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# Households' Energy Efficiency Practices in a Bereft Power Supply Economy of Nigeria

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## Abstract

The study focuses on attaining energy efficiency practices in the housing sector of the Nigerian economy. This is essentially necessary in order to reduce the energy demand on the central power supply of the nation and as well attain energy security. Nigeria as a nation is endowed with enormous energy resources, yet beleaguered with chronic energy crisis because of inadequate power supply to the citizens. The overall goal is to seek ways of improving the energy use situation of the country; and the objectives are to determine the prevailing levels of energy efficiency practices in housing design; appliances in use; and occupant behavior. The findings reveal a low level of energy efficiency consideration in housing design practice; a very low level of appliances efficiency; and a much low level of energy efficiency practice by the housing occupants. Thus, a strategic scheme of energy efficiency practices to be realized by the government and housing stakeholders is proffered for the housing sector of Nigeria.

**Keywords:** households, energy efficiency practice, bereft power supply, renewable energy resources, national economy, Nigeria

## 1. Introduction

The power drive of any nation is the state of energy supply which is the thrust of its national development in the many facets of its economy. The power supply should be adequate and sustainable in order to achieve a progressive and sustainable national development. In most situations, inadequate utilization of reliable and sustainable energy resources is the bane to the attainment of a sustainable power supply. But the case of Nigeria is paradoxical as the abundance of these resources does not portend adequate and reliable power supply.

However, the issue of energy has become one of the most sensitive discourses of our time; and as a result, the world is starting to accept the possibility of change in the patterns of consumption, leading to energy conservation measures and more rational use of existing energy sources to ensure sustainability. This change in perception is no more apparent than in the growing recognition that energy is the key to the development of the global civilization and essential to improving the quality of life beyond the basic activities necessary for survival.

According to United Nations Publication [1] energy use is keenly related to economic development, poverty reduction and the provision of vital services.

Nevertheless, its production, distribution and consumption can have adverse effects on global environment at either the local or regional levels. Consequent upon this realization, the contemporary society is faced with the challenges of developing technologies to improve access to modern energy services, increase energy efficiency and reduce air pollution; and initiating policies on energy consumption to meet future global energy demands with renewable resources. Thus, the need to adopt all possible measures to ensure that buildings use of energy is minimal i.e. Heating, Ventilation, Air conditioning and Cooling (HVAC); and Lighting systems are to use methods and products that conserve energy or reduce energy use. Furthermore, it is acknowledged that the technology-based improvement on energy efficiency is significantly influenced by the human social behavior in the utilization of the energy. In fact, well known energy analysts like Gerald Gardner, Lutzenhiser and Paul Stern have opined that a significant boost in a more efficient use of energy resources can be attained through understanding and shaping of human behavior [2].

The energy need of the society is rising daily and the pressure of sustaining this rising demand is becoming critical. Of interest is the energy consumption per household in developing countries which would be growing as income rises and more electrical appliances are installed thereby exerting rising demand on the central power supply. Therefore, to ensure sustainability in the built environment, there is the urgent need for developing countries like Nigeria to imbibe the policy of energy efficiency practice in the National Development Programmes which for now is absent or inactive.

At present, there is a prevailing state of apathy in the energy sector in Nigeria, particularly in the area of housing, with the accompanying energy inefficient households in all parts of the country. Hence, the needs for households' energy use reform through appropriate frameworks of energy efficiency practice necessary for sustainable development. To further understand the implications of the proposed reform, it becomes necessary to elucidate on the tripartite issues arising from household energy use pattern.

## **2. Tripartite issues of households' energy use**

Formidable attempts at addressing issues of efficiency in household energy use should focus on housing design practice (architectural), the efficiency of appliances in use (technology), as well as the housing occupant behavior in the consumption of the energy as thus presented.

### **2.1 The architectural (design) issue**

Housing is the shelter component of human existence, where he lives and sustains his worldly activities. Due to the current trends in civilization, housing design has embodied multiple considerations among which is the energy use pattern. This makes the issue of end-use energy in the built environment and particularly in housing more crucial than ever. Consequently, the responsibility of developing sustainable management scheme toward enhancing the quality of our environment through environmental and energy-conscious planning and design is saddled on the stakeholder personnel involved in the built environment. This obligation arises from the quest for better efficiency in the use of energy and other resources in our built environment. The result of this could be a new scope of architecture and construction, so that this branch of the industry can supply the contribution necessary for sustainable and viable development in reducing energy use, contrary to earlier assumptions that high energy consumption is reminiscent or suggestive of a superior culture. As such, the desired energy

efficiency as relates to buildings should begin with the planning and design through construction to occupancy in consideration of the natural environment. However, the most cost-effective energy reduction in a building usually occurs during the design process which makes it crucial to review some aspects of the architectural technology in terms of design and services/appliances provision in the built environment because without technology and technological advancement, the tools we need to attain efficiency would not be available [3, 42].

## 2.2 The efficiency (technology) issue

Technology in this extent is the application of practical sciences to industry; and the efficiency component is the ratio of useful work done by a device to the energy supplied to it usually expressed as a percentage. Undoubtedly, our living conditions have been rapidly improving over the years since the era of Industrial Revolution in the fourteenth century. This is because suitable technologies and appliances, networks and synergies have been developed, resulting in more and more successes; and advances in all spheres of life being recorded on a continuous basis in the bid to meet our basic needs.

The quest to meet our basic needs in most times has resulted in several other problems impacting on the environment. These associated problems are initiated from the processes of industrial development, urbanization and resources exploitation in the form of environmental pollution and resources depletion; and are usually counter 'cost-effective.' To apprehend these adverse effects is the call for sustainable development which according to Hegger et al. [4] is to be accomplished by *Effectiveness* and *Efficiency* in the management of resources. They argued that the aspect of effectiveness refers to 'doing the right things' at whatever expense while the efficiency outlook which is 'doing things right' induces resources utilization to the barest minimum [42].

Applying efficiency measures can be low-cost or can require a significant investment, and could involve a conservation practice. The accompanying conservation practice refers to change of behavior in order to save energy (and money); e.g. turning off the lights when not in need. Nonetheless, both energy conservation and efficiency measures help one to reduce energy use, energy bills, air pollution and greenhouse gas emissions. Therefore, instituting energy efficiency practice through policies implementation is specifically due for third worlds like Nigeria where the energy demand is currently on the increase as households increase their appliances and equipment with improvement on their economic and social status whilst the national energy and central power supply is in a deplorable condition.

## 2.3 The behavioral (human) issue

The forces behind behavior in action are a complex phenomenon to discern and as such deserve a meticulous attention to unveil. Energy consumption in the home is such activity that requires the appropriate behavior to attain efficient utilization for the desired end-use. On this premise, it is assumed that energy consumption in the housing sector would be significantly influenced by behavior of the people as the basic users of the energy [5].

It is notably argued that the issue of human dimension to energy use cannot be undermined since consumption is still a poorly understood phenomenon, and simply because the variables that determine consumption have not been clearly identified [6]. As such, it becomes indispensable to have an understanding of the social and behavioral issues of our built environment so that many of the benefits of greater technological efficiency that would be attained may not be lost.

Residential building sector in Nigeria is the highest energy consumption sector of the economy, and is associated with energy efficiency problems. It accounts for about 50% or more of annual electricity power consumption [7] with an associated problem of wastage due to lack of energy saving measures in place. At the moment, the energy sector of the nation is undergoing power deficit as it lacks enough/adequate power and energy to sustain her growing economy; prompting the need for increase in power generation and the institution of EE practice [8, 9]. Generally, there is a specific problem of higher energy use demand in the building sector, particularly in the urban areas arising from the rapid growing population, increase in living standards and rising number of apartments. This phenomenon calls for concern with immediate attention.

Apparently, the issue of energy has become a prime agenda of civilized nations of the world in recent times because of the circumstances surrounding its sustainability. Although, it is acknowledged that energy is the key factor to societal development in many spheres of life (economic, social and industrial), its existence is being threatened by the global fear of scarcity and high price. More so, that energy resources exploitation is being considered as one of the main causes of climate change and environmental damage is aggravating the situation. Therefore, the challenge of the sustainability of energy through efficient utilization and adoption of conservation measures to reduce the effects of the currently associated problems becomes paramount. Thus, the study is to proffer ways of improving the peoples' understanding of energy consumption and subsequently enhancing energy efficiency practice in the built environment.

### **3. Theories of energy efficiency and human behavior**

#### **3.1 Energy efficiency in housing**

Energy efficiency is a phenomenal term which is technology focused; but imbibes a behavioral essence in practice [10]. Davidson and Henderson [11] presents energy efficiency as an indicator of the economic value obtained from the consumption of fuel, which when applied to housing, is best assessed in terms of the cost of energy needed to produce a given output or level of service such as a standard of heating. On this premise, they went further to define an energy-efficient house as one which when compared with houses of similar size, costs less to heat, to light, and to operate its essential services.

According to Ahsan [12], well-designed energy-efficient buildings remain the best environment for human habitation while minimizing the cost of energy consumed; with the objective of improving the comfort level of occupants and reduced energy use for heating, cooling and lighting. Janssen [13] considers this improvement in energy efficiency as any action undertaken by a producer or user of energy products, which decreases energy use per unit of output without affecting the level of service provided. This therefore signifies that an energy efficient house has good thermal insulation, efficient heating and lighting systems and probably, well-conditioned occupant behavior.

In the view of Majumdar [14] most environmental problems of today are related to buildings construction, occupancy and demolition due to their excessive consumption of energy and other natural resources; and the associated environmental pollution. Thus, the built environment is witnessing gross resources depletion and environmental damage arising from the imposed pressure by accelerated urbanization and the sought 'energy-intensive' solutions to our basic needs. Alleviating these problems require that we design and develop future buildings on a sound concepts

of energy efficiency and sustainability. This could be accomplished by applying environmental/climate conscious design principles together with other multifarious approaches like the use of materials with low embodied energy, effective use of renewable energy resources, conditioning occupant behavior, etc.

It is pertinent to understand that more than one third of the world's energy is used in buildings; and a majority of that energy is particularly used in houses and apartments. One can therefore help humanity and save a lot of money by building a super-efficient house which uses only 10–30% as much energy as a house of similar size that is built to contemporary standards [15].

The potential benefits of energy efficient designs are immense. Of principal importance are the Europe-wide energy benefits following uptake of the climate-sensitive design. In northern Europe, passive solar gain and daylighting reduce the need for heating and lighting energy. In the United Kingdom, studies on passive solar housing have indicated a significant energy save of about 5% from improved site layout. Curiously, enormous energy could be saved by the application of sound concepts of sustainability in new buildings; and applying retrofit options to existing ones with an accompanied reduction in environmental pollution [16, 17].

Therefore, energy systems designed to be efficient, decentralized, and diversified are what national security demands, the public wants, and the market is ready to supply [18]. This can be achieved in the Nigerian households through collective efforts of the government and housing stakeholders in addressing the identified study issues.

### *3.1.1 Environmental and economic benefits in the delivery of energy efficiency*

The cumulative (environmental and economic) benefit in delivering energy efficient buildings is in the accomplishment of reduced running costs, reduced environmental impact, improved ambient conditions and increased equipment life.

Therefore, creating buildings that use less energy not only reduces and stabilizes costs, but also reduces environmental impact. It is a fact that the knowledge and technologies to reduce energy use in our homes and workplaces without compromising comfort and esthetics is available now. But the prevailing situation is that the society is not taking full advantage of these advances because buildings are typically designed and operated without considering all the environmental impacts. These buildings can improve the health, comfort and productivity of occupants in measurable ways [19].

According to Littlefair et al. [16] cities are growing rapidly, and are increasingly polluted and have become uncomfortable places to be. Industrialization, the concentrated activities of dwellers and the rapid increase in motor traffic are the main contributors to increase in energy consumption and air pollution, and deteriorating environment and climatic quality. They contend that, the urban heat island effect generated can cause temperature differences of up to 5–15°C between a European city center and its surrounding, resulting in increase demand for cooling energy; and the increase in temperature may also exacerbate pollution by accelerating the production of photochemical smog.

Consequently, new developments are unfolding the world over in the uptake of the climate-sensitive, energy efficient designs to reduce excessive energy demands on the economy, and also to counter the increasing adverse effects of these developments by maximizing use of renewable energy sources and reducing energy dependence on fossil fuel, thereby minimizing carbon dioxide emission into the environment. In addition, the housing sector in Nigeria can achieve reduction in energy demand by directing effort on occupant behavior in household energy use.

According to Horsley et al. [20], one of the most significant environmental impacts of buildings occurs through the consumption of energy during their operational lives. And that, the effective management of the design process is pivotal in the delivery of buildings with improved efficiency but, unfortunately, the monitoring of energy performance is not currently a typical part of the construction design process; which in fact, is vital to be addressed.

In due consideration of energy efficiency standards for the society, it should be noted that the built environment has significant inertia, and in order to deliver a significant improvement in energy performance for the built sector, both new and existing buildings must be considered for assessment. Consequently, a culture of energy conservation will have to be fostered among all members of the project delivery chain, from clients to architects and contractors to building users before any significant improvements in performance will be noted. With this, the building industry will be able to deliver greater, more durable buildings with reduced whole life costs. It will also make a very significant contribution to reducing CO<sub>2</sub> emissions as a step toward a more environmentally acceptable way of living [20].

Although environmental reasons are strong, in practice cost savings usually drive energy efficiency. Therefore, energy efficiency measures should generally be considered in their order of economic payback, complexity and ease of application. Measures according to CIBSE guide [21] fall into three broad types:

- no-cost/low-cost requiring no investment appraisal,
- medium cost requiring only a simple payback calculation, and
- high capital cost measures requiring detailed design and a full investment appraisal.

It is however arguable that energy-efficient buildings do not actually cost more to establish than conventional buildings do. This is because the application of ‘sustainability’ and ‘energy efficiency’ concepts does present opportunities to offset or minimize costs of avoidable mechanical systems and services [21].

### *3.1.2 Energy efficiency design principles*

Energy efficient building designs are credited partly to the adoption of climate and environmentally-conscious design principles by the creation of reduced energy loads in buildings. According to Majumdar [14], architects can achieve energy efficiency in building designs by studying the macro- and micro-climate of the site, applying bioclimatic architectural principles to combat the adverse conditions, and taking advantage of the desirable conditions. Subsequently, some common design elements have been identified to directly or indirectly affect the thermal comfort and visual conditions of building occupants, and thereby the energy consumption of buildings. Some of these elements according to literatures [12, 14, 22–24] as indicated below are the basis for the design of the ‘housing evaluation form’ (the checklist) for the case study:

- a. *Planning/design consideration* [the building site, building typology/planform, building orientation, functional distribution (room orientation), landscaping, and the design process]
- b. *Building envelope* [external walls and finishes, fenestrations and shading, thermal insulation, roof]

c. *Other services* [building materials, electrical and lighting installation, air conditioning installation]

### 3.2 Human behavior and energy use in the households; a theoretical framework

The third research issue (others being design and technology) is the behavioral issue which addresses the human dimension to energy use in the households. Thus, the theoretical background here presented provides the theoretical framework for the research survey (a quantitative approach) on household energy use analysis.

In fact, the idea of the 'behavioral approach' to energy use analysis according to Wortmann and Schuster [25] evolved from the apparently insufficient contributions of economy- or technology-based models to advise politicians on how to initiate developments toward energy conservation. The compelling scenario has made consumption a poorly understood phenomenon, as the variables that determine consumption have not been clearly defined [6]. Much technology-based improvements on energy efficiency have been accomplished but often dampened by the inappropriate human social behavior in the utilization of the energy [26]. In this regard, Diez-Nicolas [9, 27] present 'social ecosystem' and 'center periphery' theories to explain human attitudes and behaviors as relates to his actions. The former elucidates on attitudes as 'instrumental collective responses that a population develops under a given state of arts (technology) in order to achieve the best adaption to the environment;' while the latter unfolds that new attitudes are first developed at the center of the society before spreading toward the social periphery. He further argues that the concern for the built environment is more in developed societies; and among individuals of higher social status that are better informed [28].

Williams et al. [29] contend on the need to focus more on the behavior of the consumer in our attempt to conserve or utilize energy efficiently. Thus, attention should be given to how man uses his environment and how he metamorphoses in response to economic forces around him. Wilhite et al. [30] argue that energy use in the home is related to physical and structural variables like the dwelling's envelop, size, and appliances; and also to occupant behavior. But the behavior component is frequently underestimated or ignored in demand-side management (DSM) programs partly because of its complexity. The argument goes further to stress that human behavior is influenced by some interacting variables of socio-cultural traditions (attitudes, esthetic norms, comfort, symbols); economic considerations and *knowledge levels*. Based on this understanding, Beeldmann and Bais [31] have acknowledged the importance of knowledge about human behavior which they say is essential for successful energy savings policy.

In addition, Ehrhardt-Martinez [2] presents an argument that *effective policies* can make inconvenient behaviors convenient, and can as well make expensive behaviors less expensive. Instituting effective policies can remove structural, institutional, and legal barriers to behavioral change. In fact, understanding and shaping behaviors can provide a significant boost in the more efficient use of all energy resources. Nonetheless, the inefficient pattern of human behavior [32, 33] represents a large, untapped reserve that could potentially reduce current levels of energy consumption by 20–25%; and do so in ways that save money [2].

According to Golubchikov [34], the housing sector is one of the priority areas with regard to energy efficiency not only because it consumes a great amount of energy (up to 50% of total consumption in individual European states in recent years), but also because it remains *remarkably wasteful*. This is because the housing sector still and actually maintains outdated technology with inefficient practices,

despite the high potential of the current existing technology to drastically reduce energy use in housing.

As a remedial measure, Ehrhardt-Martinez [2] has suggested that efforts to understand human behavior must start with the recognition that people are motivated to action as a result of both economic and non-economic factors. On this basis, it becomes necessary to have a strategic scheme (as proffered in this study) that would identify the individual as a rational economic and socio-political actor making rational choices regarding the adoption of more or less efficient technologies and behaviors. Meanwhile, Beeldmann and Bais [31] have identified two kinds of human behavior with respect to energy use;

- i. Investment behavior; which is related to the process of buying new appliances, equipment, goods etc., with a probable consideration of product efficiency. On this platform, questions that relate to factors that influence the buying of a product and why customers buy specific products are answered. This is usually related to moments of purchase. This can be influenced, monitored and measured.
- ii. User behavior; which relates to the actual use of products after the moment they are bought. It is concerned with questions of how often a product is used and in what way it is used. User behavior is important for energy consumption during the lifetime of the appliance. Influencing user behavior can have very large effects on energy savings, but of a fact, it is more difficult to influence, monitor and measure.

In another dimension, Sanquist [35] suggests ‘curtailment’ and ‘efficiency’ actions as the two principal types of actions necessary for energy consumption reduction. The former involves actual reduction in the frequency or duration of specific activities, such as single-car commuting; while the latter involves one-time actions, such as installing improved home insulation or purchasing new-model, energy efficient appliances. On the whole, curtailment involves repeated activity that produces relatively smaller energy reductions, while one-time efficiency actions involve greater expense that produce relatively larger energy reductions. Although, applying any of these dimensions, either investment/user behaviors or curtailment/efficiency actions, depends on the level of awareness of the individual—particularly on the knowledge of the implications/benefits of the actions to be undertaken.

In all, these theories have formed the basis for the derivation of the study variables (dependent—efficiency practice/practical behavior, and independents—education, awareness, and social status) and the drafting of the questionnaires on household energy use survey. Also, the energy use framework to be proffered is in consideration of these theoretical factors and the actual results of the survey, the interview and the case study.

To understand the situation better, a theoretical analysis of how attitude can be responsible for personal behavior becomes necessary.

### *3.2.1 Attitude and behavior; a theoretical analysis*

In household energy use analysis, it is believed that attitude shapes behavior, but it is behavior that ultimately affects energy use [10]. On this background, social scientists see attitude as a predictor for behavior. In the past, they viewed attitude as individual mental process that determines a person’s actual and potential responses; and as such, developed theories that suggested “Attitudes could explain human

actions.” In 1929, Thurstone, L.L. developed methods for measuring attitudes using interval scales; while in 1947, Doob adopted the idea of Thurstone that attitude is not directly related to behavior but it can tell us something about the overall pattern of behavior [36].

Consequent upon these developments, Ajzen and Fishbein [36] assume that individuals are usually quite rational and make systematic use of information available to them. And that people consider the implications of their actions before they decide to engage or not to engage in a given behavior. This proposition was referred to as the ‘theory of reasoned action.’ Though, it was later realized that this theory was inadequate and had several limitations [37] particularly with people who have little or feel they have little power over their behaviors and attitudes. The sequence of this development led from an earlier theory of reasoned action to the ‘theory of planned behavior.’

In reality, humans can exhibit total control in certain behaviors if there are no attached constraints of any sort, but in situations where adopting a behavior requires the possession of a resource or skill which is absent in the individual; then a total lack of control is evident. On that account, planned behavior may embody control factors, which according to Ajzen and Fishbein [36] are either internal or external. Internal factors like skills, abilities, information, emotions such as stress etc.; and external factors may include such things as situation or environmental factors. Thus, the postulations that the individual’s intention to perform a behavior are a combination of attitude toward performing the behavior and subjective norm. The subjective norm being the influence of social pressure that is perceived by the individual to perform or not to perform a certain behavior; while the attitude toward the behavior includes; behavioral beliefs, evaluation of behavioral outcome, subjective norm, normative beliefs, and the motivation to comply [36]. In fact, the subjective norm can be influenced to some degree by policy formulation as recommended in the proffered strategic scheme.

Meanwhile, attitudes and subjective norm are measured on scales like the Likert scale, using words or phrases such as like/unlike, good/bad; agree/disagree, satisfactory/unsatisfactory etc.; while the intent to perform a behavior depends on the product of the measures of attitude and subjective norm. Nevertheless, the individuals are more disposed (i.e. intend) to engage in behaviors that are believed to be achievable [38]. Hence, the adoption of this scale (Likert scale) as the factor of measurement of practical behavior (energy efficiency practice) in this research survey.

### **3.3 Energy and the Nigerian economy**

Nigeria is the most populous country in black Africa (over 160 million people) with a very high abundance of natural resources, but with a very poor, weak and slowly improving economy that is heavily dependent on the oil sector. Although, Nigeria is one of the world’s largest oil producing countries, it is currently experiencing rampant energy poverty due largely to the inefficiency of the energy industry to meet the energy demands of its customers. Electrical infrastructure is extremely scarce in Nigeria. Only 40% of Nigerians have access to electricity. Although more than 70% of the population lives in rural areas, only 10% are connected to the grid. Nigeria faces a serious energy crisis due to declining electricity generation from domestic power plants. Power outages are frequent and the power sector operates well below its estimated capacity. Often without prior warning, the average Nigeria firm is without power for over 15 h a week. For this reason in the year 2000, 2400 MW of electricity was being generated by diesel and petrol generating sets (EPIC, 2004 in Odularu and Okonkwo [39]) to run households and

some other sectors of the economy. To ameliorate the situation, the government then claimed to be able to create infrastructure so that up to 85% of the population has electricity by 2010 which at the moment in 2018 remains a farce.

The residential housing sector remains the dominant area of electricity consumption among others like industrial and commercial [7]. In fact, the household energy consumption constitutes a substantial amount of societal energy demand resulting from rapid growing population, increase in living standards and the rising number of apartments.

Though, the electricity demand in the country is growing faster than the country's population, the electricity per capita is one of the lowest in the world [40, 41]. Nigeria per capita power consumption is estimated some time ago at 82 KW when that of South Africa is put at 3793 KW [39].

The utilization of renewable energy sources in Nigeria remains quite limited, although there is a realization that the renewable energy sector must grow in order for the country to develop sustainably. Solar power is being promoted as a method to improve electricity service to rural villages not connected to the national grid but in a very slow and negligible pace. There are renewed efforts by NGOs and the Centre for Renewable Energy Development in Nigeria (CREDN), urging the government to boost the use of renewable energy sources to diversify the country's energy consumption from petroleum.

Solar photovoltaic (PV) is an attractive method to try because it offers modularity and requires no fuel, but very basic and relatively simple operation and maintenance. It has long lifetimes with very little performance degradation which makes it much more suitable for rural environments and private individuals' exploration; yet this potential remains highly untapped in Nigeria.

#### **4. Approaches and methods**

The study is in three parts to address the objectives based on the issues of housing design, appliances in use, and human behavior in the utilization of household energy using the mixed-method approach.

On the issue of human behavior in household energy use, a theoretical background has provided the dependent variable of human behavior (this time; level of efficiency practice) with the independent variables of education, awareness, and social status of the individuals as the basic parameters which are subjected to a quantitative study approach. Here, the study identifies the households' respondent group as the target population which is defined as "all heads/representatives (adults) of household units (male or female) resident in Bauchi-Nigeria, and living in formal residential housing typology of flats/apartments, and not in traditional settings within the time period of this research." The sampling procedure for the group (household residents) is 'cluster sampling' of selected residential housing neighborhoods that are part of the target population. This is because the sampling frame for the entire housing units in Bauchi town could not be established. Cluster sampling therefore, allows for random selection of population elements in clusters, in which case, a multistage (i.e. two-stage) or clustering procedure was applied to identify clusters (groups of housing units) and then sampled within them. As a result, six distinct clusters of housing units were established in six different locations of the three geographical districts of Bauchi Local Government Area (i.e. 2 clusters per district) for the survey so as to be able to generalize the outcome of our results on the entire target population.

Both quantitative and qualitative study approaches were adopted in the determination of the energy efficiency consideration in housing design practice in Bauchi

town. For the quantitative approach, the population for this group (professional practice respondents) is defined as “all housing stakeholders (male or female) in the building industry (architects, building service engineers and builders) resident in Bauchi-Nigeria within the time period of this research.” The sampling procedure was purposive (judgmental) and the population was determined from the register of professional associations of the respective disciplines in Bauchi town. The sample size was the entire population due to their meager sizes, and more so that not every member of the population would respond due to some unavoidable factors of availability etc., and in some cases, outright refusal to participate in the survey. However, the qualitative approach was through case study of selected housing units (12 nos.) from the created study clusters (housing neighborhoods) within Bauchi town using a checklist (evaluation form) of energy efficiency design variables as derived from literature. Also, an interview strategy of selected and validly determined housing stakeholders (professionals in practice) in Bauchi town was undertaken using ‘structured—interview questions.’

At another level, the determination of energy efficiency level of households' appliances and lighting is undertaken using a qualitative approach by taking inventory of appliances and lighting in selected housing units (12 nos.) from the study clusters within the three geographical districts (Bauchi, Galanbi and Zungur) of Bauchi (metropolis) LGA. This was achieved by use of checklist based on the approved/certified appliances' energy efficiency rating/labelling as available in literature as well as the building market.

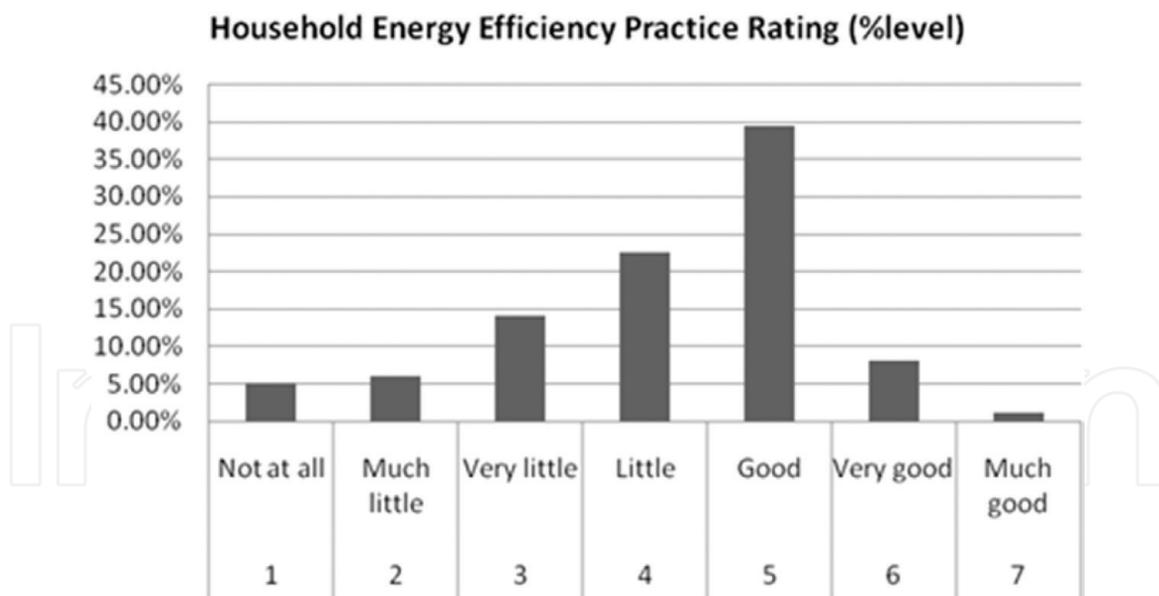
In the overall analysis, the qualitative data was subjected to content analysis while the quantitative data was subjected to both descriptive and inferential statistical analyses to obtain results.

## **5. Results and discussions**

The result of the survey conducted on energy efficiency in the residential neighborhoods of Bauchi, Nigeria elucidates on the issues of design practice, appliances in use and human behavior (focus of study) in EE practices.

On the behavioral aspect of the study, the independent variables of education and awareness; and the social status of residents have provided indicators on the levels of perception and practice of energy efficiency by the people. This indeed will foster opportunities for appropriate policy and regulations. The levels of education, awareness and social status of individuals were quite above average (greater than 50%) and that is a good recipe for energy efficiency, though actually determined by practice. On the contrary, the subsequent result on the EE practice in all the study clusters is quite unimpressive (less than 50%). To have a good record of EE practice, the rating (score) of a majority of households must be in the range of 5–7 on the Thurstone scale and should be well above 50%. But in this case, it is just 48.8%. The majority rating in the range of 1–4 on the scale (51.2%) as shown in **Figure 1** indicates gross inefficiency practice. The situation portrays household energy efficiency practice in Bauchi, Nigeria to be on a ‘much low level’ in spite of the higher levels of education and social status. Probable factors like life style and culture; the lack of awareness and absence of appropriate polices on energy issues are responsible for this result.

The correlation analyses of the relationship of the dependent variable (practical behavior) with the independent variables of education, awareness and social status have indicated varying levels of significance. This implies that these independent variables may have somewhat degree of influence on the practical behavior of the individual in household energy use but may not necessarily determine it as in this case [3, 42].



**Figure 1.**  
Rating of household energy efficiency practice on Thurstone scale.

Data on housing design practice was obtained through survey research using both quantitative and the qualitative approaches. Although, there was a satisfactory level of ‘concern for energy conservation’ from the questionnaires administered and interviews conducted on practitioners, their respective levels of awareness was unimpressive with a dampened effect of EE consideration in design practice. However, the result of the inventory (case study) indicates some varying levels of ‘adequacies’ in design variables (at low level) and ‘inadequacies’ (at high level) in energy efficiency/conservation considerations in design practice. This assessment is done in consideration of the design elements of building typology, building orientation, the building paved area, window size/openability, daylighting, cross ventilation, plan form, functional distribution, shading from trees/structures, placing of windows against solar radiation, plant landscaping, ratio of built form to open spaces, incorporation of water bodies, shading devices, etc. Although, these elements do not seem to have direct influence on energy efficiency of a building, they help to facilitate energy load reduction on buildings. They constitute factors of consideration in climate/environmental conscious design. Thus, the cumulative result of the qualitative study (interview and case study) on the level of energy efficiency consideration in housing design practice is a ‘low level’ one (indicating less than 30% for interview and 54% for case study); and also ‘low level’ for the quantitative study respectively. Several factors are responsible for this low result among which are absence of appropriate policies by the government and the lack of guidelines to regulate practice in the direction of efficiency by the professional bodies.

The third issue of consideration is the energy efficiency level of appliances and lighting in use in the households. An inventory of some selected housing units was undertaken using a checklist based on appliances EE description as ordinary (not efficient), efficient type, and undetermined (no identified efficiency rating/labelling). The lighting appliances were categorized into incandescent and fluorescent; and the fluorescent further grouped as ordinary type and efficient type (CFLs) as available in our society. The result indicates that only 36.7% of lighting points in the surveyed households are energy efficient. Acknowledging the fact that lighting is a fundamental aspect of energy consumption in Nigeria as it is the

dominating appliance in use in all of the households. Therefore, promoting efficiency in lighting alone can lead to immediate enormous gains. In short, lighting and all appliances of cooling, heating, cooking, refrigeration and electronics are in the category of low and very low scores on a 5-point scale respectively. These scores fall below the desirable 'high' to 'very high' scores necessary for the accomplishment of good EE practice in the households' appliances. Hence, the cumulative result indicates a 'very low' level of energy efficiency in household appliances in Bauchi, Nigeria. Furthermore, the finding has also indicated that cooking in Bauchi, typical of Nigeria and other underdeveloped countries (Africa) has both the modern and traditional methods incorporated in a majority of the households. The modern ways include the use of electric cooker, electric stove, gas cooker, micro-wave oven, etc., while the traditional methods include the use of kerosene stove and wood as fuel. The latter is a substitute and an alternative to the former in most cases because of the scarcity and high price of the electric energy and cooking gas required to utilize these appliances. Meanwhile, kerosene and wood are relatively cheap and readily available. As a result, almost all households subscribe to this substitute. However, it is discovered that among the electricity-type appliances only 10% are energy efficient. Therefore, improving the reliability of power supply along with the use of energy efficient appliances would assist to remedy the energy crisis situation in Nigeria.

## **6. The energy challenges and the way forward to attaining household energy efficiency**

Nigeria as a nation has been battling with energy crisis for decades in the form of inadequate power supply and inefficient utilization of the end-use energy. To combat the crisis, persistent efforts are being made by the government, the private sector, NGOs, etc. to ameliorate the situation; yet there still persists the inability to overcome the energy poverty of the nation. This is due to many factors among which is the inadequate funding of energy projects, ardent corruption in administration setting, and the lack of adequate information/know-how on energy matters in terms of sustainability of resources and end-use efficiency. In addition, there are several other barriers identified to particularly hinder the mainstreaming of energy efficient appliances in Nigeria; e.g. policy barrier, legal and regulatory barrier, technical barrier, research and development barrier, etc. [43].

To generally tackle the energy situation there is the need to explore increased penetration of renewables into the energy supply mix [7]; and to particularly expend significant effort in addressing efficiency issues of design, technology and behavior in the housing sector. The energy sector has successively been engulfed with fierce corruption that requires a strong will and logical determination of the government to stamp out through the implementation of a strategic plan.

Furthermore, the global quest for sustainable development in the environmental, social and economic dimensions coupled with the demand to attain energy security has prompted a dire need for a strategic scheme of energy efficiency practice for a bereft energy economy of Nigeria. More so that most nations of the world have instituted energy efficiency programs in this direction, Nigeria with a chronic energy crisis cannot be left behind. Examples are; the energy efficiency strategy of South Africa launched in April, 2004; the US Energy Commission on Behavioral and Social Sciences in 1985 and several individual states programs like the Texas ENERGY STAR Home Programme, Guarantee Home Programme; EU Energy Commission, etc. [42].

## **6.1 Main pillars of the strategic action plan for energy efficiency practice and its attendant obstacles**

There is no gainsaying the fact that the current and persistent energy poverty in Nigeria requires the implementation of a strategic plan or scheme to recover. Hussaini and Abdul Majid [42] have expounded much on this plan in the aspects of policy formulation and implementation, research and development, public information and participation, technology/housing evaluation and monitoring, financial incentives and market introduction, and institutional strategies.

Effective policy formulation and implementation is the beacon of genuine and progressive national development; and this should be fashioned to regulate energy use in the direction of efficiency. This is necessary in order to enforce control in the manner and pattern of energy consumption in general. Emphasis should be laid with details on (i) design practice which is to be safeguarded with professional practice codes; (ii) technology procurement and its marketability; and (iii) the attainment of conditioned human behavior in the utilization of the energy in recognition of Ehrhardt-Martinez [10] postulations that 'effective policies do in fact make inconvenient behaviors convenient; and expensive behaviors less expensive.'

The government and the various stakeholders in the building industry should endeavor to promote research and development in all aspects of the built environment in which end-use energy is operatively involved. Research constitutes the primary tool used in all fields of endeavor to expand the frontiers of knowledge. It is the key factor to societal growth and development. This is because, progress made in every aspect of life depends on the contributions made by systematic research. Therefore, research into architectural design practice should embrace the aspect of energy use in the home which according to Wilhite et al. [30] is related the physical and structural variables of the buildings; and should also include both technology deployment in appliances manufacture and occupant behavior in order to determine which aspect requires behavioral attention or demand side management (DSM) attention in our complex energy use phenomenon. Funding avenues for research and development directed at promoting design and technology innovations in conjunction with occupant behavior on energy efficiency should be identified and adequately established.

The need for adequate and reliable information on energy efficiency matters available to the people, and their comprehensive/inclusive participation in energy efficiency programs for a successful outcome is unequivocal. This is because the power of public information is undaunted, and the effect of people-oriented participation is sublime. On this note, Laitner et al. [33] has suggested the establishment of a 'people-centered initiative' to promote public participation in energy savings in both active and passive ramifications.

Technology as the back bone of societal development is the application of practical sciences to industry and commerce which in the building industry should be monitored and evaluated for performance and possible improvement both in appliances installation and housing design. Technology procurement is necessary for achieving desired innovation, while the monitoring and evaluation exercises are put in place in order to determine the level and pattern of consumption so as to identify the gray areas of needed improvement in attaining concrete energy targets.

Motivation of stakeholders and the public to be actively involved in energy efficiency matters can be achieved through financial incentives and market introduction. Indeed, Laitner et al. [33] have argued that great efficiency gains can be achieved through financial incentives and motivation to the public in the form of subsidies on energy-efficient products and services. However, the introduction of market transformation is to arouse the supply of energy-efficient products and

services by technology procurement and should be provided in the arena of all-inclusive and all-embracing residential energy services.

The vision and missions of a culture of efficiency practice in the housing sector can be accomplished through organizational strategic planning. Establishing institutional strategies is the realm of the professional stakeholders and should effectively steer the practice procedure in the direction of efficiency with ethical connotations. Continuous Practice Development (CPD) programs should be fervently entrenched in professional practice so that stakeholder practitioners are adequately trained to always imbibe efficiency practices and to be kept abreast in new trends and developments.

## **6.2 The obstacles**

Hussaini and Abdul Majid [42] have lucidly outlined the hitches in our household energy-use phenomenon that are likely to be responsible for the absence or lack of structures in the main features of the strategic scheme as follows:

1. the lack of comprehensive National Energy Policy resulting from certain barriers of policy, legal and regulatory origin;
2. financial constraints due to low budgetary measures on energy efficiency matters;
3. technical incapability due to lack of adequate experts in the area of energy efficiency;
4. the low level of public awareness due to “lack of the willingness” of the government and housing stakeholders to adequately mobilize and sensitize the public toward energy efficiency; and
5. the persistent widespread corruption of the Nigerian public in all aspects of the society (private and public) where all that matter is the immediate material gain out of little or no significant effort.

Regardless of the above obstacles, a strong and keen determination of the government and all parties concerned to implement the strategic plan for EE practice as indicated is a good recipe to overcoming any impediments on our energy efficiency path.

## **7. Recommendations**

The under-given recommendations have been offered in recognition of the tripartite issues and the eventual research findings.

The first recommendation is to strictly adhere to the strategic scheme of EE practice as specified in order to realize the goal and objectives.

However, the primary concern in addressing the issues should be focused on energy saving, including all the possible methods to accomplishing it; and should form the policy hallmark at all levels of decision making. Thus, the idea of energy saving should be promoted throughout all structures of the society including the family and at all levels in schools and educational systems. This should include the public and the professional communities (stakeholders in housing provision), explaining the main challenges and what can be done to save energy and reduce greenhouse effect. This may require the provision of energy manuals to housing residents accompanied by periodic household energy use monitoring exercise.

In summary, the study suggests a three-way (tripartite) practical approach to achieving energy-efficient households, and as well improving on energy efficiency practice based on some researchers postulations (as derived from literatures) in the aspects of building design (architectural), services/appliances design (technology) and conditioning occupant behavior (behavioral).

### **7.1 Improving on the architectural (design) dimension**

The issue of energy efficiency practice in residential buildings cannot be ignored, and should be accomplished by the following measures;

- Reduce energy consumption by improvement on building design and thermal isolation according to modern climate control principles.
- Qualified energy audit of buildings should be carried out before executing energy saving measures.
- Stimulating research, development and demonstration of modern technologies/design techniques and their use within the context of domestic energy resources and local conditions.

### **7.2 Improving on the technology (appliances/services efficiency) dimension**

- Reduce energy consumption by substitution of electric heating by other energy sources.
- Reduction of energy consumption of air conditioning systems and lighting. Lighting in particular takes up to 20% of total electric energy produced worldwide.
- Reduction of energy consumption of electronic equipment in stand-by mode.
- Development of windows with heat transfer coefficient less than  $2 \text{ W/m}^2 \text{ K}$  and the development of special glasses with increased reflection and selective absorption and emission abilities.
- Consideration of the passive energy design strategies for natural lighting (daylight) and natural ventilation; and the development of measurement techniques for evaluating the energy efficiency of buildings.
- Development of ventilation and air conditioning systems based on heat and moisture recuperation is particularly important.
- Setting energy efficiency standards by the controlling authority by imposing minimum level of efficiency though manufacturers are not usually disposed to it because of administrative and adaptation costs.
- Stimulating the supply of efficient products by technology procurement, i.e. offering incentives to manufacturers to take part in development and diffusion of highly energy efficient products.
- Introducing DSM (demand-side-management) at the appropriate levels where environmental condition is sufficient as a control.

### **7.3 Improving on the behavioral (human) dimension**

- Saving of energy in households by stimulation and support measures which include, introducing new methods of energy consumption management, educating people through the electronic and print media; and giving financial incentives in the form of subsidies in the price of energy efficient materials.
- Stimulate consumer choice by labeling of appliances to enable consumers compare efficiency of certain products; and showing annual power consumption which translates into running costs.

## **8. Conclusion**

It is evident that Nigeria is witnessing increased population growth which is associated with increased energy demand and consumption in all facets of the economy. The increased energy demand and the prevailing inefficient pattern of consumption coupled with the associated environmental issues in energy delivery system has been a cause for concern. Therefore, the current call for energy efficiency practice is not out of place, and could play a valuable role in guiding the society in the choice of the energy path to follow.

The proposed schematic plans or strategy for the realization of energy efficiency practice is justified because the residential building sector for now is energy-inefficient and also the largest energy demand sector of the Nigerian economy. This is provided as a wake-up call to the government, the housing stakeholders as well as the public for the attainment of energy efficiency. It prescribes the application of sound concepts of sustainability and energy efficiency through the deployment of environmental/climate-sensitive design principles together with multifarious approaches like the use of materials with low embodied energy, effective use of renewable energy resources and conditioning occupant behavior. It is also essential to disabuse the mindset that energy-efficient building costs much more to establish than a conventional building. It does in fact offsets avoidable costs due to installation of energy-intensive mechanical systems and services.

Interestingly, the implementation of the strategic scheme would eventually lead to sustainable environments of a free or declined environmental damage/pollution where energy conservation is utmost, producing healthier and more viable productive settings.

## **Declaration**

This is to acknowledge the fact that this work constitutes majorly on the excerpts from the following works by the same author [3, 42].

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