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Research Article

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Effectiveness of Solar Energy Technologies for Building Construction

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Abstract Many nations across the globe have successfully been moving towards clean and environmentally friendly renewable energy sources (RES), especially solar energy, with the aim of supplementing fossil energy supplies and reducing CO_2 emissions. The discussion in this paper shows that during the planning and construction stages of most buildings in Nigeria, little thought is given to solar energy technology such photovoltaic cells (PV), inverters, and other accessories. When mounting solar panels on a roof with a south-facing orientation, the ideal angle is between 30 and 45 degrees, with the solar array pointed directly at the sun and perpendicular to the line connecting the panel installation and the sun. Therefore, it is crucial to plan the building's rooftop for better orientation and inclination for the installation of solar panels in order to generate sustainable energy. The government must implement an energy policy that encourages the integration of PV technology into building construction for both residential and industrial purposes in light of the rising popularity of solar energy.

Keywords Building construction, Solar energy, Planning and construction stages, Orientation and inclination, Energy policy

1. Introduction

Over the past few decades, solar energy has experienced incredible growth in popularity as "green energy." As more residences, workplaces, and industrial facilities choose to use this "clean energy," usage has increased recently. This "photovoltaic energy" has gained a lot of interest in recent years. 93% of the world's population resides in nations with an average daily solar photovoltaic potential of 3.0 to 5.0 kWh/kWp [1]. In the UK, solar energy accounted for 28% of all renewable energy produced in 2021. Along with growing interest in the traditional sources (coal and oil), the related technology is also expanding. It's encouraging to see that investment in this energy sub-sector has increased by twofold since 2012. We have to look to the sky going forward because up until now we have looked down for energy. A cost-free, clean, and sustainable energy source is solar energy. An alarmingly rapid increase in per capita energy usage is occurring [1] Additionally, the cost of energy is rising to new heights. The life and development of human communities depend on energy. As a result, as human civilization has advanced, so too has the requirement for energy. Additionally, in recent decades, the world's population has been expanding quickly and has become more dependent on technological advancements, which has led to an increase in energy demands. Green technology sources are crucial for delivering energy supplies in a sustainable manner, particularly for reducing climate change [5, 6, 8]. Energy efficiency is being taken into consideration when building a structure. Utilizing alternative solar energy, which has numerous advantages, is the goal in order to reduce energy consumption. Technology can be a major factor in four areas of a building's energy efficiency as follows:

i. Zero-energy passive building design must be completed prior to construction;
ii. Low-energy building materials should be used throughout construction;
iii. Equipment that is energy-efficient: to reduce the amount of energy needed for operation; and
iv. Integration with other applications is the final step, followed by integration of renewable energy technology.

Today, after industry and agriculture, buildings are the third biggest consumer of fossil fuels. The Asia-Link program is a European Commission project to advance and disseminate information on sustainable built environments with a focus on almost zero energy [2]. This sustainable built environment program encourages the incorporation of reliable renewable energy technologies into the building for a variety of purposes, including power generation, heating and cooling, and water heating. Around the world, people are paying more attention to how much energy is used for building operations. Building sustainability assessment is thus increasingly essential for sustainable growth, particularly in the global building industry. Building energy efficiency is crucial to the national energy conservation policies since buildings account for 25% to 40% of all energy consumption and are one of the three primary energy consumers along with transportation and industry. The main objectives of sustainable design were to decrease the depletion of essential resources like energy, water, and raw materials; prevent environmental degradation brought on by facilities and infrastructure throughout their life cycles; and create built environments that are secure, beneficial, and efficient in utilizing water and solar energy [2]. Also the study of [4] revealed that the purpose of implementing solar energy and building integrated technologies is to alter the fragmented, disjointed status quo of each branch and link, incorporate solar energy into the environment's overall design, make architecture, technology, and aesthetics coexist as an organic whole, and make solar facilities a part of the building. Burdova and Vilcekova's tool for creating an environmental assessment system (BEAS) has been implemented in Slovakia as shown in Table 1 [3] for all resource conservation efforts.

Building Integration of Solar Energy

Building integration of renewable energy resources (RES) has the benefits of creating more room on the structure for the installation of the required area of the RES systems and of substituting the RES component for the traditional building component, increasing the economic viability of the systems. In the event that this concept is used, numerous practical problems, such as rainfall sealing and protection from overheating (avoiding higher cooling demands during the summer), must be handled in addition to the aesthetic and architectural obstacles of building integration. In the winter, the building can be heated using the surplus thermal energy [7]. Due to the fact that solar incidence angle impacts and façade application for RES are latitude-dependent, these factors must be taken into account. Although countries near the equator have high incidence angles (the sun is higher in the sky), they have greater energy availability than those at higher latitudes [7]. Prior until recently, small-scale residential buildings were the main focus of research and development on energy efficiency and the use of renewable energy in the building sector, and significant progress has been made in lowering energy use in these types of structures. High energy costs and rigorous building regulations in mid- and northern European climes have mostly led to residential buildings that use relatively little energy for space heating. The term "building-integrated photovoltaics" (BIPV) refers to materials that have many uses and can produce power while also sustaining a structure. Table1 provides a summary of some benefits and difficulties related to this technology [9].

Table 1: Advantages and challenges of building integrated photovoltaics

Advantages	**Challenges**
Lower cost due to multi-functional nature of materials and due to more efficient design. Currently, PV contributes 0.5% to national energy demand; DOE expects it to reach 50% (!) with BIPV implemented.	System orientation, weatherability, durability are the factors that affect the system performance. Those parameters may be not easy to optimize if it is BIPV rather than add-on PV.
Improved aesthetics: panels are produced as facade lining, roof tiles, slates, shingles, windows (glazing, etc.).	BIPV modules can be heavier than regular building elements. Because of potential overload, new building standards and codes need to be in places to regulate this integration.
Thin-film PV can be applied directly to conventional building materials because the flexible and light.	BIPV modules are costly compared to regular add-on PV due to their multifunctional value, but that is not always recognized. BIPV is not mass-produced, but rather custom made, and that adds to the price.
	Social acceptance: not many see long-term value because PV technology is thought to be soon outdated. There should be more acceptance from contractors and end-users alike.

Source: [9]

While the primary purpose of a conventional PV system is to generate electricity efficiently, building-integrated PV systems, which become parts of the building envelope, must also meet a number of additional criteria, including:

i. appearance:
ii. colour,
iii. image,
iv. size;
v. weather-tightness;
vi. wind loading;
vii. durability and maintenance;
viii. safety during construction and in use (fire, electrical, structure stability); and
ix. cost. [9].

Figures 1–3 show various photovoltaic installations in a building environment.

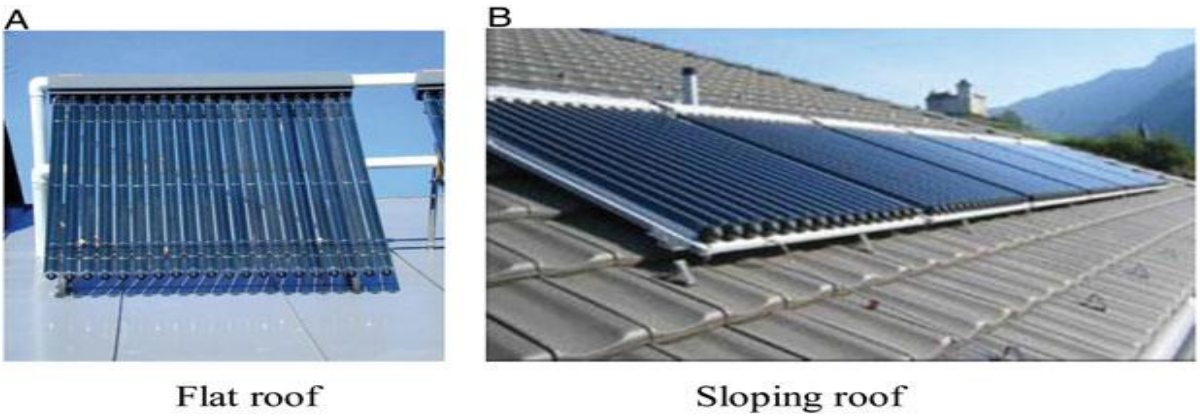

Figure 1: Evacuated tube solar collector on building roofs. (a) Flat roof. (b) Sloping roof. [6]

Figure 2: Typical applications of PV shading on buildings [6]

Figure 3: Building façade with integrated photovoltaic panels [9]

1.3 Orientation and inclination of the solar panel on the building

The term "Solar Panel Orientation" describes our azimuth position. The majority of the energy from the sun travels in a straight path. If a solar panel or solar array is pointed directly at the sun and perpendicular to the line between the installation of the panels and the sun, it will be able to harvest more energy. Solar panel oriented so that it faces the terrestrial equator (either south in the northern hemisphere or north in the southern hemisphere) in order to capture the most solar radiation possible during the day [11; 12]. There are different ways of achieving the required solar panel orientation. The PV could be pointed on panel or array due south or north using a compass, find the central angle between the summer and winter azimuth settings or more accurately position the panels relative to the central solar noon. The solar noon is the point in the sky where the sun is at its greatest point during its arc from east to west. In terms of time measurement, solar noon differs from midday or noon at 12:00. Depending on where you are, the solar noon usually happens between 12:00 and 14:00 [12].

The direction of the roof is one of the key elements that affects how much solar radiation solar panels receive during the day. True south and true north do not line up with the Earth's magnetic poles; rather, they face the axis of the planet. The optimal direction for solar panels is south for regions north of the equator, while southern hemisphere regions would place solar panels on roofs with a northern-facing orientation. By aligning solar panels with true south and the azimuth angle, the angle of the sun with respect to true north and true south would be obtained, giving the solar panels and the array their optimal direction. The majority of solar panels are set at an angle that maximizes the amount of sunlight reaching the area. The perfect angle for installing solar panels on a roof that faces south is between 30 degrees and 45 degrees for the great majority of property owners in the United States. According to physics, the longer the sun illuminates the solar panel, the closer it is to vertical illumination, and the most energy is received. When panels are positioned due south they will function at the very top of their efficiency, 24% if using 104 Half Cell monocrystalline panels. Fig. 5 and 6 show the orientation and tilt angle.

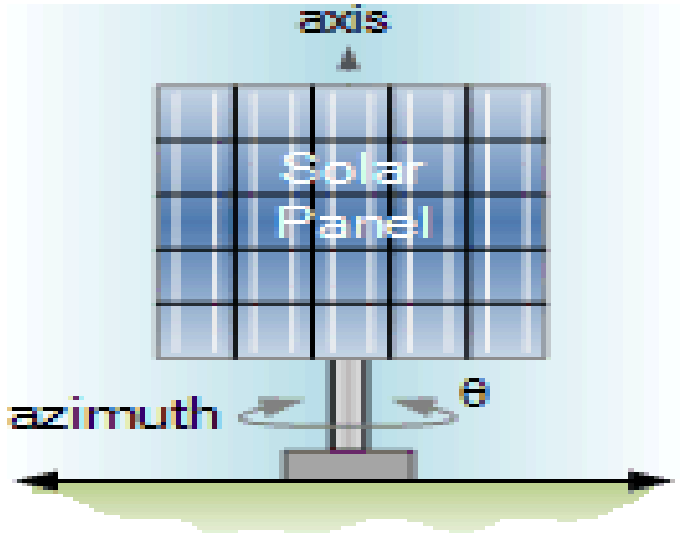

Figure 4: Azimuth positioning of solar panel

Figure 5: Orientation and the tilt angle

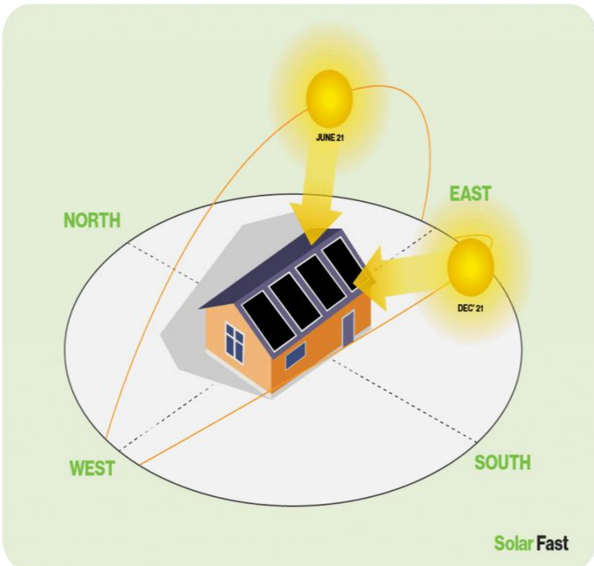

Figure 6: Angle and direction on solar panel output

Solar Panel Tilt

The zenith or elevation setting is referred to as solar panel tilt. The height of the PV panel is the next factor that must be considered in order to generate the most solar electricity once the best azimuth location has been identified. For a fixed solar installation, it is desirable that the PV panels be positioned with a centralized tilt angle that corresponds to the vernal equinox or the autumnal equinox, which in our example data above would be roughly 38 degrees (38°) [9;10]. The tilt orientation of the solar panels, however, is less crucial because even at a tilt angle of nearly 45 degrees (45°) with respect to the sun's solar rays, they will still receive more than 75% as much energy per unit surface area as they do when they are perfectly aligned. Consequently, a photovoltaic panel's output is barely affected by an alignment error of up to 15°, whether positive or negative. Solar panels should ideally be placed where they will get the most sun exposure possible, averaged out over the course of the day and the year [11]. A fixed solar PV panel or array's solar panel orientation and tilt can also be tailored for a certain month or time of year. For instance, a solar power system may be configured to produce its maximum output only during the winter in order to lower peak electricity costs. As a result, the system must be placed in such a way that the solar panels are oriented and tilted for the best possible winter power production.

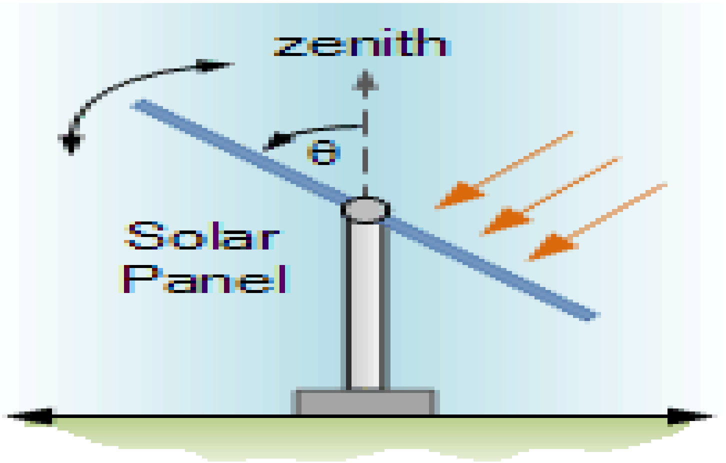

Figure 7: Zenith positioning of solar panel

Conclusion

State-of-the- Art and modern buildings consume a high degree of energy due to the installation of several technological devices for the comfort of the occupiers. However, more than 80% of the energy source is from the burning of fossil fuel, particularly in Nigeria, where energy supply through hydropower is highly erratic and unreliable. For this reason, a large number of people are currently moving to environmentally friendly and clean energy sources for constant energy supply and probably to mitigate the emission of elevated CO_2. The most widely adopted renewable energy source is the use of photovoltaic cells, or solar energy. PV is mostly installed on the rooftops of buildings, depending on the orientation and angle of inclination. Due to the significance of this RES, it is imperative to design the installation of PV with the building plan from the inception of the project. Also, all the electrical fittings would be technically protected and ensure easy access for maintenance. In addition, it creates some level of aesthetics for the building compared to a building project without initial consideration for solar power installations. Due to the growing adoption of solar energy, it is important for the government, through relevant agencies, to enact an energy policy that promotes the integration of PV technologies into buildings for both residential and industrial applications. The development will not only address inadequate energy supply but also mitigate possible climate change impacts by reducing CO_2 emissions.

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