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Original Article

Renewable Energy Integration in Building Construction: The Nigeria Experience

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Abstract *- The construction industry accounts for most of the world's energy consumption and contributes to environmental hazards due to greenhouse gas emissions. However, the solution to these problems lies with the introduction and application of renewable energy resources, which involves both sustainable architectural design practices in combination with allied built environment professions like engineering and technology, especially Information and Communication Technology (ICT). This study examines the techniques involved in integrating renewable energy resources into both smart and existing non-smart buildings to make buildings more energy efficient. The study employs qualitative survey research, which combines the* use of *questionnaires and interviews to determine the level of awareness and application of renewable energy sources in design and construction by architects in South-South Nigeria and an extensive review of the literature. Findings reveal that although technological advancement in ICT through building energy and environmental systems could be integrated into both existing and new buildings to make smart buildings, most architects in Nigeria only integrate solar energy sources in their designs and construction of non-smart buildings. The study concludes that architects in Nigeria should embrace renewable energy resources, which can contribute significantly to energy efficiency by meeting the Heating, Ventilation, Air-Conditioning (HVAC), and lighting building needs by creating cleaner energy with fewer emissions for the benefit of humans and the environment.*

Keywords *- Building construction, Energy efficiency, ICT, Renewable energy sources, Smart buildings.*

1. Introduction

Buildings have been known to be the greatest consumer of the world's total energy, accounting for over 41% of energy use and greenhouse gas emissions, which constitute environmental pollutants that affect humans in the community [1]. Therefore, it has become very imperative that attention be focused on how these negative environmental hazards can be drastically minimized through sustainable architectural solutions in the designs and constructions of new smart buildings and re-integrating renewable energy resources into existing non-smart buildings that form the bulk of the housing population in developing countries.

In most developing countries of the world, the concept of smart buildings is still an illusion that is yet to be fully understood and embraced not only by individuals but also by government agencies alike. This is evidenced in government policy's non-implementation of smart city/building initiatives in most developing countries like Nigeria [2]. But one must understand that the various reasons adjourned for the failure of governments of developing countries not fully to embrace smart building initiatives can no longer be accepted today due to technological advancements and because the world has become a global village. However, this study intends to dwell less on smart buildings and more on renewable energy resources in buildings to achieve cheaper and cleaner energy sources.

Renewable energy has become one of the most effective ways of saving energy in buildings and construction-related activities in the built environment. Examples of renewable energy include bio-organic fuel, hydrogen energy, geothermal energy, solar energy, and water energy, among others. Thus, the renewable energy source is described as energy capable of renewing itself at an equal rate to the energy received from the energy source or faster than the depletion rate of the source [3], [4]. The importance of renewable energy in buildings today cannot be underestimated, ranging from its inexhaustible cost-effectiveness to clean-healthy energy. Therefore, these sources of energy must be used to power the heating, ventilation, and air-conditioning (HVAC), and lighting building needs by creating cleaner energy with less emissions for the benefit of humans and the environment. Thus, this study aims to highlight the importance of integrating the use of renewable energy into both smart and non-smart buildings in developing countries through conventional and technological ways, respectively.

2. Literature Review

The technological advancement of the 21st century has led to the creation and design of buildings that are operated and regulated with the help of Information Communication Technology (ICT), which are now referred to as smart buildings. A Smart building is any building that exhibits 'the combination of design, materials, systems, and technologies in order to offer users an interactive, flexible, productive, economical, integrated, and dynamic environment.' It is also described as a building that essentially programs itself by monitoring the environment and sensing actions performed by the users (such as turning lights on and off, adjusting the thermostat), observing the occupancy and behaviour patterns of the occupants, and predicting the future status of the building [5], [6].

Buildings become smart when certain elements of smartness are introduced into them through ICT, which includes monitoring and communication devices such as sensors, actuators, and BMS, which combine to monitor, measure, record, and interact with building occupants and users [7], [8]. The benefits of smart buildings include, among other things, energy saving and reduction of energy consumption in buildings by up to 10% globally, regulating internal temperature, thereby enhancing thermal comfort and reducing emissions globally [9].

However, it should be stated clearly that proposed new buildings are better planned and designed to accommodate the latest technology of smartness in buildings. However, it is quite different when considering older buildings, which lack features of smartness, as with buildings in most developing Countries of the world like Nigeria, which form the bulk of the existing buildings, there is a need to embrace the technology of 'retrofitting.' This is a system that allows the introduction and infusion of the latest smart technology into already existing buildings to make them smart and energy efficient.

Therefore, the literature review shall focus on renewable energy, energy efficiency in building retrofitting, and the application of renewable energy in smart buildings.

A study carried out by [10] on the 'application of renewable energy resources in buildings' centred on Renewable Energy Sources (RES) with particular emphasis on energy efficiency transformation and energy saving. The study analyzed the current state of design, construction, and issuance of operating permits to install green materials supporting renewable energy sources and building efficiency. The research method was basically a literature review, while discussions were on the types of renewable energy sources that could be introduced to save energy in buildings using Serbia as the study area. The study outlined RES to include biomass, geothermal energy, solar energy, and wind energy. It concluded that the benefits derivable from using RES are enormous due to its free energy sources, cost-effectiveness, and ecological friendliness. The outlined RES discussed in this study is relevant to this study and thereby adapted.

Similarly, the study by [11], Renewable Energy Applications for Existing Buildings, focused on the various technical prospects, avenues, and methods for integrating renewable energy technologies into building designs and operations. The study addressed the technology involved in effectively offsetting both electrical, mechanical, and thermal energy loads in buildings and outlining the role and tips for implementing renewable energy projects and building energy efficiency. The methods of study were an extensive review of literature, and the discussions were on the synergies between existing buildings and renewable energy technologies, stressing the need for retrofitting older existing buildings that already have features of natural daylighting and ventilation, among other energy-efficient features in their design.

The research study carried out by [12] titled 'Smart Buildings: ICT as a driving energy-efficient solution for retrofitting of existing buildings' discussed the emergence of a new ICT architecture based on communications between smart buildings and smart grid for reduced energy consumption and gas emissions for societal benefits. The aim of the research was 'to identify and analyze the potential energy saving which can be obtained through ICT solutions in an existing Swedish single-family household built during the 'record years' (1961-1975), without the need for extensive change or renovation'. The study was done mainly by literature review through data analysis from international organizations and the Swedish government using Sweden as the study area. The study emphasized the importance of ICT for integrating renewable energy into smart grids, which reduces buildings' energy consumption. It also analyzed the potential energy saving in existing buildings' methods of making them energy efficient. It concluded that smart buildings are the way to go if buildings are to reduce energy efficiency. The various analyses of data and outline of some sub-themes are relevant to this study and are thereby adapted. Furthermore, certain concepts that form the study's core are explained for better understanding. This includes renewable energy sources, smart buildings, and retrofitting, as well as the techniques involved in integrating renewable energy into existing buildings, including the benefits respectively.

2.1. Renewable Energy

The harmful effects of fossil fuels and other non-renewable energy sources on man and the environment have necessitated the choice of cleaner energy resources for efficient and effective energy use in buildings today. Thus, renewable energy has been advocated to replace non-renewable energy in our environment. Renewable energy, as the name implies, is the type of energy which can be renewed by nature. In other words, renewable energy is a type of energy that uses energy sources that are constantly and repeatedly renewed by natural elements such as the sun, wind, water, and plants. According to [13], renewable energy resources are those forms of energy "derived from natural processes and replenished at a faster rate than they are consumed." However, an all-inclusive and statutory definition was put forward by The International Renewable Energy Agency (IRENA), which stated that "renewable energy includes all forms of energy produced from renewable sources in a sustainable manner, including bioenergy, geothermal energy, hydropower, ocean energy, solar energy, and wind energy."

Renewable energy sources (RES) can be integrated into both smart and non-smart buildings alike because they are nature-based sources. The importance of RES includes providing a better and cleaner energy source in buildings, producing non-pollutant and harmless energy, and developing energy independence and security [10].

2.2. Smart Buildings

Smart buildings have emerged as one of the products of technological advancement in ICT in the 21st century. Buildings are smart due to the integration of some ICT software embedded in them either from the planning, design, and construction phases or after construction, as in the case of existing buildings that are prevalent in developing countries of the world today. The objectives of the energy-saving policy encourage the transformation and upgrading of the vast numbers of non-smart buildings currently existing to become smart buildings that can communicate with building occupants in terms of energy usage per time and the environment as well. A smart building is defined as a building with many sensors that help monitor the energy-related activities of occupants in a building[14]. They are described as the relation and link between architecture, urban planning, and ICT characterized by a set of smart technologies and software such as sensors, control systems, smart meter/grid, and building management systems [15].

According to [16] and [17], smart buildings differ from other buildings in their abilities to carry out computerized operations such as access control, power management, lighting control, and video surveillance, among other things, because they have ICT hardware and software, and other smart appliances. Some critical areas of ICT-driven innovations that are incorporated into buildings to make them smart include the use of nanoparticles to coat material to enhance the specification of material properties, occupancy sensors to determine when a space is occupied or not, use of smart materials in facades to provide controls in feedback, regulation of air, heat and light controls in buildings; use of smart glass also known as electrochromic windows for visible lighting and glare reduction [18]; [19]; [20].

2.3. Retrofitting of Buildings

The term retrofitting, according to Designing Buildings [21], is mostly used to connote the installation of new building systems, such as heating systems, or the fabric of a building, such as insulation and double glazing. It is usually very easy to retrofit a new building because the design and construction of new buildings normally consider new technological innovations at the planning stage, thereby making the implementation simpler. But this is different from old buildings already in use as these must undergo a series of renovations to introduce such new technologies. This is what has given rise to a broader meaning of the word retrofit. Thus, according to [22], 'to retrofit means to provide something with a component/feature not fitted during manufacture or adding something that was not there when it was initially constructed. Retrofitting generally means introducing or adding new technologies/functionalities to existing systems to strengthen or improve older buildings for energy efficiency [23].

The importance of retrofitting buildings cannot be overemphasized. It is one major way to bring life and new technologies into old, existing buildings to make them sustainable and adaptable. These include, among others, healthier indoor air quality (IAQ), improved thermal comfort, energy efficiency, and lower noise levels [24]. Although the concept is now a global trend, it is however not fully embraced in developing countries, possibly because of high initial cost, delay in the return of investment, or challenges of non-viability of retrofitting in historic buildings for conservation purposes [25]; [26].

2.4. Techniques for Integration of Renewable Energy into Existing Buildings

Building retrofitting undoubtedly repositions existing buildings for new and current realities expected of any functional building. Thus, one of the benefits of building retrofitting is the decrease in energy consumption through the introduction and use of renewable energy sources in addition to the enhancement and upgrading of the building functionalities and architectural quality [27].

However, several strategies and techniques for building retrofitting abound, but selecting any suitable technique with minimal negative effects requires proper analysis and critical evaluation. It should be noted that the strategies for achieving effective building retrofitting technologies are grouped into three actions which, according to [27]. are:

- Actions about building services and management tools, including using sensors and controlling buildings during operation.
- Actions about the building envelope and design aspects, including improving thermal insulation by reducing air leaks and using insulated doors and windows.
- Actions about building systems and equipment, which include the use of renewable energy, the use of energy-efficient electric lighting equipment, and the installation of high-efficiency HVAC systems.

Similarly, the various applicable building retrofit technologies available currently are grouped into three, namely demand-side management (which includes the use of energy-efficient equipment and strategies for reduction in demand for heating and cooling), human factors (attitude of users), and supply-side management (which include application of RES such as solar hot water, wind energy, geothermal energy [28]. Nevertheless, the application of RES in buildings can only be successful if certain conditions are in place, which include high levels of energy saving and sustainability features, namely sustainable construction environment (site adaptability), sustainable building materials, proper lighting, and ventilation; efficient heating and cooling (through panels, cells, water heat pumps) and savings/reduction in energy loss (insulation of windows and doors, façade, solar roof). In addition, there should be initial planning for integrating RES into the building through the architectural design of the building, services design, structural design, information technology design, and proper appraisal of the introduction of innovations [10].

3. Methodology

The methodology employed in this study is qualitative survey research, which combines questionnaire interviews with practicing architects in public and private organizations, construction consultants, and building contractors in selected cities of the south-south geopolitical zone of Nigeria. One hundred thirty-five questionnaires were grouped into sections containing information on personal data, practice experience, knowledge of RES, and application of RES in design and construction, among other information. The study employed purposive and expert sampling methods to locate respondents across the study areas. The data obtained were analyzed using simple statistics, and the results are presented in tables and charts.

4. Results and Discussions

One hundred thirty-five questionnaires were administered to architects, construction consultants, and building contractors across four capital cities in four States of South-South. The cities are Calabar (Cross River State), Uyo (Akwa-Ibom State), Port Harcourt (Rivers State), and Benin City (Edo State). From the 135 questionnaires distributed and administered, 105 were retrieved, representing 77.8%. This is shown in Table 1 below.

Table 1. Questionnaire distribution and administration

City	Benin City	Calabar	Port-Harcourt	Uyo	Total	(%)
Number Distributed	30	40	30	35	135	100
Number Retrieved	21	33	22	29	105	77.8

Source: Author's Fieldwork 2023

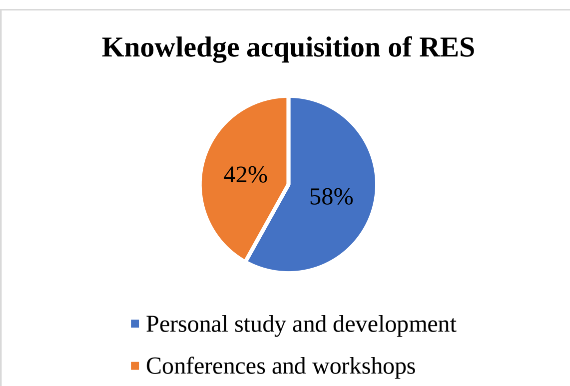

Fig. 1 Respondents' knowledge acquisition of RES

From section A of the questionnaires, from the total of 105 respondents, 76 are male, while 29 are female. All 105 respondents are still in practice today and are involved in architectural services such as design, construction consultancy, and supervision.

From section B of the questionnaire, on the knowledge and awareness of RES, all the respondents have good knowledge of RES and its advantages. This means that there is none of the respondents that does not have any knowledge about RES which shows a sign of being current professionally.

On the mode of knowledge acquisition of RES, as in Figure 1, 61 respondents, representing 58%, got the knowledge through personal study and development, while 44 respondents, representing 42%, got the knowledge through attendance of conferences and workshops. Furthermore, in the statistics on integrating RES in designs, 34 respondents (32%) have introduced RES in their designs, while 71 (68%) respondents have never. From this, it is very clear that most consultant architects across the study areas have not introduced or integrated RES into their designs, which is very worrisome. This is shown in Figure 2 below:

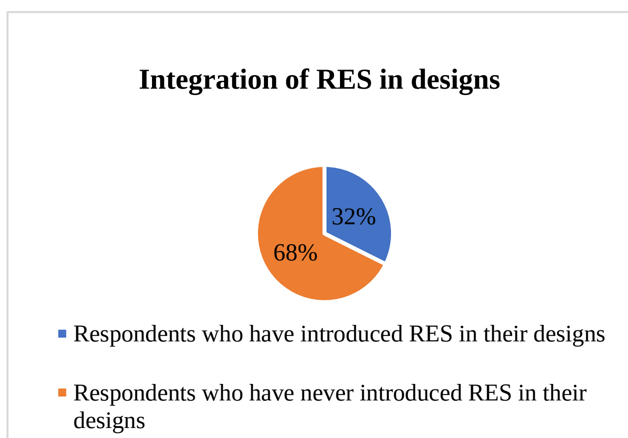

Fig. 2 Respondents' integration of RES

On integrating RES in building construction activities on site, 21 respondents (20%) claimed they have, while 84 respondents (80%) have not, as shown in Figure 3 below.

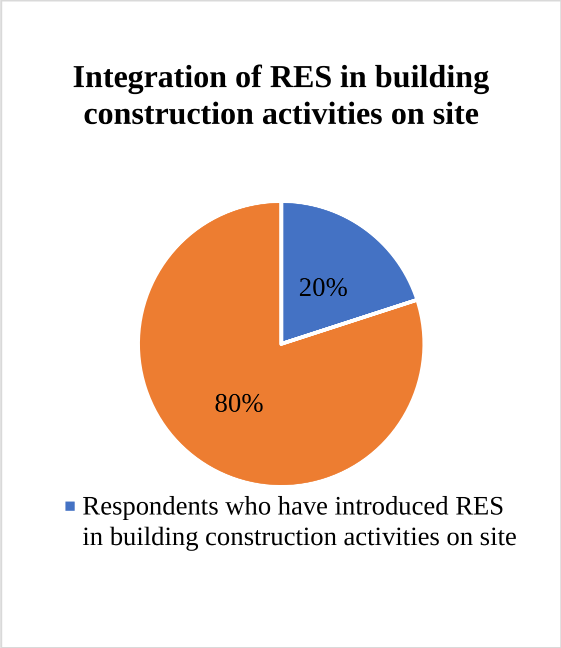

Fig. 3 Respondents' integration of RES in construction

This implies, too, that most building contractors and consultants in the study areas have not started constructing buildings with RES provisions, except for a few of them that have carried out construction of buildings with RES.

Similarly, on the type of building RES have been integrated, 78 respondents (74%) agreed it was in old/existing buildings, while 27 respondents (26%) have theirs in new buildings, as shown below in Figure 4.

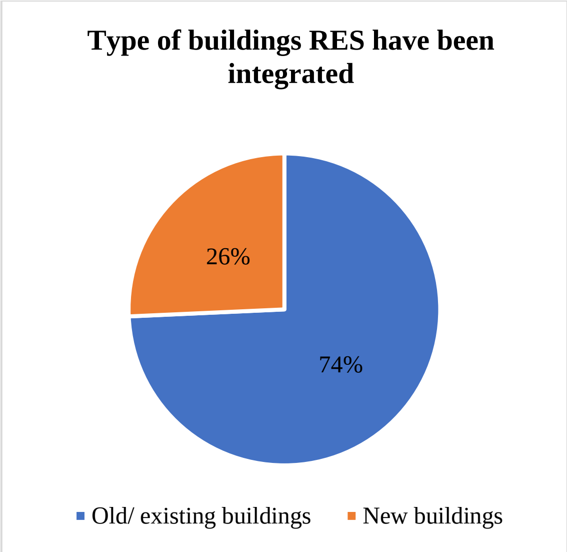

Fig. 4 Type of buildings RES have been integrated

On the nature of the building in which RES was integrated, the results show that 88 (84%) respondents claimed it was a non-smart building, while 17 respondents (16%) were on smart buildings. This also indicates that a larger percentage of buildings in the study areas are non-smart buildings. This is shown in Figure 5 below.

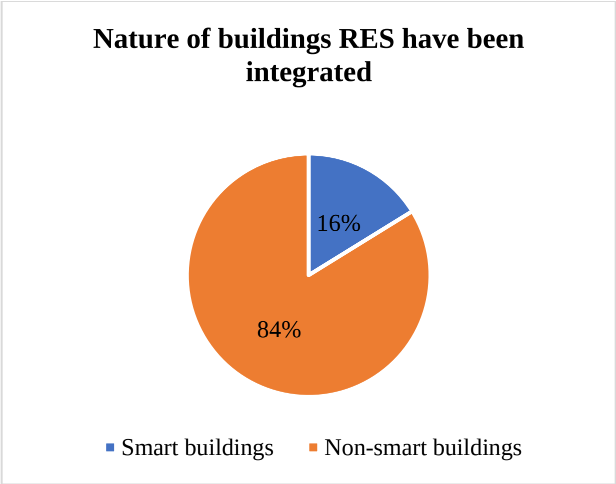

Fig. 5 Nature of buildings RES have been integrated

However, knowledge of smart buildings indicates that all 105 respondents have the knowledge, but only 12 respondents (11.4%) have designed smart buildings, while 93 respondents (88.6%) have not. This is shown in Figure 6 below.

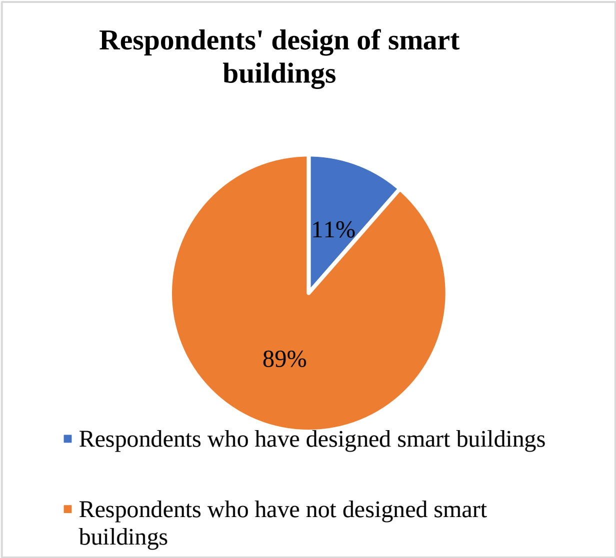

Fig. 6 Respondents' design of smart buildings

On whether RES should be enforced as part of building plan approval requirements by relevant government agencies, 42 respondents (40%) said YES, 27 respondents (25.7%) said NO, while 36 respondents (34.3%) said it should be optional, as indicated in Figure 7.

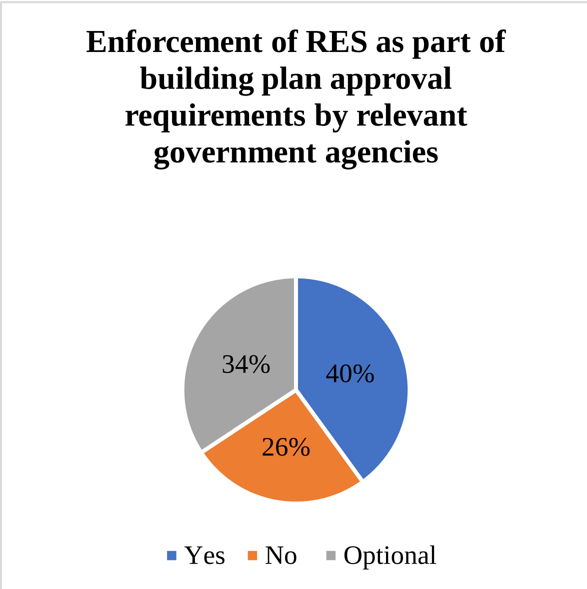

Fig. 7 Respondents' response to the enforcement of RES as part of building plan approval requirements by relevant government agencies

4.1. Analysis of Interviews

The interview featured 20 persons, all of whom were selected by expert and purposive sampling methods. The interview questions were basically on RES smart buildings and the integration of RES in design and construction. The interview responses were collated, and analyses were carried out using content analysis with reoccurring issues selected as themes and presented thus:

4.2. Cost of building construction

There is the assertion that RES integration into either old or new buildings will increase the cost of construction, which the clients are afraid of and want to avoid due to the economic downturn currently being experienced in most developing nations of the world.

4.3. Type of RES Integrated in Buildings

Almost all the respondents agreed that the RES known to them, which they have also integrated into buildings, is active solar energy. This is seen in some buildings with solar panels installed on roofs of buildings to produce electricity. The system consists of mechanical and electronic elements that help to convert the solar radiation collected and transform the solar radiation into solar thermal systems and photovoltaic (PV) systems, which produce electrical energy. This indicates that active solar energy is well-known and popular among the respondents.

4.4. Clients Awareness/Taste

Awareness level is still very low regarding the clients and public who commissioned the architects to design and build for them. The architects agreed that though they have the knowledge, they cannot design or construct outside the clients' brief.

4.5. Government Policy

Respondents decried using foreign contractors and consultants to design and construct buildings with RES and smart buildings. The respondents were unanimous in the opinion that the major clients (government and a few organizations) that would have promoted the use of RES and smart building constructions patronize foreign building construction firms and consultants as expatriates to the detriment of indigenous architects and consultants.

5. Conclusion

Comfort of buildings for occupants brings about sustainable energy facilitated by the ability to easily combine and switch from one renewable energy source to another. Nevertheless, it is also important to emphasize that existing buildings in large numbers across the study areas and developing countries, in general, can be retrofitted to be smart through integrating some ICT software embedded in the buildings that were not originally built at the initial construction time.

Most importantly, is the fact that both smart and non-smart buildings can have renewable energy sources integrated into them through various technologies for energy efficiency for the benefit of building users and the environment.

However, this study has shown that many people in this part of the world have not embraced RES integration in either old or new buildings for whatever reasons.

The study, therefore, recommends that efforts should be geared towards educating the people to increase their awareness of the benefits of RES as an energy-efficient measure for sustainable housing construction. Thus, this will help people to know more about the other types of RES other than solar energy.

In addition, the government should be advised to look inward by patronizing her indigenous architects, consultants, and building contractors in the design and construction of modern buildings, both smart and with RES, to promote the growth and development of local content as it is being proclaimed by government in recent times.

The buildings of today should be planned and designed to be energy efficient using the various renewable energy sources described in this study. However, it is required that, as much as possible, the combination of more than one renewable energy source should be employed for effectiveness. The concept of smart buildings, when planned along renewable energy sources, enhances the interior.

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