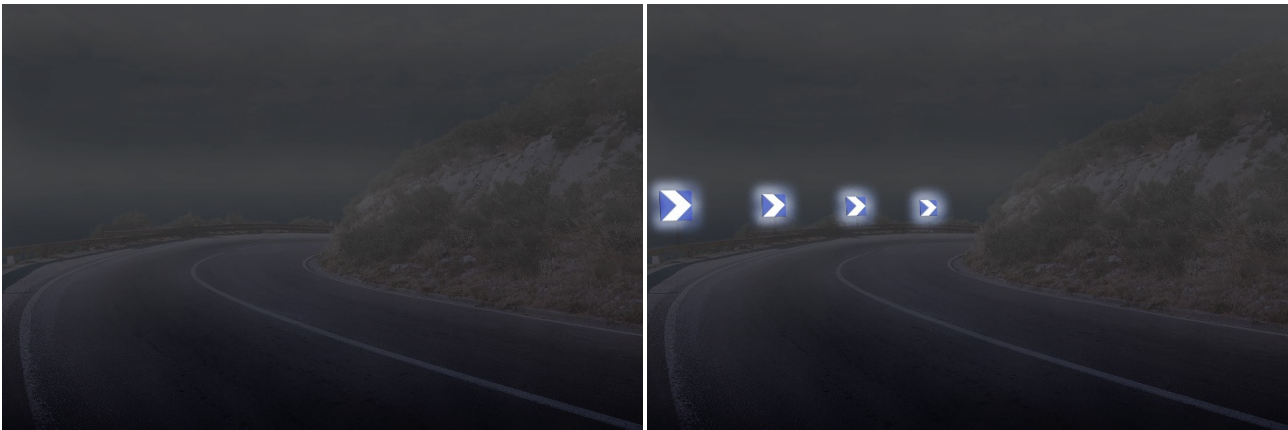


Fig.6 Pictures show the different visibility in the same place between hairpin during the night with fog and during the night with fog but with LSCs panels integration.

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 ($21,9\% \pm 1,6\%$ versus $10,83\% \pm 1,4\%$), 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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