

(A High Impact Factor, Monthly, Peer Reviewed Journal) Visit: <u>www.ijirset.com</u> Vol. 8, Issue 3, March 2019

# Solar-scape as an Effective Tool in Urban Solar Design

Reeman M. Rehan Hussein<sup>1,2</sup>, Mohammad Refaat M. Abdelaal<sup>3,4</sup>

Professor, AE Dept, College of Engineering, University of Prince Mugrin, Madinah, KSA<sup>1</sup>

Professor, Architecture Department, Faculty of Engineering, Helwan University, Egypt<sup>2</sup>

Assistant Professor, AE Dept., College of Engineering, University of Prince Mugrin, Madinah, KSA<sup>3</sup>

Assistant Professor, Architecture and Urban Planning Dept, College of Engineering, Suez Canal University,

Ismailia, Egypt<sup>4</sup>

**ABSTRACT**: Nowadays urban environment has a great potential to increase the applications of renewable energy, solar-scape is one critical step in the acceleration process to use more solar power in our urban environments.

The combination of making buildings and our built environment more energy-efficient and using a more significant fraction of renewable energy is a vital tool to reduce greenhouse gas emissions and using non-renewable energy. This is due to the global political directives, which already moving towards zero-energy buildings, communities and whole cities. So This research focuses on the implementation of solar energy in urban design.

The main research objective is to develop urban design elements for solar energy. This objective is achieved through exploring the concept of the solar-scape as it is the critical factor, from the theoretical, analytical, and practical viewpoints, to reduce the energy use in buildings and outdoor environments. Then, the paper analyses how the concept of solar-scape in the world is developed and explores a practical approach toward solar-scape applications. Finally, the research suggests a framework towards urban solar design through the uses of solar-scape concept and a set of recommendations to develop the urban environment by applying the solar-scape concept to achieve the urban solar design.

KEYWORDS: Solar-scape, Outdoor Urban Spaces, Sustainable urban design, Photovoltaic, Renewable energy

### I. INTRODUCTION

Increased use of solar energy is a critical part of the development ahead, where the urban fabric needs to utilise passive solar gains and daylight to reduce the energy use in buildings and for outdoor environments, as well as to improve the inhabitants' comfort indoors and in urban outdoor areas. Also, active solar energy systems integrated into the urban context will enable the supply of renewable energy primarily as heat and electricity, and also for solar cooling, helping cities reach sustainable solutions. Therefore, the research focuses on the use of solar-scape in outdoor environments, and it shows how solar-scape affects positively on the sustainability of the built environment.

Planning energy-efficient environments which produce on-site renewable energy in an urban context is a challenge for all involved actors in the urban planning and design process.

#### II. RELATED WORK

The trend for integrating PV application in building and urban environment is not something that has only just appeared. Also, the potential for using PV into the urban environment and outdoor spaces have been sought since the early of the 21st century.

According to Johannesson (2001), and Prasad (2005) the potential for using PV in Non-Building Structures in the built environment is large, even in a modern society where the electricity network is well developed.



(A High Impact Factor, Monthly, Peer Reviewed Journal)

### Visit: <u>www.ijirset.com</u>

### Vol. 8, Issue 3, March 2019

For applications with low power, requirement PV can be suitable as a commercial alternative to grid connection, avoiding the need to dig up roads or pavements to lay cables. PV systems integrated into Non-Building Structures need to consider a range of criteria such as irradiation, shading, orientation, visual impact, available surface and other technical requirements.

Also, Gaiddon (2009) claimed that buildings are not the only structures suitable for the installation of PV systems. In many cities around the world, PV has been integrated into non-building structures. This integration in the urban space takes advantage of the architectural quality of PV and its ability to supply electricity suited to the needs of products used in urban areas and this should without neglecting the effect of three main elements; solar resource, visual appearance, and cost. According to him public spaces equipped with PV systems can:

- offer additional surfaces suited for the installation of PV to increase the amount of locally produced renewable electricity;
- bring PV closer to people and help to inform visitors about sustainable energy solutions;
- promote the sustainability of the area, particularly as PV on non-building structures is sometimes more visible than building integrated PV.

Recently Basaly (2019) in the study "Improving the Functional Performance of Outdoor Spaces in Hot Arid Region Using Photovoltaics" claimed that "there is a rapidly increasing in the deployment of photovoltaic, but most of its installations are still concentrating on building facades and roofs. "Therefore, to achieve the needed large-scale integration of photovoltaic into our energy system will require large-scale deployment beyond the building scale, which will become a part of our landscape". Also, he claimed that other dimensions could be considered as improving the functional performance of outdoor spaces through the potential of power generation by photovoltaic in outdoor spaces, in hot regions, and improving the thermal comfort.

### III. THE RESEARCH PROBLEM

Planning energy-efficient environments which produce on-site renewable energy in an urban context is a challenge for all involved actors in the urban planning and design process. The main potential for energy efficiency in utilising solar energy remains unused. To generate renewable energy integrated into our living urban environment is by making use of solar energy such as in solar-scape. So this research is directed to answer the following questions:

- What is the definition of solar-scape?
- What are the objectives of solar-scape?
- How can we improve the urban design process to facilitate better integration of solar energy in urban environments?
- What are the applications of solar-scape to achieve urban solar design?.

### IV. RESEARCH METHODOLOGY

The methodology for sustainable solar urban design is based on determining the solar potential in the existing urban area, and it could be achieved through theoretical, analytical, and practical viewpoints for sustainability. It seeks to identify the solar-scape concept and how this concept affects to achieve urban solar design through the analysis of some international case studies were developed and explores a practical approach. Finally, it uses this concept in formulating a framework towards urban solar design and a set of recommendations to improve the urban environment.



(A High Impact Factor, Monthly, Peer Reviewed Journal)

### Visit: www.ijirset.com

### Vol. 8, Issue 3, March 2019

### V. RESEARCH OBJECTIVES

The primary research objective is to integrate solar systems in urbanised, and a built area is challenging, and there is a need to identify methods and tools to support the use of solar energy in urban design elements. This is achieved through a combination of sub-objectives as follows:

- Advancing knowledge related to solar energy in urban design for a successful implementation of solar scape in urban areas.

- Identify the main principles that should be considered to define the urban solar design.

- Achievement of environmental efficiency and economic operations.

### VI. SOLAR-SCAPE AS A NEW APPROACH TO SOLAR URBAN DESIGN

#### **Definition of Solar-scape:**

It is first necessary to define solar energy to understand the concept of a solar-scape. First, solar energy is a vital source of renewable energy, and it is regarded as one of the most interesting energy sources of the future. "Solar-scape is the solution to the most demanding solar design and installation problems" [1]. The Solar-scape can be defined as "the totality of phenomena distributed around a place, creating a perceptible solar ambient for users of those urban spaces" [2].

### Solar Urban Design

Solar urban design plays a crucial role in creating sustainable living environments. It makes use of sustainable technologies such as solar energy to reduce the city's carbon emissions. "such approaches help in establishing sustainable energy infrastructure, and as a result, it helps reducing greenhouse gas emissions. Also, the use of solar energy has created new jobs, such as in Barcelona City, as it generated 5000 direct jobs [2].

However, urban designers can contribute significantly to a more energy-efficient built environment since they make early critical decisions within the design process [9].

Urban design can affect the energy use and energy production in cities; more dense settlements will reduce the needed amount of transportation energy [3], while Lehmann showed that savings in the energy cost of 20-50% are possible through integrated planning and urban solar design [4]. So, urban solar design promotes solar energy use in urban design elements. According to Abdelaal (2009), this explains the global direction to transform cities and settlements into new power stations, through integrating renewable energy applications intensively in urban-scale schemes. This is also as a tool to achieve a general sustainable urban development. In this manner, Basaly (2019) claimed that "outdoor spaces could be contributing to the power generation of the future, with photovoltaic systems built into landscape elements including seating, shading devices, cycle paths, highway barriers, road surfaces and pedestrian paving. The current perceptions of solar power generation may well be changed through this new technology from being separate as in PV roof installations and solar farms to be an integrated component of the public realm."

### VII. SOLAR-SCAPE APPLICATIONS

This section discusses some international case studies in which the solar-scape concept was applied at the level of urban design to achieve the urban solar design.

### "World's Largest Solar Bridge Opens in London" [5]

The world's largest solar bridge opened in 2014 in London (Fig.1). It runs over the "Thames River" at the Blackfriars railway station. The bridge roof has been covered with 4,400 photovoltaic solar panels, which are expected to generate 900,000 kilowatts of energy per year. This amount covers half of the railway station's energy needs, and it is supposed to cut carbon emissions by 511 tons per year.



(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: <u>www.ijirset.com</u>

### Vol. 8, Issue 3, March 2019

The roof gives the passengers an even more sustainable journey; the distinctive roof has also turned the station to be an iconic landmark visible for miles along the River. This bridge will promote London's efforts towards sustainability, for residents, tourists, and workers alike.



Fig [1]: World's largest solar bridge Ref: http://www.treehugger.com/renewable-energy/worlds-largest-solar-bridge-now-officially-launched.htm https://ourgooglegallery.wordpress.com/2015/02/09/different-way-to-reduce-your-expenses/

#### "Solar Canopies"

Solar canopies (Fig. 2) are elevated structures that host solar panels and provide shade. These overhead solar panel installations are typically installed in parking lots or other paved areas. Solar canopies enable users to provide shade from the sun and shelter from the rain while collecting clean energy. These applications are also perfect for users who are unable to install solar panels on their buildings roofs due to the direction that the building is facing, or if shading is a problem. In such cases using canopies is a way to ensure reaching the maximum efficiency of solar panels as in Fig 2.

### "Prefabricated Carports:"

Prefabricated Carport (Fig. 2) is an example of manufacturing and integration of solar carport systems. A wide range of residential and commercial carport structures provide energy solutions nationwide. With innovated architectural appearance and engineering, [6]. Solar carports are overhead structures designed to cover parking spaces and are distinct from panels installed onto a pre-existing carport structure. Solar carports have many issues smiler to ground-mount solar panels that are angled panel modules connected on the ground. Both of them eliminate the need for a surface on which the PV panels could be mounted. The main difference between them installation is that carports are taller to make space for a car to park. Else, the two are relatively similar, and each offers the maximum benefit of allowing installers to face the panels at the most optimal angle for sunlight exposure. The main advantage of solar carports covers is that they don't require additional land the way ground mount does.



Fig [2]: Prefabricated Carports as a solar Canopy Ref.: Steven Bushong, Five Stellar Solar Canopies



(A High Impact Factor, Monthly, Peer Reviewed Journal)

### Visit: <u>www.ijirset.com</u>

### Vol. 8, Issue 3, March 2019

### Solar Photovoltaic Curtain Walls:

Solar photovoltaic curtain walls (Fig. 3) are unique methods for creating architectural solar glass modules. These glass solar modules create a stunning and architecturally pleasing effect when used as atriums, canopies, building facades and more. The benefit of designing and building passive solar heat from the glass structure combined with the encapsulated photovoltaic energy produces a real "green" product that can be used anywhere regular glass would usually be installed in a building envelope.

One of the core purposes of solar-scape is to provide unique products to cities, enabling the generation of power wherever required for example; Architectural 'Solar Sail' landmark. Custom designed for the township of Ajax, Ontario, Canada (1850 Watt power output) [7]. It can also be used as solar highway noise barriers/walls. This kind of barriers/walls is now used in many countries as in Holland.



Solar Photovoltaic Curtain Walls

Solar Sail' landmark

Noise barriers/walls

### Fig [3]: Solar Photovoltaic Curtain Walls and solar landmarks Ref.: Solar-scape innovations, solarhighways.eu

#### Outdoor Lighting

One of the main solar-scape applications is the solar outdoor lighting application; these lighting applications are powered by photovoltaic energy. Solar outdoor lighting is a critical element in building sustainable communities. Sustainability isn't just concerning creating "green" elements or designs; it involves economic, social, and environmental consideration. The aim is to illuminate outdoor spaces using "green energy", without any use of electricity from the utility network.

Figure 5 represents three examples of such applications. The first one is a floor integrated outdoor LED light-fitting powered by photovoltaic energy (paving-tiles). It is a modern product designed for pedestrian paths. It is made in aluminium fusion recycled and recyclable painted with polyester powder. The photovoltaic panel is on the top, and it is covered by tempered glass. This type of applications does not require electrified wires, and it is waterproof and designed to be placed outdoor. Recently many developers as "Onyx Solar" teamed up to launch a new type of photovoltaic paving stones made from ceramic and glass as in (Fig. 4.A, B, C). The streamlined solar stones are manufactured using a process that produces less CO2 and uses less energy than traditional pavement, making this energy-generating material even better for reducing the environmental impact of building projects.

The  $2^{nd}$  example in (Fig 4.D) is an outdoor LED light powered by photovoltaic energy for pedestrian paths also. It can be easily removed from the ground. The base and the head are made by aluminium fusion painted with polyester powder.

The 3<sup>rd</sup> example is a LED lamp powered by photovoltaic energy as (Fig 4.E). It is designed to illuminate outdoor spaces, parks, and pedestrian, cycle paths, and streets.



(A High Impact Factor, Monthly, Peer Reviewed Journal)

*Visit: <u>www.ijirset.com</u>* Vol. 8, Issue 3, March 2019



### **Outdoor PV Integrated Shading Structures and Urban Solar Seating:**

Place photovoltaic modular shade structures, made in laminated timber and steel, equipped with photovoltaic panels placed on the roof. The energy produced it can be stored and used to power outdoor lights and street-lamps.

### Solar Games in Open Spaces:

The solar games are interactive outdoor games that offer an interactive experience. So, it is a solar game for children powered by photovoltaic energy. For example, the "Piano" outdoor game (Fig. 5). It is an interactive outdoor game that offers a new experience to the child. It is a solar game for children powered by photovoltaic energy.

The top of the element is a touch screen; every single tap is transformed into a different sound to learn by game. The solar game is also available in other topics "Drums" and "Pet". All of the products are wheelchair accessible [2].



Fig [5]: Outdoor furniture with solar energy Ref.: NA, Urban design and photovoltaic outdoor lights made in Italy, (products catalogue), 2008.



(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

### Vol. 8, Issue 3, March 2019

From the above description, these applications contribute to meeting the urban solar design as an approach for sustainable urban development as summarized in table 1.

### Table (1): The objectives of applying the solar-scape concept in the built environment

	The objectives of solar-scape					
ements of solar-scape		Improve Air Quality	Reduce Heat Island Effects	Improve economic efficiency	Improve Energy Efficiency	Reduce Light Pollution
	Solar Bridge					
	Solar Canopies					
	Solar Photovoltaic Curtain Walls					
	Outdoor lights					
E	Urban solar seating					
	Solar games					

Ref.: The author

### VIII. FRAMEWORK - TOWARDS URBAN SOLAR DESIGN

This section suggests a framework that depends on the previous study, and it will contribute to meet urban outdoor solar design through the applications of the solar-scape concept. Fig 6 shows that the framework includes four main steps concerning the typical urban design strategy. These steps will consist of the following:

- 1. *Energy Objectives:* To define the strategic Goals as Improve Air Quality, Reduce Heat Island Effects, ... etc.
- 2. *Solar Potential:* Data Collection regarding three main issues; environmental analysis, urban analysis, solar analysis.
- 3. *Solar Design:* define the application concepts, for example, solar-scape concept solar bridges, solar canopies, solar photovoltaic curtain walls
- 4. Implementation and Evaluation: Economic efficiency, environmental performance, energy balance



(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: <u>www.ijirset.com</u>

Vol. 8, Issue 3, March 2019



Ref .: The author



(A High Impact Factor, Monthly, Peer Reviewed Journal)

### Visit: www.ijirset.com

#### Vol. 8, Issue 3, March 2019

#### IX. CONCLUSION

Recently, cities all over the world have developed construction systems that incorporate the idea of creating urban environments that are more energy-efficient. The consideration of solar design in urban design is essential to improve the comfort conditions of people in urban environments.

in this realm, the solar-scape concept that indicates the combination of making the built environment more energyefficient and using a more significant fraction of renewable energy is, therefore, a vital tool to decrease the nonrenewable energy use and greenhouse gas emissions. This study focused on some applications of the solar-scape concept at the level of urban design, and it concluded that the solar-scape concept could contribute to improving the outdoor urban spaces, offering more energy-efficient outdoor spaces.

In this realm, the paper suggests a framework towards urban outdoor solar design through the applications of the solarscape concept. This paper concluded that solar-scape concept would be a crucial part of the design process and it will contribute to achieving the urban solar design.

#### REFERENCES

- [1] Lumos Solar, Solarscapes, Sep. 26.2018. [online].
- Available: http://www.lumossolar.com/products/solarscapes/#WhatAreSolar-scapes, [Accessed: Sep. 26.2018]
- [2] ICLEI Local Governments for sustainability, using solar energy supporting community energy self-sufficiency, Barcelona City Council, Barcelona, 2014.
- [3] Hestnes, A.G., Building Integration of Solar Energy Systems. Solar Energy, 67(4-6): p. 181-187, 1999.
- Lehmann, S., Sustainability on the Urban Scale: Green Urbanism New Models for Urban Growth and Neighborhoods in Urban Energy Transition, Elsevier: Amsterdam. p. 409-430, 2008.
- [5] David Statham, World's Largest Solar Bridge Opens in London, Aug. 18.2018. [online].
- Available: http://www.earthday.org/greencities/portfolio/worlds-largest-solar-bridge-opens-london/ [Accessed: Aug. 18.2018]
- [6] Steven Bushong, Five Stellar Solar Canopies, Aug. 18.2018. [online].
- Available: http://www.solarpowerworldonline.com/2014/03/five-stellar-solar-canopies/3/, [Accessed: Aug. 18.2018]
- [7] Solarscape innovations Inc., Custom Solar Photovoltaic Solutions, Aug. 20.2018. [online].
- Available: http://www.ssisolar.com/curtainwalls.html [Accessed: Aug. 20.2018]
- [8] NA, Urban design and photovoltaic outdoor lights made in Italy (products Catalog), NA, Mezzolombardo, 2008.
- [9] Wall, M., Windeleff, J., & Lien, A. G., Annex Plan. IEA-SHC Task 41, SHC, Lund University, Lund, 2008. Available: http://task41.iea-shc.org
- [10] Abdelaal, Mohammad, Development Concepts and Implementation Strategies for New Settlement: Renewable Energy and Sustainable Urban Development in Hot Arid Regions, Case of Egypt, PhD Thesis, Faculty of Architecture and Urban Planning, Stuttgart University, Stuttgart, 2008.
- [11] Abdelaal, Mohammad, "Towards an Urban Integrated Photovoltaics Development in Egypt", The 5th International Conference Archaeiro 2009: Towards A New Architectural Vision New Glasses, Cairo University, Cairo, Dec. 16-17. 2009, Marriott, Cairo, 2009.
- [12] Abdelaal, Mohammad & Reeman Rehan, "Renewable energy resources as a new global development approach for the residential areas in the Arab regions", Beirut University, 2013.
- [13] Basaly, Lucienne G., et al., "Improving the Functional Performance of Outdoor Spaces in Hot Arid Region Using Photovoltaics", (Accepted paper in the "Sustainable Environment and Urban Infrastructure International Conference"), Dubai, 2019.
- [14] Johannesson, C. Michael, "PV in Non-Building Structures: A design guide", Report IEA PVPS T7-02:2000, The IEA's PV Power Systems Programme Task VII, IEA, Stockholm, April 2001.
- [15] Gaiddon, Bruno, et al., "Photovoltaics in the Urban Environment: Lessons Learnt from Large-scale Projects", Earthscan, London, 2009.
- [16] Prasad, Deo, Snow, Mark, "Designing with Solar Power: A Source Book For Building Integrated Photovoltaics (BIPV)", Routledge, 2005.