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CLIMATE CHANGE PARTNERSHIP ACTIONS FOR SUSTAINABLE FUTURE AND RESTORING LIFE ON EARTH

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PREFACE

There is a growing concern on the adverse impacts of climate on biodiversity. This phenomenon is greatly manifested in form of shifting weather patterns threatening global food security, health and species existence. Humanity is at the receiving end of the consequences of climate change hence there is a need to step up actions on all fronts- overtime, everywhere all at once.

This calls for collaboration, partnership and networking to strengthening synergy among relevant stakeholders in a bid to tackling climate change menace. This forms the basis for the theme of this year world Environmental conservation conference: **CLIMATE CHANGE PARTNERSHIP ACTIONS FOR SUSTAINABLE FUTURE AND RESTORING LIFE ON EARTH.** The theme is conceived with a view to create an interface for information sharing and offer opportunities for participants to refine their commitments and pledges in the quest to achieving Sustainability in the face of climate change.

This year World Environmental Conservation Conference is memorable in the sense that it received overwhelming funding from the host - West African Science Service on Climate Change and Adapted Land use). WASCAL is posed to provide information and knowledge at the local, national and regional level to cope with the adverse impacts of climate change. Thus, this conference will offer opportunities for participants to learn from good practices demonstrated and showcase by WASCAL during the course of the conference. It will also strengthen staff-student exchange and provide prospect for Doctorate Research Doctoral Research in West Africa Climate System Programme (DRP WACS) – WASCAL among others.

Special appreciation goes to the management of The Federal University of Technology, Akure the host institution, National Park Service and African Regional Center for Space Science and Technology Education-English (ARCSSTE-E) that co-host this conference. We equally acknowledge other private, individual and corporate organizations that have contributed towards the success recorded in this event.

All the submitted articles were subjected to strict double blind peer-review process by the reviewers that are experts in the area of the particular submitted manuscript. The accepted manuscripts are published in WECC 2023 proceedings and also available for download on the organization website (www.necorng.org).

The accepted manuscripts fall within the underlisted subthemes:

- Climate change adaptation strategies in Agriculture, Forestry and Other Land Use (AFOLU)
- Climate smart city and architectural landscape design
- Retrofitting and decarbonization in tourism and hospitality industry
- Indigenous knowledge and local innovation in climate change adaptation
- Climate risk management, health, safety and hygiene
- Carbon credit-offset marketing/circular economy
- ICT development in environmental conservation (image processing and acquisition, computer vision, graphics, speed, interface technology, HMD devices, GIS: Body Tracking, AI and IOT, VRT, IVE).

We commend our keynote speaker Prof. Douda Kone Director Capacity Building Department, WASCAL Headquarter, Ghana and other guest speakers Prof. Babatunde Rabiu, Director General, Chief Executive Office, African Regional Centre for Space Science and Technology Education-English (ARCSSTE-E) and Dr. Goni I. M., Conservator General National Park Service.

It is hoped that researchers, students and policy makers will find the papers in this book very useful. Even though all the papers were reviewed and edited, the content and option expressed remain essentially that of the authors and not necessarily that of Netlink Environmental Conservation Organization.

Dr. Oladeji S. O.

President Netlink Environmental Conservation Organization

Convener World Environmental Conservation Conference

TABLE OF CONTENT

BUILDINGS AND CLIMATE CHANGE: INTEGRATING SHADING DEVICES TO SOLAR SYSTEMS

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ABSTRACT

This paper is an analytical review of the integration of active solar technologies (solar system) in buildings involving in particular, the purpose designed union of solar technologies such as photovoltaic and solar thermal collectors as shading devices in the building system. The study revealed that technical considerations in planning and designs of this integration, such as e- glazing of solar thermal and photovoltaic materials, solar altitude and azimuth angles subtended by the building, the U-values of solar collectors, and Photovoltaic materials used for the integration are germane to achieve optimum results. The research posits that the Building Integrated Photovoltaic technology is recourse to current world dependence on fossil fuels to mitigate the impact of climate change.

Keywords: *Solar system, shading devices, photovoltaics, azimuth angle, active solar.*

INTRODUCTION

A large number of existing buildings and new buildings are facing the demand for energy conservation and emission reduction (Lee, *et. al.,* 2014). As a result, passive buildings, low energy consumption buildings, zero energy consumption buildings, green buildings have become the main trend (Waddicor, *et. al.,* 2016). The building sectoris also considered to be the easiest to achieve results throughlow energy consumption buildings and zero energy consumption buildings (Andrić, Koc, and Al-Ghamdi, 2019). In view of this, the integration of active solar technologies (solar system) into buildings which relates to the condition of annexing photovoltaic and solar thermal to serve as shading devices to achieve low energy consumption and zero energy consumption buildings (Sabunas, and Kanapickas, 2017) is examined in this study. Aside from these, most studies have found that climate change will lead to an increase in temperature and humidity, resulting in overheating in buildings, increasing the cooling load of building energy consumption, and reducing the heating load (Kerner, 2019). In addition, the frequency of extreme weather events will increase, and the most direct impact on buildings is a power failure especially in developing countries. To mitigate the adverse effects of these, other studies (Xu, *et al.,* 2021; Bilardo, Ferrara, and Fabrizio, 2023) have suggested the active solar technology techniques in buildings are recourse for alternative energy. This study therefore takes a critical examination of the active solar system (solar system) in buildings to evaluate their performance and material properties with a view to enhance their use as alternative to fossil energy and thereby managing the effect of climate change.

The development of the active solar technology is an all-encompassing procedure that synthesizes the buildings with photovoltaic and solar thermal collectors as adaptive shading devices. Academic literature has defined this procedure as Building Integrated Photovoltaic (BIPV) and it redefines the task for the architect and designers as those who recall from the various elements such as the design of the building itself, the solar path, (which to a large extent determines the sun altitude and which in-turn, affects the position of shading devices), the photovoltaic in a logical, scientific, economic approach to achieve desired result. The result is based on the required aesthetics, e-glazing and optimum energy requirement to mitigate the impact of climate change. Indeed, the procedure is a complete package which requires an in-built knowledge and technical know-how of buildings solar system, issues relating to solar altitudes and azimuth, nature of glazed materials in the photovoltaic by architects and designers concerned. Roecker and Munari, (2012) lending credence to this, posits that architectural integration is the result of a controlled and coherent integration of solar collectors and photovoltaic simultaneously from all points of view. They went further to say that, when the solar system is integrated in the building envelope (e.g. a roof covering, façade cladding, sun shading, or balcony fence), it must properly take over the constructive, functions and associated constraints of the envelope elements it is replacing, while preserving the aesthetics and formal attributes of the building.

METHODOLOGY

The study is a review of the solar system shading devices. It examines succession of the features and types of these devices. In view of this, the review technique is analytical as it provides a narrative of each solar system employed, examines patterns and presents results.

Solar System in Buildings

Solar system in building relates to the use of active solar technologies in buildings. Typically, Active Solar technology involves the use of photovoltaic and solar thermal.

Buildings, Greenhouse gases and Climate change

Buildings emit 38% of the Carbon dioxide which is the primary greenhouse gas associated with climate change (IEA, 2008). Moreover, 49% of the sulphur-dioxide, and 25% of the nitrogen oxides in the air are traceable to activities connected with buildings (Santos & Richardo, 2012). Currently, the vast majority of energy produced is from non-renewable, fossil fuel resources and with the dwindling Earths supply of fossil, increase in the demand for fuel, concern for energy supply security and the global impact of greenhouse gasses on climate change, it is imperative to find alternative source of energy in other facets through recourse to renewable fuel supply. In fact, account from literature revealed that the HVAC (heating, ventilating and air conditioning) which is an integral part of contemporary buildings consumes 39% of total energy load in the United States while building as a whole takes up 39% of US energy supply and 68% of electrical supplies (Scogna, Adinofi, Graditi, & Saretta, 2014). From these realizations, a stark redirection in design approaches in the active solar technology to mitigate the adverse effects of existing modern practice is urgent and imperative.

Solar Thermal Collectors

Solar thermal collectors are surfaces optimized by heat collection through solar absorbers. The heat is thereafter transported for storage or used accordingly through hydraulic heat collectors or air collector system. Heat gains from the solar thermal collectors are however pro-actively exploited to process before-hand, the required air for ventilation. The bulk of solar thermal systems in buildings is represented by the Hydraulic system. Indeed, it is a recourse to the practical method employed for preserving energy necessary for space heating and domestic hot water production. Solar thermal collectors are important for reducing fossil energy consumption in buildings as well as cost effective. They can be divided into three types which are: evacuation tube collectors- Fig. 1 & 2(b) glazed flat plates collectors- Fig. 3 (c) unglazed flat plate collectors- Fig. 4. Despite this, the solar thermal is suitable for space heating and domestic hot water production, they vary in effectiveness, operating temperatures and capacity. With this backdrop, it is germane that some important factors should be considered when choosing solar thermal collectors for multiple and specific functions. These include: (a) the desired solar fraction (b) seasonal solar radiation on the envelopes and (c)availability of space on building's envelope. It is the integration of this task with the building design for optimal solar performance within the context of climatic peculiarities of the region to mitigate the impact of climate change that is the architect's challenge.

Fig. 1: Evacuated tube collector used as desk sun shading

Fig. 2: Evacuated tube collector used as plate used

Fig. 3: Facade integration of glazed plate collector

Fig. 4: Façade integration of unglazed

Photovoltaic

Photovoltaic (PV) are building integrated system that generate electricity from solar radiation. Often, they may be after-thought retrofitting to existing buildings. Purpose Built PV has a generic name: "Building Integrated Photovoltaic'' (BIPV) and can be used for power production or building shell. BIPV are less costly compared to retrofitted PV and this owes to the following reasons: (a). It does not require further leverage or support owing to the fact that it is integrated into the building as part of the structure (b) they are cheaper (c) are more amenable to the environment and as a result, enhances environment friendly designs (d) enhanced aesthetics due to ease of design and flexibility with construction in the structure or facades – (Fig. 4 and 5) and (d) can be included as part of the entire building's budget plan.

Fig. 5: PVRoof integration

PV and Solar Thermal Collectors as shading Devices

Illustrations and example used in this study have not discriminated in the uses of solar thermal or PV as integral organ of the building. However, in most cases, PV is lighter than solar thermal and therefore affects the integration possibilities especially in the facades. Thus it is easier to use PV modules as shading devices while the thicker solar thermal panel makes sun shading application more problematic (Yin, Wang, Xiong, Cai, Li, Zhang, 2014).

The Implications of Solar Altitude and Azimuth Angle

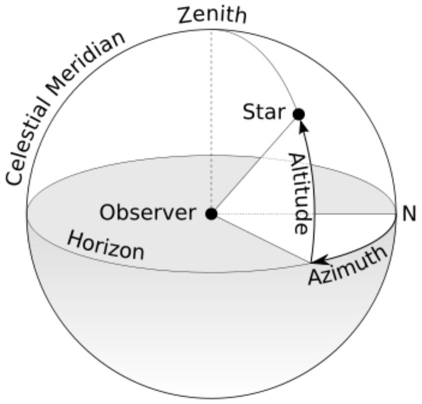
The implication of the solar altitude and azimuth angle (Fig. 6) on the building can be reflected in the shading system of the building.

Fig. 6: Façade integrated with glazed PV collectors

Shading system in the context of this study implies the type of material used for shading i.e. the shading coefficient of the material and the R-value- the R- value being a function of the thermal resistance of the material. In fact, it is defined as the ratio of the temperature variation across an insulator and the heat flux (amount of heat transfer per unit area per unit time) across the insulator; in this case, the PV integrated material may be the building envelope or roof. The U-value is the amount of heat loss in watts (W) per square mere (W/m^2k) in the building material such as the roof, wall, floor, or other elements, when the outside temperature (y) is reduced by at least, one Degree. The quality of the insulation provided by a material is enhanced as the U-value decreases. Hence, the U-value of a building material can influence or determine whether a low e -glass should be used in glazing the solar technology adopted. Usually, the relationship of solar heat and light to a building is broadly dependent on sun path, solar altitude and azimuth angle that subtend the building's fenestration to the sun and the orientation of the building. Moreover, these factors influence the type and sizes of shading devices and/or hoods that architects need to specify in buildings designs.

The Azimuth angle

Shinner (2015) observed that the azimuth angle is traditionally defined as the angle between a line due south and the shadow cast by a vertical rod on Earth (Fig. 7). The solar altitude however, depends on the rotational movement of the Earth around the Sun. This is because the Earths rotate around the sun, tilting 23.5 Degrees relative to its natural orbit around the sun. In this way, the orbit produces a 47 Degree peak solar altitude angle difference resulting in the hemispheric specific-difference between summer and winter (Fig. 8). Thus, it is important to underscore the importance the 47 Degree solar hemispheric variation particularly because it relates to design efficiency of active or passive solar system in buildings (Fig. 8).



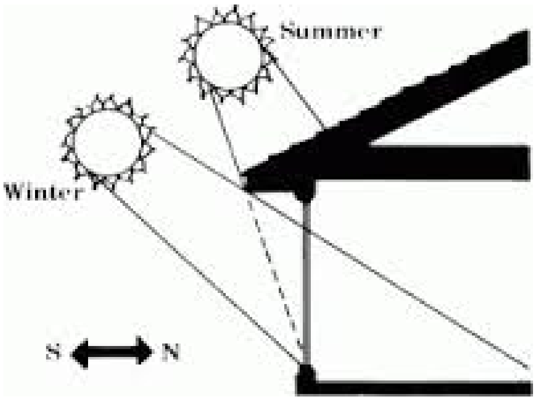


Fig. 7: Showing the azimuth angle **Fig. 8:** Showing roof overhang technically designed

As a result, during the summer, the sun altitude increases untill the summer solstice which is at June 21 when it reaches its peak and gradually decreases till December 21 when the winter solstice occur (Fig. 8). With these variations which is essentially because of the tilting in the Earth's axis as it rotates as pointed out earlier, building's shading devices needs to be designed to accommodate the changes as exemplified in Fig. 8. The design is therefore the technical manipulatiopns of the factors relating to e-glazing, U-value, R-value, aestheics and built form of building to achieve the optimum result. In Fig. 8,the overhang is technically constructed to promote warmth during winter and coolness during summer. More so, shading device that is suitably adapted to specific latitude might be unsuitable for another site as a result of latitudinal variation, thereby creating a need for caution in the application of shading strategies. Zerka(2014) whose position is in tandem with these views, observed that an understanding of sun angles is critical to various aspects of design including determining basic building orientation, selecting shading devices, and placement of Building Integrated Photovoltaic (BIPV) panels or solar collectors.

4. Photovoltaic Integration in Building Design

While recalling that the PV is integrated into buildings as Building Integrated Photovoltaic (BIPV) and as earlier mentioned, it is imperative to note that these 'technical synergy' involves a replacement of some building's structural elements of the building by the PV; in other words, the PV is acting and serving in place of the structural element such as a roof and window-hood (when it is acting as a shading device) amongst others. Moreover, the PV may not be replacing the structural element, in which case, the synergy meant that the PV and the element of the building are conjoined. The elements include:

- The Roof(Tortellini, Hayter, and Judkoff, 1999)
- Shading devices (Torcellini, Hayter, and Judkoff, 2002)
- Atriums, and
- Façades(Ibrik, and Mahmoud, 2003)

The Roof

PV roofing is the integration and/or synergy of the roofs as photovoltaic (Fig. 9 and 10). The PV building integrated roof serves a dual purpose of roofing and energy production. In effect, it serves to drain off condensations such as rain, serves for insulation and it is water tight. It can be slanting or flat, with the slanting variation being more efficient in terms of energy generation especially if the slope is south-facing. Variations in PV roofs are common with slates, tiles and shingles being the most common typology usually adopted. PV tiles are used more often on flat roofs while PV shingles and slates, are used on/as sloping roofs.

Fig. 9: PV integration in the roof **Fig. 10**: PV integration in the roof

There are other alternatives to conjoining the PV modules on rooftops. For example, at the Carlisle House (Fig. 11) and Georgetown University (Fig. 12), PV modules mounted on steel plates were set up on upper side of the roof substratum. Often, PV roofs are insulated to increase its R-value and consequently resulting to a more efficient photovoltaic.

Fig. 11: The Carlisle House in Carlisle Massachusetts.

Fig. 12: PV adapted for the entrance foyer

Façades

PV integrated façades are inherently large and covers much space. In actual sense, it is the use of PV on façades elements (such as windows, hoods, balconies and galleries) in their merits, or simultaneously for multiple benefits. PV integration on the facades should be aesthetically pleasing and may take-up different use of colors to reinforce this appealing effect. Moreover, it should protect the building from unfavorable weather. Often, PV integrated facades are vertical (after the building's) envelope, facing southward and therefore cannot optimize solar gains. To resolve this challenge, the PV integrated facades is technically designed as grooved or saw-tooth or serrated designs (See Fig. 13) in such a manner that it slopes sun-ward. In this way, it is adjusted to improved efficiency and improved electricity generation to cope with summer conditions when energy for cooling is most valuable.

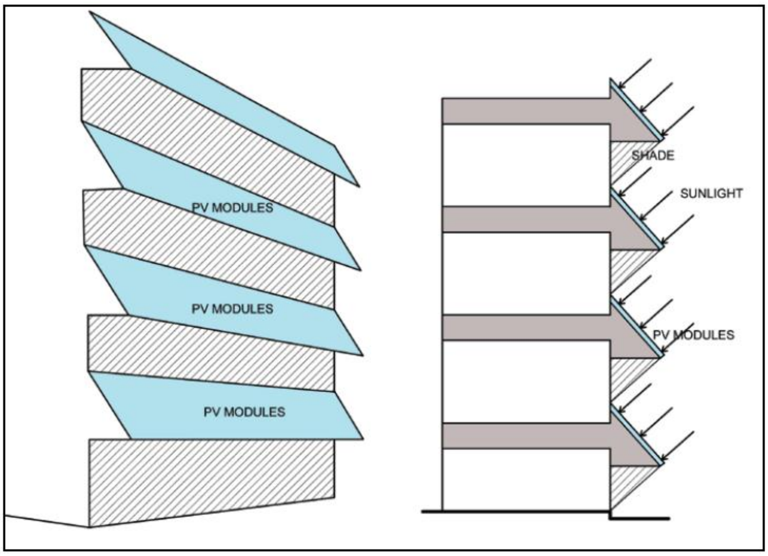


Fig. 13: Saw tooth PV facade consisting of overhanging PV shade screens and clear windows (window hoods).Other Façade's application include Balcony eaves, entrance foyers and window hoods

BIPV Shading Devices

The integration of shading device with solar system in buildings is more of a sun control shading process owing to its dependence the passive solar system. In this method, passive solar and active solar are conjoined in a series of mutually inclusive relationship. The sun control shading device seek to optimize the utility from solar gains during cold or rainy seasons and aim at strategic positioning during dry or hotter periods to ward-off unwanted solar radiations. Often, this dual ability is not easily achieved using a fixed window overhang through-out an annual regime. For instance, fixed simple south-ward facing windows shade-off sun rays during dry season effectively but ineffectively shades-off low afternoon sun in west façade windows at peak heat periods. With this backdrop, it is obvious that the sun control shading strategy should be tactically implemented for optimal results.

Technically, the strategy adopted embraces active solar shades- solar shades integration of PV, (Fig.14and 15) which acts as the shading device in form of awnings and overhangs to reflect unwanted heat. This technology underscores the azimuth angle and solar altitude and the specific characteristic of the glazing in which the PV shading materials are enclosed. The glazing characteristic of the PV is captured by its shading coefficients and its e –glazing.

Fig. 14: PV shade Screens (Finland)

Fig. 15: PV shade Screens

Generally, a well-designed PV integrated shading device enhances day lighting and can reduce cooling load, glare and energy requirement for heating during winter from 5% to 15% (Zogou & Stapountzis, 2011).

In this study, the importance of solar energy system integration in buildings, resulting into Building Integrated Photovoltaic - BIPV has been discussed. This implies that apart from its function as shading device, other aspects of its functions ranging from its application in the roof and wall claddings have also been discussed. Essentially, the BIPV with all its constituents' elements work as a system and therefore, increased insulation in the solar panel on the roof for example, increases the buildings U- value which in turn, is capable of influencing the value of e-glazing used as panels for façade integrated PV serving as shading device such as the type used in Fig. 15. Moreover, apart from its use as shading device, this study has evaluated the BIPV to be economically advantageous than retrofitted PV. Other dimensions of integration ranging from, entrance foyers and balconies applications are also mentioned. Thus, this study points out that a comprehensive active solar technology and strategy to meet or close to meet user's own needs for energy conservation, emission reduction, and comfort can be developed. This study therefore provided a technical and strategic basis for building reconstruction and new construction to manage or minimize the effects of climate change in the future.

CONCLUSION

The study analysis solar systems and PV in buildings. It examines the use of the PV as screening, shading, and roofing devices in buildings. It argues that technical considerations in planning and designs such as e- glazing of solar thermal and photovoltaic materials, solar altitude and azimuth angles, the U-values of solar collectors, are germane to the efficient use of the PV. Hence, the study posits that a logical and coherent integration of PV and solar thermal in building designs is alternative to overdependence on HVAC, fossils and other pro- carbon practice to promote a sustainable, environmental friendly and energy efficient designs to manage climate change.

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