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Renewable Energy Integration in African Buildings: Criteria and Prospects.

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***Abstract**: Of all the continents of the world, Africa seems the most hit when it comes to energy crisis. Africa is blessed with both the renewable and non renewable energy sources which can be harnessed to mitigate her daunting energy inadequacy. This papers takes a critical look at how this energy problem can be solved using this God given resources, therefore, presenting an array of criteria that can be helpful in the proper integration of renewable energy system in the buildings. This in a way was aimed at sustainability of the entire practice and the system. The criteria were developed as the energy efficiency concept was utmostly discussed in relation to African buildings. Prospects and issues on the environment that may possibly arise in the integration of renewable energy system were highlighted. The study made use of; focus group discussion, questionnaires, and review of literatures to conclude that while there are a handful of renewable energy technologies that can be deployed in buildings, Photovoltaics (PV), small wind turbine and solar hot water systems are the most practical technologies that can enjoy easy integration to building; however, other options of renewable energy technologies are also very much possible.*

***Keywords:** Integration, Building, Efficiency, Renewable, Energy, Africa.*

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I. INTRODUCTION

Energy is used in buildings for various purposes: heating and cooling, ventilation, lighting and the preparation of hot sanitary water among them. In residences and commercial buildings, installed equipment and appliances require energy, as do removable devices like mobile phone chargers and portable computers. However, identification of fixed and fluctuating demand for energy rarely appears in a building's consumption metric, as most measurement consider only the total amount consumed by the whole building (Laustsen J. 2008). Buildings use about 40% of global energy, 25% of global water, 40% of global resources, and emit approximately 1/3 of GHG. They consume approximately 60% of world electricity, yet energy consumption can be reduced by 30-80% using proven technologies (ECN-JICA 2017).

One of the first steps in determining how to integrate renewable energy requirements into building energy codes was to review other groups that have already implemented a requirement. We conducted a web-search to identify what local, state, or national governments have adopted renewable energy requirements. Broadly speaking, there are few renewable energy requirements either globally or within Nigeria. Most code jurisdictions used globally are permissive – they allow use of renewable energy equipment – but few have mandatory requirements (Kaufmann J. R. *et al* 2011).

The aim of this study is to research and propose suitable criteria, strategies, tools and guidelines that will promote the effective integrated implementation of Renewable Energy Sources (RES) system and techniques in both existing and new-build settlements. The specific objectives of this work include the combination and adaptation of scientific and technological knowledge with best engineering and architectural practice in order to study, develop, propose and disseminate indigenous actions on the integration of RES systems and techniques in the African settlements since Africa has peculiar features.

II. OBJECTIVES

The objectives of this study are; To develop criteria for renewable energy integration in building, improve the local microclimate, improve building design and implement the use of passive and active RES systems and techniques in them, study the potential of centralized cooling and heating systems operated with the use of RES, study the potential and the applicability to specific demand side management actions, managing and controlling the energy requirements of the developed settlements.

III. METHODOLOGY

Questionnaires were developed as a means to obtain input from stakeholders on the key issues and possible strategies. The intent of the questionnaire was to solicit qualitative input, not to take a quantitative poll. While most of the questions provided for 'yes-no' or 'multiple-choice' answers, every question provided a comment box and asked respondents to explain their answers or provide other information. Focus discussion, work through and direct measurement were all employed where applicable. Above all, existing literatures on the subject area were also reviewed upon which we built on our submission. Our practical experience as energy personnel were brought to fore too. Data obtained were both quantitatively and qualitatively analyzed.

IV. RENEWABLE ENERGY OPTIONS

Notable amongst the renewable energy options are solar photovoltaic, wind energy, biomass, hydro power and emergent technologies such as fuel cells. In the world over, most habitable landmass and sea shores have access to sun energy, making solar power harness able in such areas, therefore solar energy is the most abundant, however it has not been adequately exploited (ECN NEMP 2014). Wind power just like solar is abundant but presently has been considerably exploited by only developed and few of developing countries such as Germany, China, USA and India because of its technical requirements. In Africa, more than 68 percent of energy needs are met by biomass and the hydro power constitutes about 2 percent of energy consumption.

4.1 Criteria for Renewable Energy Integration

Solar Photovoltaic modules can be integrated into every part of the building envelope. They are particularly suitable to be used together with materials that are common in buildings such as walls, glass or metal.

4.1.1 Integration Possibilities In The Building Envelope

No categorization is exhaustive enough for describing all the ways to integrate solar PV into the building concept. However, in order to simplify how solar PV can be integrated in a building, four main categories have been defined: Solar PV as added technical element, Solar PV as free standing structure, Solar PV as part of surface composition, and Solar PV as complete façade/roof surface.

4.1.2 Photovoltaic and the technological integration into the envelope

Photovoltaic modules can either be applied on top of the building skin (BAPV-Building Added Photovoltaic), or integrated into the envelope constructive system (BIPV-Building Integrated Photovoltaic). See figure 1 which depicts a roof-top solar PV system.

Figure 1: 15 kW Roof-top solar PV system at ECN, Abuja.

4.1.3 Technical assessment criteria for Integration of Renewable Energy (Solar PV) in Public Buildings

The following are basic assessment criteria that are to be considered while planning the renewable energy integration;

Building Types; Bungalow, Storey, Sky scraper are to be ascertained. One equally needs to find out possibilities for modification.

Geographical Location of the public building; Longitude**,** Latitude**,** Topography**,** Accessibility**,** Proximity to public utility

Space for Installation/Shading; Rooftop, Parking lots, vacant land**,** Roof types and colours (Black Coloured roof absorbs too much heat)**,** Orientation of rooftops or Parking lots: North, south, east, west**,** Inclination (Steepness in degree)**,** physical structures e.g Skyscrapers**,** Natural features e.g Trees, stream, mountains etc**,** Area layout need to be critically assessed..
Structural and architectural design; Tensile stress consideration**,** Vibration assessment in case of hybrid solar/wind. Every building has a threshold load carrying capacity.
Energy Audit of the building; Load Estimation: Types (a.c or d.c loads), ratings**,** Lighting points (Fluorescent, Incandescent, CFL, LED)**,** Heavy loads e.g Air conditional, Refrigerators**,** Retrofitting/ Wiring types (Conduit, Semi-conduit or surface wiring)**,** Distribution board types and capacity**,** Source(s) of power**.** Type of renewable energy technology that can be deployed in alternative must be established.
Cabling System; Cable sizes and types**,** Possibility of using existing cable/circuitry**,** Modification requirement
Solar resources; Solar insolation**s,** Average sunshine hour, Daily hourly energy usage, Humidity of the area, Solar/wind resources for hybrid system are to be assessed.
Economic viability of solar Option (Comparative Advantage); Energy bills**,** Possible savings/Loss**,** Comparative cost of Energy option have to be considered.

4.2 Building and Energy Efficiency

4.2.1 Buildings

Buildings cover large portion of land and responsible for the huge quantity of energy, electricity, water, and materials consumption. Buildings account for approximately 31% of global final energy demand, approximately 18% of energy-related CO_2 emission today, this is equivalent to 9 billion tonnes of CO_2 annually and approximately 25-33% of black carbon emissions (Diana *et al*, 2016). If the trend continues the emission will double by 2050. However, building sector has greatest potential to give up significant cuts in emissions at little or no cost and provide room for other energy installation and proper utilization. The rational for building green is the direct impact on environment, economic, and social benefits. However, modern sustainability initiatives approach is on the integrated and synergistic design to enhance both new construction and in the retrofitting of existing structures. This approach integrates the building life-cycle with each green practice employed with a design-purpose to create a synergy among the practices used.

Green building is a process of employing various ways of practices, techniques, and skills to reduce and ultimately eliminate the impacts of buildings on the environment and human health. Sustainable building design encourages efficient energy consumption by enabling passive heating, cooling and ventilation. It often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic equipment, and using plants and trees through green roofs, rain gardens, and reduction of rainwater run-off. Many other techniques are used, such as using low-impact building materials or using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of ground water (US CLID, 2013).

4.2.2 Energy Efficiency

The motives of green buildings is to minimize the energy consumption especially on the demand side; both embodied energy required to extract, process, transport and install building materials and operating energy to provide services such as heating and power for equipment. Perhaps, for this to be achieved there is need to address the following areas (Dino, 2013);

- **Minimize energy waste** by applying proper building insulation, ventilation. Eliminating air and water leaks and avoiding poor quality in construction that leads to future damages and energy waste. This reduces the amount of energy required to reach desired comfort conditions.
- **Adoption of sustainable practice** The application of basic energy saving practices such as; dressing up appropriately while indoors, optimizing use of electrical appliances such as dish-washing cycles and switching off unnecessary electrical appliances if not in use or install automated power monitoring systems. Finally, use of energy efficient appliances.
- **Incorporating bioclimatic principles and passive energy principles at design stage** is a simple and relatively economical way to optimize the energy in a building; by controlling ambient temperature of a building through natural means.
- **Use renewable energy sources** such as solar (solar PV and solar thermal), wind, geothermal or biomass energy. On site generation of renewable energy through solar power, wind power, hydro power, or biomass can significantly reduce the environmental impact of the building. Figure 2 shows typical hybrid PV systems.

Figure 2: Solar-Wind Hybrid mini-grid systems with solar water heating systems at Guzape, Abuja.

Holistic retrofits can achieve 50-90% final energy savings in thermal energy use in existing building with the cost savings typically exceeding investments.

Benefit of Green Building

New technology in construction and retrofitting of buildings is important in improving the efficient use of environment and also mitigation of the building sector's contribution to climate change. Some of the benefits are: Improvement in energy security and sovereignty, Net job creation, Elimination of or reduction in indoor air pollution-related mortality and morbidity, Health improvement and benefits, Alleviation of energy poverty, and improvement of social welfare.

V. PROSPECTS AND ISSUES

Factors affecting renewable energy integration

The integration of renewable energies into buildings is faced with a lot of challenges and some of these factors affecting the integration are highlighted below;

- **Energy yield**

A rough estimation of the energy yield of a PV system depends on the following: Location of the PV plant: The orientation of the modules gives then the effective radiation reaching the modules (orientation factor), The adopted module technologies and the number of installed modules: a simple multiplication of the cell efficiency (eff) and the modules area is used to calculate the installed Power of the system, The type of the installation: the Performance Ratio (PR) of the systems and the PV modules efficiency strictly depends on the cell temperature. The wind power in its own case demands more technical expertise in order to be able to achieve a considerable energy yield.

- **Nominal power of the system**

The nominal power is defined as the output power of a PV system under standard test conditions (STC): irradiance of 1009 W/m², solar spectrum of AM 1.5 and module temperature at 25°C.

However the working conditions of a PV module are very dependent on the location and the climate, and only seldom meet the STC.

- **Orientation of the modules**

For each geographic situation, there are different irradiation levels associated with different orientations. The yearly sum of global irradiation is specific to the location. To maximize the annual energy yield, the PV surfaces should be south-facing when situated north of the equator and north facing for southern locations.

- **Conditions at the location**

Even partial shading can cause significant efficiency losses in the PV module output. Considering that within an array, the PV modules are connected in series, also the partial shading of one single module of the array, even if it is equipped with bypass diodes, can affect the whole system performances. On the other hand, wind power plant may encounter some problem in an undulating topography if not professionally developed.

- **Inverter and system**

Sizing the inverter for its required purpose is extremely important for solar photovoltaic system. If it is undersized, then it could shut off during operative conditions. If it is oversized, it will be much less efficient.

- **Space requirement**

To produce the same amount of electric energy, very different amounts of envelope surfaces are needed, depending on technology efficiencies and area orientations. Certain category of renewable energy technology requires large expanse of land or space.

- **Cost**

The cost of a photovoltaic system is composed of the PV modules price and the Balance of System (BOS)/Installation costs. This BOS/Installation includes the equipment such as the inverter, the switches, the cabling, the mounting system and the cost of installation. Modules typically represent 40-60 % of the total PV system cost. In all, renewable energies generally are capital intensive.

VI. CONCLUSION

Attempt has been made at taking critical look at the energy efficiency in building, creating assessment criteria, examining the prospects and issues with different forms of renewable energy sources and their possible integration in buildings. The effect of such integration on the environment has also been examined and it is concluded here that developing countries have been fed through this article the necessary knowledge needed to appreciate the concept of renewable energy integration and energy efficiency in buildings. Notwithstanding the peculiar issues of the integration, the concept provides an alternative way of meeting the energy demands of the people while still ensuring the protection of both our immediate and global environments.

While there are a handful of renewable energy technologies that can be used or deployed in buildings, Photovoltaics (PV), small wind turbine and solar hot water (Solar Home System SHS) are the most practical technologies that can enjoy easy integration to building; however, other options of renewable energy technologies are also very much possible.

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