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Energy Audit Of Selected Public Buildings In Abuja

Energy Commission of Nigeria
Japan International Cooperation Agency

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Abbreviations and Acronyms

AC	Air Conditioner
AEDC	Abuja Electricity Distribution Company
AVR	Automatic Voltage Regulator
AV Con	Average Consumption
CCTV	Closed Circuit Television
CEO	Chief Executive Officer
CFLs	Compact Fluorescent Lamps
CO_2	Carbon IV Oxide
CPC	Consumers Protection Council
CPU	Central Processing Units
DG	Director General
ECN	Energy Commission of Nigeria
ECOWAS	Economic Community of West African States
EUAC	Equivalent Uniform Annual Costs
FCT	Federal Capital Territory
FGD	Focused Group Discussion
FGN	Federal Government of Nigeria
FMST	Federal Ministry of Science and Technology
GEF	Global Environment Facility
GIZ	German Agency for International Cooperation
Hp	Horsepower
HVAC	Heating, Ventilating and Air Conditioning
ICLs	Incandescent Lamps
IEA	International Energy Agency
IPEEC	International Partnership for Energy Efficiency and Cooperation
JICA	Japan International Cooperation Agency
KVA	Kilovolt Ampere
kW	Kilowatt
kWh	Kilowatt Hour
LCCA	Life Cycle Cost Analysis
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LFLs	Linear Fluorescent Lamps
MEPS	Minimum Energy Performance Standards
MW	Megawatts
MYTO	Multi-Year Tariff Order
NCEEC	National Centre for Energy Efficiency and Conservation
NEP	National Energy Policy
NERC	Nigerian Electricity Regulatory Commission
NESP	Nigeria Energy Support Programme
NIMET	Nigerian Meteorological Agency
OM&R	Operation, Maintenance and Repair
PAS	Public Address System
PDA	Personal Digital Assistant
PV	Photovoltaic
PVC	Polyvinyl Chloride
REA	Rural Electrification Agency
SI	International System of Units
TV	Television
UN	United Nations
UNDP	United Nations Development Programme
UPS	Uninterruptible Power Supply
V	Volt
W	Watt
Wh	Watt hour

Foreword

It is my pleasure to introduce the Report of Energy Audit of Public Buildings to the reading public. It is a comprehensive outcome of the first-ever detailed energy audit of three (3) public buildings in Abuja, namely, the Energy Commission of Nigeria (ECN); the Rural Electrification Agency (REA) and the Consumer Protection Council (CPC).

The energy audits were conducted by a multi-stakeholder national energy audit team in November/December, 2016; coordinated by the Energy Commission of Nigeria with the support of the Japan International Cooperation Agency (JICA) under the auspices of "JICA Follow-up Cooperation for Training on Policy Planning for Energy Efficiency and Conservation in Nigeria" which can simply be referred to as the "Follow-up Cooperation Programme".

Overall objective of the Follow-up Cooperation Programme is to develop strategic plan for reducing energy consumption in public buildings by utilizing energy saving measures that are identified through energy audits; and elicit information that will serve as a guide to strengthen policy measures for the promotion and adoption of energy efficiency and conservation in Nigeria.

The report contains the outcomes of the general assessment of all energy consuming appliances that are being used in the three (3) public buildings with a note on their current efficiencies, as well as recommendations on either replacement or modifications for better efficiency. The assessed attitudes and behaviours of the office users in relation to energy utilization in the buildings were also documented with attached best practices recommended for better comfort and energy conservation.

Also, the publication reports the findings of an assessment undertaken by the energy audit team on the possibility of integrating renewable energy technologies (solar PV) as an alternative source of electricity and the bioclimatic conditions (BCD) of the buildings. Detailed designs and estimated costs of solar PV are provided and compared against the current costs of diesel for fuelling of generators in the buildings, thereby determining the cost recovery period if the solar PV is adopted. Recommendations are also made on how to maximize the exploitations of the bioclimatic conditions to reduce dependence on generated energy.

I am glad that our vision for energy efficiency and conservation to feature as one of the critical factors of the national energy mix has started manifesting. The ECN on behalf of the Federal Government of Nigeria deeply appreciates the financial contribution of JICA to the Programme. I am optimistic that the study will guide more comprehensive studies in the nearest future that will lead to establishment of evidence based baseline data for effective policy planning of sustainable energy management in public buildings in Nigeria.

Prof. Eli Jidere Bala, FNSE, FAEng

Director-General/CEO, Energy Commission of Nigeria

Preface

The technical report of Energy Audit of Public Buildings in Abuja is undoubtedly a significant milestone in the development of evidence-based baseline data that would serve as reference guide in determining the potentials and benefits of energy efficiency and conservation (EE&C) in public buildings in Nigeria. The effort to promote and popularize the potentials of EE&C in Nigeria can only have logical acceptance when it is presented with factual data and not mere extrapolation of other countries' experiences. In the course of achieving this objective, the Energy Commission of Nigeria is collaborating with the Japan International Cooperation Agency (JICA) in follow-up cooperation training on policy planning for EE&C in Nigeria. Consequently, a multi-stakeholder Energy Audit Team was constituted to conduct a pilot energy audit of three (3) buildings in November/December, 2016, namely the Energy Commission of Nigeria (ECN), the Consumers Protection Council (CPC) and the Rural Electrification Agency (REA).

The energy audit team monitored and measured the general energy consumption patterns of the buildings and specific equipment/appliances; the occupants' attitude to energy utilization as well as the possibility of integrating renewable energy (solar-PV) and bioclimatic conditions (BCD) into existing buildings were also assessed. The thirty one (31) member energy audit team was drawn from the three (3) agencies mentioned above. They were constituted into groups and sub-groups to handle the different aspects of the energy audits. The team members were earlier trained and coached on handling of energy audit equipment and methodologies of energy audit.

The Report of the Energy Audit in Public Buildings in Abuja consists of four (4) chapters. Chapter 1, the Introduction consists of background, statement of the problem, justification and objectives; chapter 2, the Methodology contains the scope (and design), method of data collection, description of instruments, method of analysis and limitation of the study; Results and Discussions are found in chapter 3 and were presented separately under each of the building studied; while the key findings, policy directions recommendation and conclusion are in chapter 4.

It is noteworthy that the report covered only three (3) public buildings in Abuja, hardly a competent baseline data for all public buildings in Nigeria. But it is surely a starting point which could serve as reference guide to be built upon and consolidated in future.

The appendices pages contains list of energy audit equipment used in the study, tables and figures obtained from the data analysis. The Abbreviations and Definition of terms are placed at the opening pages of the report for easy references.

Finally, on behalf of all the team members, I wish to express our profound gratitude to the Director General/CEO, Energy Commission of Nigeria Prof. Eli Jidere Bala, FNSE, FAEng, for the opportunity to serve on the energy audit team. Also, we extend our appreciation to the JICA for its support and all the organizations that honoured our request for their premises to be audited as well as the participation of their staff in the team. I equally salute the erudition and patience of the energy audit team members and the consultants for successfully conducting the energy audit and developing the report.

Dr. (Mrs.) Roseline Kela
Director, EMTMD Department
& Project Coordinator

Acknowledgement

The Project Team wishes to express its appreciations to certain organizations and individuals for their supports and contributions towards the successful implementation of the JICA Follow-Up Cooperation Training Programme on Policy Planning for Energy Efficiency and Conservation of Public Buildings in Nigeria. The Team will like to appreciate the Director General, Energy Commission of Nigeria, Prof. Eli Jidere Bala for his enormous support towards the successful completion of the project. Our gratitude also goes to the Japan International Cooperation Agency Nigeria Office (JICA) for its continuous support to the Commission in developing its manpower capacity through different training programmes. The Follow-up Cooperation is outcome of our collaboration; we remain grateful and appreciative of the gesture from the good people of Japan, Land of the Rising Sun. The goodwill of Mr. Hirotaka Nakamura, the Chief Representative, Mr. Shikano Masaaki, Project Advisor, and Mr. Agidani Gabriel, In-House Consultant: Infrastructure Development, JICA Nigeria Office shall long remain in our memory.

The Commission is likewise thankful the Mrs. Dupe Catherine Atoki, the Director General/CEO, Consumer Protection Council (CPC); Engr. Moh'd Abubakar Wasaram, Ag. Managing Director/CEO, Rural Electrification Agency (REA) for graciously allowing the Team to conduct the energy audit of their buildings.

The efforts and cooperation of the staff of the three agencies during the exercise are highly valued; specifically, we want to thank Engr. Shamm T. Kolo, Deputy Director, Engr. Anaedobe Ugochukwu, Senior Quality Assurance & Development Officer, Mrs. Vivian Iroegbu, Senior Estate Officer and Mr. Anyaogu Charles, Maintenance Officer all of CPC; Engr. Ahmed Yahaya Alhassan, Principal Manager and Engr. Musa Mohammed, Principal Manager (Electrical), both of REA; Engr. Olu Felix, Deputy Director/Head-Maintenance Unit and all the staff of Maintenance Unit, ECN.

Profound appreciation also goes to Mr. Etiosa Uyigue and Dr. Ohunakin Olayinka Soledayo, the Project Consultants, JICA Nigeria Office for their contributions and guidance. We give due acknowledgement to all the members of the Energy Audit Team for their tremendous efforts and enthusiasm in the implementation of the energy audit, also to some individuals that facilitated the works of the team; to all we say big thank you.

Executive Summary

This is a report of the outcome of collaboration between Energy Commission of Nigeria and the Japan International Cooperation Agency under "JICA Follow-up Cooperation Training on Policy Planning for Energy Efficiency and Conservation in Nigeria". It is a study of energy consumption of some public buildings in Abuja using energy audit, carried out by a multi-stakeholder Energy Audit Team from September, 2016 to January, 2017.

The **Objectives** of the study were primarily: identifying current energy consumption pattern and energy waste streams; identifying low-cost measures of reducing energy consumption; deducing baseline information to develop a National Energy Efficiency Programme; and demonstrating the advantage of integrating all the three components of energy audit studied under this project.

The study monitored the real-time energy consumption of all electrical appliances in the selected public buildings; assessed the attitudes of the users to electrical appliance and energy consumption in general; as well as assessing the need and technical possibility of integration of renewable energy source(s) into the building's energy mix and, the building's compliance to bioclimatic design requirement and opportunities for improvement.

Data was collected using Focus Group Discussions with the maintenance units of the buildings; review of existing literature/documentations such as monthly electricity bills, previous energy audit reports and others; questionnaire administration to the occupants to assess their level of awareness and compliance with issues on energy management; direct measurement of actual energy consumption of the appliances in the building using energy logger devices; measurement of solar irradiation; orientation and inclination of roof-top; building orientation and sun path using Cardinal Compass.

Among the key findings observed and common to all the three buildings was inadequate sizing of back-up generator sets. This has become a source of serious wastage of diesel and also a threat to the environment due to GHG emissions. The wastage is even more when the generator had to be switched on just for a few staff attending to urgent works outside the normal working hours. At CPC building, the ideal generator size could have been 120KW/150kVA; the new generator set of 200kW/250kVA which the organisation uses for an average of 6 hours daily, wastes 4.5 litres of diesel per hour, hence about 6920 litres of diesel (22.5%) or over ₦1.2 million per annum could have been saved had the generator been properly sized; though replacing it will take less than 13 years to pay back.

The energy audit also found out that many ACs in ECN and CPC are not efficient and have out lived their life span indicated by the manufacturers. Ninety five percent (95%) of ACs in the Energy Commission of Nigeria consumes above their nameplate rating; if they were to be replaced with 1.5Hp ACs, a saving of 50,178kWh (₦2.36million) per annum would be achieved representing 32.45% and 12.35% of total annual energy consumption by ACs and the total annual cost of electricity supply to the building respectively. Similarly, of the 26 ACs (out of 60 ACs) observed at CPC, about 50% consumes above their template value; if retrofitted, a saving of about 18,634kWh (about ₦880,000) per annum could have been achieved representing about 30% and 10% of the total annual energy consumption by ACs and the total annual cost of electricity supply to the building respectively. Retrofitting the ACs in both buildings will take less than 7 to 8 years to pay back.

Furthermore, lighting in the buildings was found to be mostly LEDs and CFLs except, CPC that has 544, 18W LFLs and if retrofitted with 5W LEDs can reduce the non-ACs consumption of 13.974kWh (₦658,048) per annum representing 24.7% of non-ACs total annual consumption in the building.

Most of the plug loads surveyed during this study were found to be efficient when compared with the manufacturer's rating; hence, replacing them as means of saving energy has to be tactical and selective. In addition, users' awareness of how the appliances consume energy and how to use them efficiently to conserve energy should be emphasized among the occupants of the buildings; the study discovered that occupants' ignorance and/or neglect of the in-built energy saving mechanisms and procedures in appliances contributes to energy waste stream in public buildings. This also included disregard for operational procedures of some electrical appliances and violation of standards of electrical circuitry and accessories in buildings. For example, the cumulative percentage of the users/occupants in all the three buildings that are in the habit of leaving the ACs on when their office is un-occupied during working hours for an average of 30 minutes weekly wastes 195,309kWh or over ₦9 million per annum.

Other findings were reported delays in attending to repairs, maintenance and replacement of appliances/equipment and various other components such as doors, windows, partitioning etc. It was confirmed that timely management's decision and approval on these matters will save significant amount of energy. For instance, a faulty switch in an office room in ECN that was not fixed promptly wastes 407kWh of electricity or over ₦19,000 annually.

Windows with small area make it impossible to take advantage of day lighting and ventilation. Similarly, poor design and materials of partitioning and, poor-geometry of doors and windows in some buildings surveyed were discovered to be additional energy waste streams, especially for cooling; where lowest achievable temperature is 25^{o}C despite continuous working of AC.

The assessment of integration of Solar PV into the public buildings showed that it is a completely viable alternative to diesel generator and will cost from ₦32m (26.78kW) to ₦184m (156.25kW) depending on the option and building. The pay-back period ranges from 13 years for 26.78kW Solar PV Plant at REA to 21 years for 28.59kW Plant at CPC; and this is where tactical intervention may be needed to make it more appealing.

Effectively managing the above energy saving opportunities, the public buildings have the potentials to reduce energy cost/wastage by up to 30%; to this end the following priority measures as immediate policy directions were recommended:

- Institutionalisation of position of **energy manager and team** in public buildings;
- Establishment of organization based guideline for **equipment/appliances** covering procurement, operation and maintenance, energy labeling, MEPS and life span;
- Implementation of existing building codes, standards and practices in the country and their continuous review to ensure energy efficient **building envelope**;
- Promotion of energy efficiency conscious **users/occupants** and creating supportive environment to facilitate their compliance;
- **On Site Energy Generation** of energy using solar photovoltaic technology and possibly wind and where necessary solar water heater to compliment the supply from the national grid;
- **Top Management** of an organization should ensure existence of in-house energy policy and guidelines, energy action plan, prompt approval or directive on O&M of energy system;
- **Federal Government** should **Buy-in** by given approval to energy efficiency policy and programme for the public buildings backed by strong financing schemes.

The enablers were designed to support the actualization of the priority areas and they are:

- Target specific **Energy Efficiency Awareness and Education;**
- A multi-layer energy efficiency **Financing Scheme** accessible to all public buildings;
- **Capacity Building and Manpower Development** including certificated courses for energy auditors, energy managers, solar PV technicians, architects etc.;
- Generation of reliable, comprehensive and representative **Baseline Data –** for SMART policy planning at all levels.

In conclusion, the study revealed that the optimal framework for energy audit is combination of energy audit of electrical appliances/equipment, behavioral energy audit, renewable energy audit and bioclimatic design energy audit. Each of the four components strengthens the other and produces the highest energy savings; reduction in energy wastages, bills as well as GHG emissions and; impacts on the environment and society. It is also recommended that further studies be carried out to capture more public buildings thus providing adequate and reliable data to aid the establishment of Energy Efficiency Baseline Data for Public Buildings in the country.

Chapter 1: Introduction

Background

The study essentially focused on the strategy of mainstreaming energy management in public buildings; the process that begins with energy audit. The Nigerian Energy sector is characterized by heavy reliance on self-generation as a result of frequent power outages due to inadequate supply from the national grid. Buildings along with transport and industrial sectors are seriously affected by this inadequacy. Public building is the hub of governance, its activities are digitally automated; hence, quality and adequate energy/power supply to public buildings is paramount for competitive socio-economic development of a nation.

Over the years, successive administrations have invested a lot of efforts and resources to close the gap between electricity supply and demand in the country. However, such efforts focused largely on capital investments at supply side with little considerations to the demand side management, which is Energy Efficiency and Conservation. Energy efficiency and conservation globally is regarded as the cheapest and fastest form of generation and one of the main drivers of sustainable development in modern energy based economy. The efficient use of energy will enhance the sustainable use of natural resources and in turn contribute to national growth and sustainable development of a nation. In addition, it is a means of climate change mitigation through greenhouse gas (GHG) emissions reduction. It is a major enabler of the United Nations' Sustainable Energy for All initiative.

Since the beginning of this millennium; Energy Commission of Nigeria and other stakeholders have been implementing different energy management projects and activities geared towards the benefits highlighted above. Among such efforts are:

- Conduct of series of walk-through energy audits between 2001 and 2005 by ECN with the support of the United Nation Industrial Development Organisation (UNIDO) in industries in major commercial cities in the country;
- Replacement of 1million incandescent lamps with high quality CFLs across the country in 2008 by ECN representing the Federal Government of Nigeria in collaboration with the ECOWAS Commission and the Cuban Government;
- Implementation of National Energy Efficiency Programme under the Global Environment Facility (GEF) and the United Nations Development Programme (UNDP) in 2012 by the Energy Commission of Nigeria. The programme developed Minimum Energy Performance Standards (MEPS) for lighting appliances and refrigerators and also established testing laboratories for lighting products and refrigerators;
- Inclusion of Energy Efficiency and Conservation as a separate chapter in the 2013 National Energy Policy draft review; originally developed with stakeholders' participation and approved by the Federal Government of Nigerian 2003;

- The German Cooperation with the support of the European Union is currently running a programme – the Nigerian Energy Support Programme with special focus on energy efficiency.

Today, across the country, evidences of consciousness of energy management and penetration of its devices are obvious, thanks to all the above listed efforts; however, there is need to consolidate these gains, and, comprehensive energy audit is central and fundamental to this. Baseline data is pivotal to any meaningful energy management policy planning and energy audit plays key role in the establishment of the baseline. Generating baseline data in all the sectors – buildings, industry and transport – for the whole country will be a herculean task; hence the actuality and appropriateness of this project "JICA Follow-Up Cooperation Training on Policy Planning for Energy Efficiency and Conservation" focusing on public buildings.

The choice of public buildings is not accidental; it is a space where the occupants/energy users are not property owners and therefore individually, they are not the ones paying the energy bills, in addition, it has multitude of occupants hence, the high possibility of negligence to energy management practices. Along with residential and service/commercial buildings, public building has many energy saving opportunities being a large consumer of energy: *buildings use about 40% of global energy, 25% of global water, 40% of global resources, and emit approximately 1/3 of GHG emissions; making building sector one of the largest contributors to global GHG emissions. Residential and commercial buildings consume approximately 60% of the world's electricity. Yet, buildings also offer the greatest potential for achieving significant GHG emission reductions, at least cost, in both the developed and developing countries. Furthermore, energy consumption in buildings can be reduced by 30 to 80% using proven and commercially available technologies.*[1]

Also, significant numbers of buildings in Nigeria have been constructed without taking the requirements of energy efficiency and conservation (EE&C) into consideration and this has resulted in huge avoidable costs related to the provision of cooling, lighting and powering of appliances in the buildings.

Justifying the choice of public buildings is the fact that, the existing national documents on energy have outlined energy efficiency targets and the likely benefits of implementing EE&C measures. However, what is mostly lacking is that the targets and potential benefits are largely not based on results of empirical studies on the energy consumption of the different economic sectors; they are mostly developed by extrapolating other countries' experiences and programmes.

It is therefore paramount to embark on evidence based study nationwide to understand the current pattern of energy consumption in our public buildings, waste streams and energy management opportunities in order to establish baseline data, which could then be benchmarked before setting guidelines and making recommendations for sustainable public building energy management. This will enable quality integration of energy management policy planning with other national

[1] UNEP Sustainable Buildings and Climate Initiative Website:
http://www.unep.org/sbci/AboutSBCI/Background.asp

plans/documents. By this, targets and implementation plans will become SMART –specific, measurable, achievable/agreed upon, realistic/relevant and time-based.

It is in this light that the Energy Commission of Nigeria graciously collaborating with the Japan International Cooperation Agency to implement the Project. The current Project is a follow up activity to the JICA sponsored training on Policy Planning for Energy Efficiency and Conservation for three ECN staff in Japan.

Furthermore, the project was to develop a monitoring mechanism, provide training to relevant stakeholders, and launch a public campaign to promote energy efficiency and conservation in public buildings in Nigeria. Under this Project, energy audit of three public buildings in Abuja was conducted and this is the report of the energy audit. It is hoped that the project will go into phases II and III where additional 20 public buildings within Abuja and 150 nationwide respectively will be audited leading to the establishment of a National Energy Management Baseline in Public Buildings in Nigeria.

1.2 Statement of the Problem

In an attempt to harness the energy management opportunities in public buildings(or reduce energy consumption in the country), various documents on policy and programme in the field of energy efficiency and conservation have "proposed/recommended" targets and schemes which to a large extent, were not based on data resulting from empirical studies. Some of these documents include the National Energy Policy (NEP) and, the National Renewable Energy and Energy Efficiency Policy (NREEEP); the National Energy Masterplan (NEMP), Renewable Energy Masterplan (REMP), National Energy Efficiency Action Plan (NEEAP), the National Renewable Energy Action Plan (NREAP). Consequent of this approach, some recommended targets were inadequate and schemes not holistic enough to deliver sustainable projects. Policy formulation and planning not based on authentic data is the problem.

1.3 Justification of the Energy Audit

The absence of baseline data generated by empirical studies that can be used as the basis of smart policy and planning has been identified as the gap. In energy management, the pre-requisite method is energy audit study; it is the first technical step in the energy efficiency and conservation program. It is an inspection, survey and analysis of energy flows for the purpose of determining how, where and when energy is being used and/or wasted, identifying opportunities to reduce energy usage and formulating prioritized recommendations for implementing process improvement to save energy. The difference between observed performance and designed performance level or best practice is the potential for energy and cost savings (energy management opportunities).

Furthermore, energy audit of electrical appliances, end-users attitude, renewable energy (RE) supply option in the building energy use mix and integration of bioclimatic design into building (BCD)) were not adequately integrated in most of the existing documents. Therefore, this study – "mini" pilot energy audit study of the three selected public buildings becomes actual in that it is capable of generating data that can help in designing a bigger study with the objective of establishing national baseline data for energy efficiency and conservation upon which national targets can be set after benchmarking.

1.4 Objectives

The overall objective of the study is to institutionalize energy audit as a pre-requisite for SMART policy planning for energy efficiency and conservation in the country by way of:

i. assessing the current energy consumption pattern in public buildings;
ii. identifying the energy waste streams in public buildings vis-à-vis attitude of occupants, appliances/equipment and the bioclimatic design of the buildings;
iii. identifying low-cost ways of reducing energy consumption in buildings;
iv. gathering information that will guide development of implementation plan of relevant sections on public buildings in the National Energy Efficiency and Conservation Policy, and the Building Energy Efficiency Guidelines in Nigeria;
v. establishing a platform for continuous promotion of end-use energy efficiency and conservation in public buildings;
vi. incorporating behavioural energy audit, bioclimatic design and renewable energy audit into energy management of public buildings in Nigeria.

Chapter 2: Methodology

2.1 Scope of Energy Audit

In the context of the current study, public building is defined as a building owned or used by federal government agency to carry out their operations. A total of three buildings were selected for the study, they included the administrative headquarters of the Energy Commission of Nigeria, the Consumer Protection Council and the Rural Electrification Agency. The three buildings are located in the Federal Capital Territory, Abuja (Latitude 9^0.15'N, Longitute 7^0 00'E) and it is at an elevation of about 343.1m above sea level. Abuja has a hot and humid climate and shares border with Kogi State (South), Nasarawa State (East), Niger State (West) and Kaduna State (North) as shown in Figure 2.1.1. The selected sites for the energy audit in Abuja are shown in Figure 2.1.2.

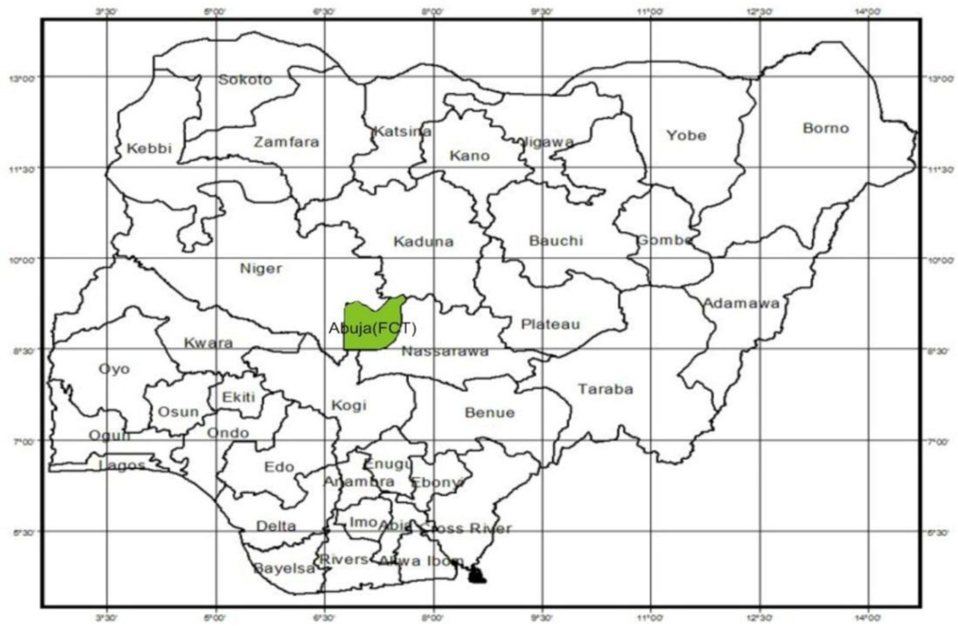


Figure 2.1.1 Map of Nigeria Showing the Study Area

The buildings were selected based on the following criteria: prior cordial relationship between the ECN Management and the agency; and ease of access to the buildings and the proximity to the offices of the Energy Audit Team.

The energy audit was designed to monitor the energy consumption of electrical appliances in the selected public buildings; assess the attitudes of the users to them and energy consumption in general; and also the need and technical possibility of integration of RE source into the energy mix of the building and the building compliancy to bioclimatic design requirement and opportunities for improvement. The study was conducted between September, 2016 and January, 2017.

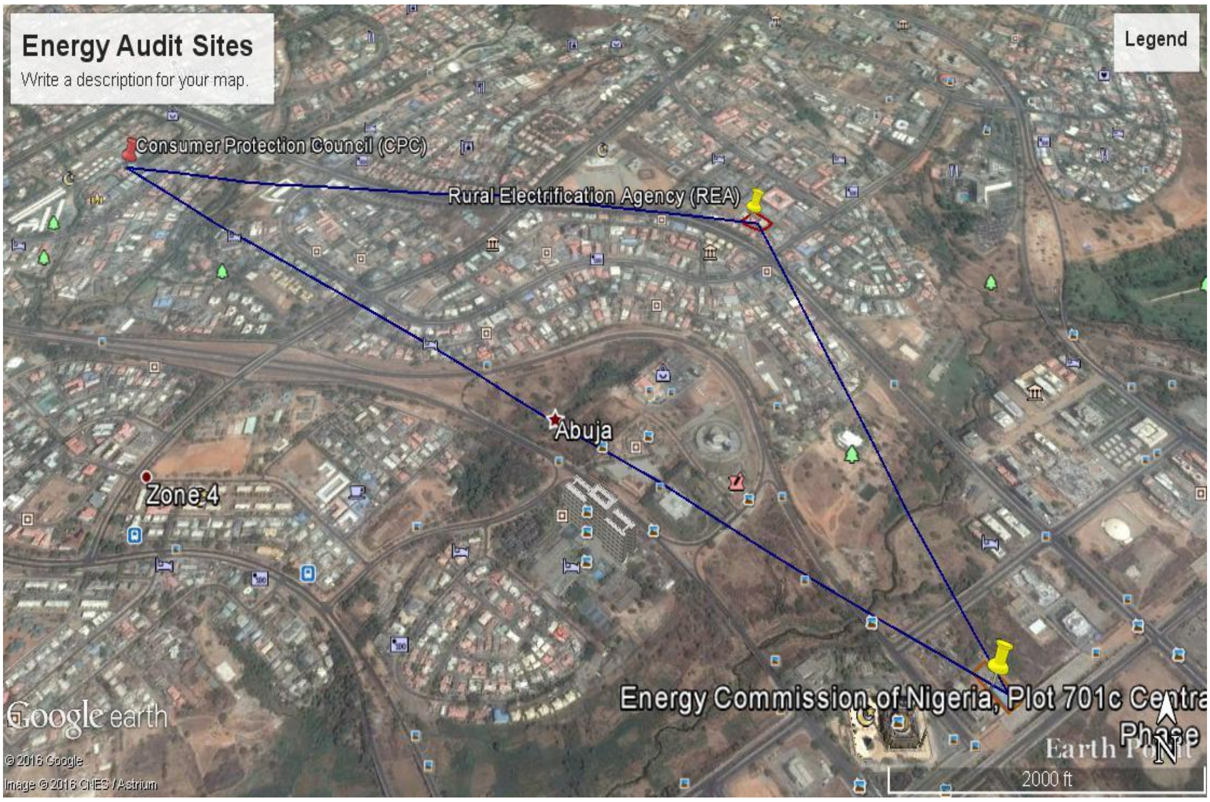


Figure 2.1.2 Selected Energy Audit Sites in Abuja

2.2 Method of Data Collection

Consequent upon the recommendation at the end of a “1-day Inception Workshop on the JICA Follow-up Cooperation Training on Policy Planning for Energy Efficiency and Conservation” held on the 20th September, 2016 the Management of Energy Commission of Nigeria constituted a 31-man multi-stakeholder Energy Audit Team which was domiciled in the Department of Energy Management, Training and Manpower Development.

Focused Group Discussions (FGD)

To compliment data collected using questionnaire administration, focused group discussion was conducted to get the relevant information from them. The data included preliminary information on the facility or building to be audited and to access other information that will be relevant to the audit exercise. FGD was conducted with the unit responsible for the maintenance of the building. A list of questions was prepared to give direction during FGD (Appendix 1).

Review of Existing Literature/Documentation

Existing documentation that was relevant to the study were collected and reviewed. Such documentation provided secondary data that complemented the primary data that was collected during the study. They included monthly electricity bills and previous audit reports.

Questionnaire Administration

Questionnaires were administered to the occupants of the different offices to get specific information on the offices and the type of appliances in the building and also to access the level of consciousness and compliance of the staff to the concept of energy efficiency – behavioural energy audit. The questionnaire was administered by first listing the entire occupants of the building in order of hierarchy cognizant of their status at the time of the audit such as annual, maternity, causal, study leave; and secondment. Thereafter, through systematic sampling technique, 25% of the total population was selected for questionnaire administration (a one on one interview) covering four broad areas of energy utilization namely; Lighting, Cooling and Heating, Building Envelope and Office Equipment (Appendix 5).

Direct Measurement

Measurement of actual energy consumption of the appliances in the building was carried out using different energy logger devices for a period of 3 to 10 days. These included the Serial Wattmeters and the Multvoies System. The Serial Wattmeters were connected in series with all the appliances connected to the building electrical circuit through wall sockets to measure their energy consumption. The Serial Wattmeter was directly plugged into the wall socket and the appliance to be monitored was then connected in the trailing socket of the wattmeter. These appliances included refrigerators, computers, television sets, standing fans, printers, electric kettles and others. Some appliances such as air conditioners and lighting appliances, and the building total consumption were monitored directly from the distribution board of the building. These measurements were done using the Multivoies system.

Renewable Energy and Bioclimatic Design Energy Audit assessed the need and technical possibility of integration of RE source into the energy mix of the building and the building compliance to bioclimatic design requirement and opportunities for improvement. Solar irradiation using HT Solar-02/HT304 Solar Cell; building orientation, sun-path, orientation and inclination of roof-top using Cardinal Compass; area square meter were measured using Infra-Red Tape and Measuring Tape; window orientation, size and materials; existing circuitry, historical energy data, internal wall partitioning and materials, and space availability for power house were also assessed.

2.3 Description of Energy Audit Instruments

The Multivoies System

The Multivoes System was developed by the French OmégaWatt Company. The logger device is designed for the measurement of several channels of power consumption and energies through the electrical Distribution Board. It has a rail-mounted concentrator to measure voltages and electrical power and several modules equipped with current sensors. The system interfaces with the user's Personal Digital Assistant (PDA) using infrared communication or low power radio (Bluetooth). The concentrator and the modules are connected to a high speed industrial data bus with factory assembled RJ11 connectors. The modules are fitted with standard closed miniature current transformers (0-45 Amps).The main features of the Multivoies system as shown in figure 2.1.3 include:

- Simultaneous measurement of electric power in tens of lines per switch box;
- Measurement of power ranging from 2 W to 230 kW per phase with a wide range of current sensors with typical accuracy of 2%;

- Recording of active energy and voltages with periods of 1 second to 60 minutes (5 month memory for 10 minutes period – independent on the number of current modules);
- Records power quality (voltage).

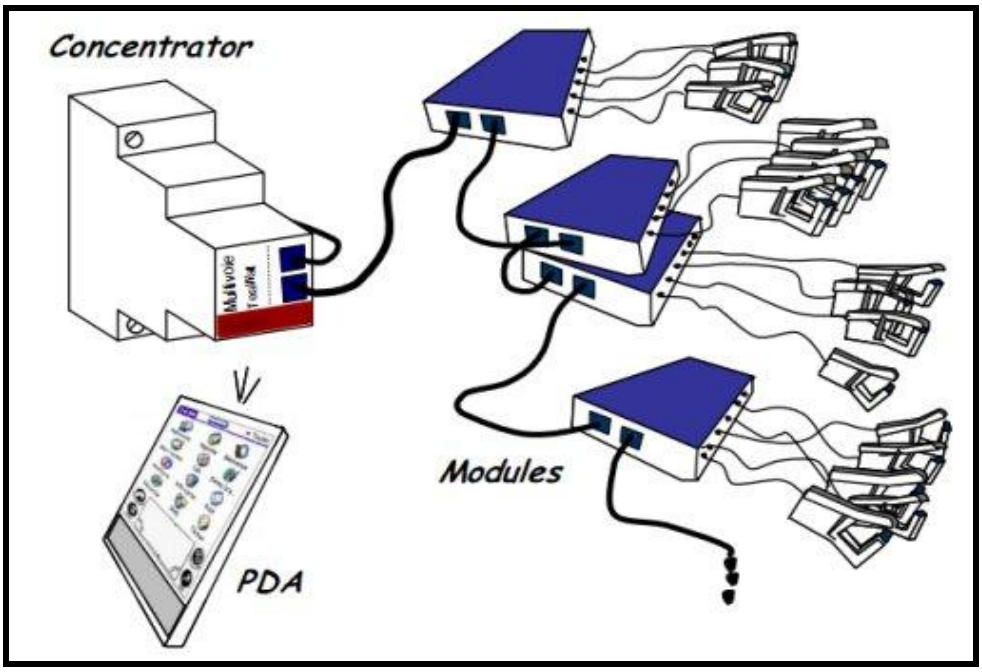


Figure 2.1.3 Multivoies System

The Serial Wattmeter

This logger device measured the active energy and voltage for single-phase appliances with power level lower than 2.6kW, with over one month autonomy. The Serial Wattmeter was developed by ENERTECH and it is placed in series between the standard socket outlet (up to 230V) and the plug of the appliance to be measured. It does not require any direct interface with the distribution system of the building. The serial wattmeter is entirely autonomous and can be left to collect data for several months. At the end of the measurement period, the stored data are read using the Oscar Software which transfers them to a personal computer for analysis. The features of the Serial Wattmeter as shown in plate 2.1.1 include:

- Voltage range is between 0–250V; measurements continuous even in the absence of voltage
- Maximum load is 12 amps
- Serial Wattmeter power supply is by standard batteries: 2 X LR6 (AA) 1.5V (which can last up to 400 days)
- Current measurement done with two automatic gauges
- Resolution is 0.1Wh – the resolution decrease with the power (progressive coding)
- Working LED light with a short impulse every 4 seconds
- Period of measurement is adjustable from 1 to 60 minutes
- The drift of the clock is of approximately 10 minutes per year
- 65 KB of memory, this can record data for up 1.3 years in term of memory size for recordings at 10mn.

Plate 2.1.1 Serial Wattmeter

Other Equipment

The other equipment used by the Energy Audit Team that enhanced the installation of the logger devices included portable aluminum ladders with collapsible property that can reach a height of over 1.5 meters; PVC gloves with protection against electric shock; standard tool box to enhance the installation of the logger devices and; Digital Multimeter that can measure up to 800V to test the quality of voltage before installing the logger devices.

2.4 Method of Analysis

Data collected from the Multivoies System were decoded using the Crebase software while the data collected from the Serial Wattmeter was decoded using the Oscar software. Subsequent analyses was done using Microsoft excel. All data collected were subjected to qualitative and quantitative analysis. Graphs and charts were done using the Microsoft Excel software.

2.4.1 Measured Average Energy Consumption per Hour

The stored data in the Serial Wattmeter are read using the Oscar software which transfers them to a personal computer for analysis. The Serial Wattmeter took recording at 10 minutes interval of real time energy consumption in Watt hour (Wh) and the supply voltage.

The recorded data were analyzed by listing all the relevant data recordings in sequence where there was energy consumption by the appliance (when in active usage). The listed energy consumption data were then sum up at the frequency of six data to get energy consumption per hour. The average energy consumption per hour of each appliance was calculated by summing up the energy consumptions per hour and finding their average.

2.4.2 Estimated Average Daily and Annual Consumptions

The annual energy consumption (in kWh/annum) for each set of plug load appliances and air conditioners was calculated using the readings from the Serial Wattmeter and the Multivoies System respectively. From the measurement of the logger devices, the average daily energy consumption for each of the appliances that was monitored during the study was calculated and their annual average energy consumption was then estimated on the basis of the following assumptions:

- number of days in use in a year was taken to be equal to the number of official days in a year in Nigeria – 247 days; except for refrigerators which are used in all the days of the year;
- appliances such as computers, air conditioners, fans, lighting are used actively for six hours in day while appliances such as refrigerators – 16 hours in day putting into consideration 65% power availability in Abuja[2];
- for other appliances, such as electric kettles, printers and photocopy machine, it was assumed that they are used actively for 2 hours in day.

2.4.3 Life Cycle Cost Analysis

Life-cycle cost analysis (LCCA) is an economic method of project evaluation in which all costs arising from owning, operating, maintaining, and ultimately disposing of a project are considered to be potentially important to that decision (Fuller and Petersen, 1995). It is a method of evaluating energy conservation options over the life of a system is through life cycle costing. The most commonly included costs are the initial installed cost, maintenance costs, operating costs including energy, fuel escalation rates, inflation, interest on the investment, salvage value, and other lifetime expenses for the equipment (Thumann and Younger, 2008; Capehart et al., 2003). LCCA provides a significantly better assessment of the long-term cost effectiveness of a project than alternative economic methods that focus only on first costs or on operating-related costs in the short run (Fuller and Petersen, 1995). It is also used to compare systems over the same lifetime, usually that of the building project. A new emphasis on the comprehensive identification of all costs associated with a system may also be brought about by LCCA (Thumann and Younger, 2008; Capehart et al., 2003). LCCA is particularly suitable for the evaluation of building design alternatives that satisfy a required level of building performance (including occupant comfort, safety, adherence to building codes and engineering standards, system reliability, and even aesthetic considerations), but that may have different initial investment costs, different operating, maintenance, and repair (OM&R) costs (including energy and water usage), and possibly different lives (Fuller and Petersen, 1995).

Energy conservation projects provide excellent examples for the application of LCCA. There are abundant opportunities for improving the thermal performance of building envelope components (e.g., walls, windows, roofs) in new and existing buildings to reduce heat loss in winter and heat gain

[2] Derived from the previous study conducted by the ECN under the UNDP-GEF Energy Efficiency Programme in 2012

in summer (Fuller and Petersen, 1995). Similarly, there are many alternative heating, ventilating, and air conditioning (HVAC) systems which can maintain acceptable comfort conditions throughout the year, some of which are considerably more energy efficient (or use less expensive fuels) than others. When energy conservation projects increase the initial capital cost of a new building or incur retrofit costs in an existing building, LCCA can determine whether or not these projects are economically justified from the investor's viewpoint, based on reduced energy costs and other cost implications over the project life or the investor's time horizon (Fuller and Petersen, 1995).

Other methodologies that have been developed to provide some uniform methods of comparison in evaluating the economics or comparing the cost effectiveness of competing investments include: Simple Payback, Net Present Value, Internal Rate of Return, Equivalent Uniform Annual Costs (EUAC). Due to all the inherent advantages of LCCA among all other economic analysis tools (e.g. NPV, IRR, EUAC etc.), it is thus adopted in this work to carry out the economic performance analysis.

Mathematical Expression of LCCA

General expression for the LCCA model as discussed in Fuller and Petersen, (1995) is given Equation (2.1) as:

$$LCC = \sum_{t=0}^{N} \frac{C_t}{(1+d)^t} \qquad (2.1)$$

where:

$LCC$is the total Life Cycle Cost in present-value Naira (NGN) of a given alternative,

$C_t$is the sum of all relevant costs, including initial and future costs, less any positive cash flows, occurring in year t,

$N$is the number of years in the study period, and

$d$is the discount rate used to adjust cash flows to present value.

Expression in Equation (2.1) may be simplified for computing Life Cycle Cost of energy and water conservation projects in buildings (found in Equation (2.2)) as follows (Fuller and Petersen, 1995). Equation (2.1) can require extensive calculations, especially when the study period is more than a few years long and for annually recurring amounts, for which future costs must first be calculated to include changes in prices. This necessitated the need for a much simplified form in Equation (2.2):

$$LCC = I + Repl - Res + E + W + OM\&R \qquad (2.2)$$

where:

- LCC is the total Life Cycle Cost in present-value Naira (NGN) of a given alternative,
- I is the present value investment costs,
- $Repl$ is the present value capital replacement costs,
- Res is the present value residual value (resale value, scrap value, salvage value) less disposal costs,
- E is the present value of energy costs,
- W is the present value of eater costs, and

- $OM\&R$ is the present value of non-fuel operating, maintenance, and repair costs.

Assumptions used for the LCCA Computation

Computation of LCC analysis was based on the following assumptions:

1. On an average these public office are occupied for 8hours daily and two hundred and forty seven (247) days in a year.
2. The energy consumption for the present lighting use is calculated based on the hours specified by the respondents.
3. The energy consumption for the high quality energy efficient alternative in each of the offices is calculated based on 4 hours of daily use. This is done to enable incorporation of natural lighting into the buildings lighting requirements.
4. On the life-cycle cost calculation, a study period of 15 years is used on lighting while a 4-year study period on computers, printers, scanners and photocopiers.
5. The present computers, printers, scanners and photocopiers are expected to be replaced every three years due to constantly changing technologies.
6. On useful life of lighting fixtures, incandescent lamp has 1000hrs, fluorescent tube has 15,000hrs, and presently installed CFL has 6000hrs.
7. The proposed high quality compact fluorescent lamp has 20,000hrs of useful life.
8. All the presently installed incandescent bulbs are expected to be replaced twice annually, the fluorescent tubes at year 7, and the CFLs at year 3.
9. The unit costs of the appliances and items considered for the life-cycle cost analysis are as presented in appendix 24.

2.5 Limitations to the Study

There were several limitations encountered during the audit exercise and are enumerated below:

- The epileptic power supply to the buildings from the national grid has effect on the data recorded by the energy logger devices. During the period of power outage, the appliances are shut down and the logger devices are unable to take any measurement. Thus, it was difficult to have a continuous measurement for up to 12 hours from the logger devices.
- During the walk-through energy audit, the team was unable to read many of the manufacturers declared power rating of the appliances. For example, many of the air conditioners were Window Unit air conditioners and the Team could not access the part of the equipment where the power rating was inscribed. Consequently, they had to rely on information from the Maintenance Unit and were only able to provide the rating of some window unit ACs in Horsepower.
- Some of the equipment were not captured during the walk-through energy audit; This is because some offices were locked during the audit process.
- The energy logger devices especially the Serial Wattmeter were installed for a short period of time and the possibility existed that the appliance being measured was not in use during the monitoring period or was left on standby mode. In this case, it would not have been possible to read the actual energy consumption of the appliance when in working mode.

- There were constraints in accessing the DBs of some buildings; however this has no serious impact on the study.

Chapter 3: Presentation of Results

3.1 Energy Commission of Nigeria

Mandate: The Energy Commission of Nigeria (ECN) was established by Act No. 62 of 1979, as amended by Act No.32 of 1988 and Act No. 19 of 1989. The Commission is charged with the responsibility for strategic planning and coordination of national policies in the field of energy in all its ramifications.

Building Description: The administrative headquarters is located on Plot 701C, opposite National Mosque in the Central Business District of the Federal Capital Territory, Abuja. The ECN building is owned by the Federal Government of Nigeria and was built in the year 1996 while full operation in the building commenced in 1997. The building is made up of five floors and each floor is clearly marked – Ground Floor, First Floor, Second Floor, Third Floor and the Fourth Floor. Each floor is made up of concrete walls with wooden internal partitioning; each floor was originally built as an open space without internal partitioning. The First, Second and Third Floor is made up of terrazzo flooring while the Fourth Floor is marble tiles. The ECN building is crowned with blue aluminum roofing sheets and suspended ceiling of soft particle boards. Every part of the ECN building is painted with white emulsion paint except the area around the stair cases. It has two adjoining annexes – four and five room blocks.

Plate 3.1.1: ECN Headquarters

Activities: The building is used mainly as offices except for the library and the store. In addition to the office of the Director General, the Commission is divided into six departments: Administrative and Finance Department; Energy Planning and Analysis Department; Energy Management and Manpower Development Department; Energy Information System; Renewable Energy Department; and Nuclear Science and Technology Department. There are ten units under the Office of the Director General; they are the Special Duty Unit, Legal Unit, Linkages and Consultancy Unit, Protocol Unit, Media Unit, Procurement Unit, Audit Unit, Monitoring and Evaluation Unit, Budget and Fund Unit and Maintenance Unit. The daily occupancy of the building is estimated to be about 270 persons per day and it operates on Monday to Friday from 8am to 4pm.

3.1.1 Electrical Energy Audit

3.1.1.1 Sources of Power Supply

There are three main sources of power supply to the building. They include power supply from the public utility, standby diesel generator and solar PV system.

Public Utility: The first one is the electricity supply from the public utility company – Abuja Electricity Distribution Company (AEDC) through a 500kVA distribution transformer located in front of the building. The transformer also serves the neighboring building housing the liaison office of the Nigerian Association of Chambers of Commerce, Industry, Mines and Agriculture (NACCIMA). Chart 3.1.1 shows the monthly electricity consumption for 2014 and 2015. The highest electricity consumption was recorded in the months of March for both 2014 and 2015.

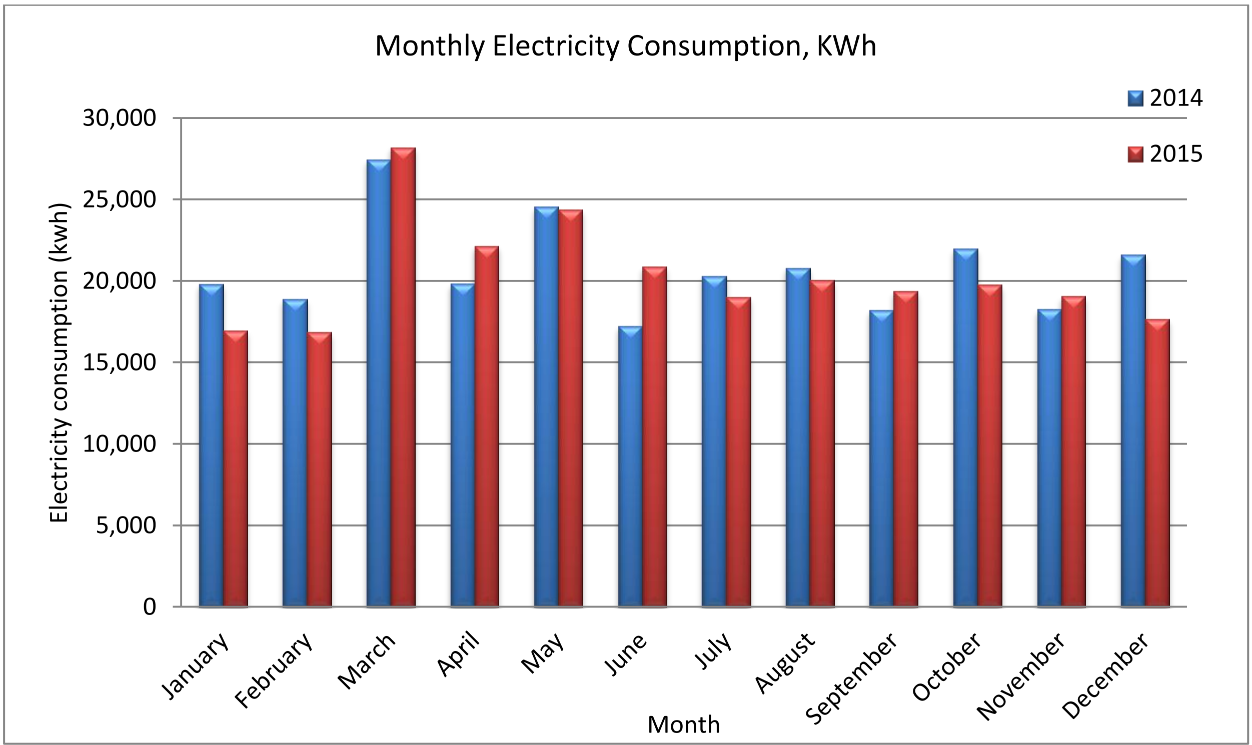


Chart.3.1.1: Monthly Electricity Consumption for the Years 2014–2015 in kWh

The total electricity consumed for 2014 and 2015 are 249,003kWh and 244,419kWh respectively. Thus, the average monthly electricity consumption for the year 2014 was 20,750kWh while the average monthly electricity consumption for the year 2015 was 20,368kWh.

Furthermore, electricity bill was highest in the month of March for 2014 and 2015 (Chart 3.1.2), while the lowest electricity bills were recorded in the month of June for the year 2014 and in the month of July for the year 2015. The total electricity bill for the year 2014 was ₦6,257,528.83 while the average monthly bill was ₦521,460.74. For the year 2015, the total amount of money spent on electricity bill was ₦8,742,388.74 and monthly average expenditure on electricity was ₦728,532.40.

From the available data, the electricity tariff increased from an average of about ₦25.20/kWh in 2014 to ₦35.76/kWh in 2015, that is 42% increase in tariff; therefore increase in the total amount spent on electricity bill between 2014 and 2015 may be as a result of the increase in tariff.

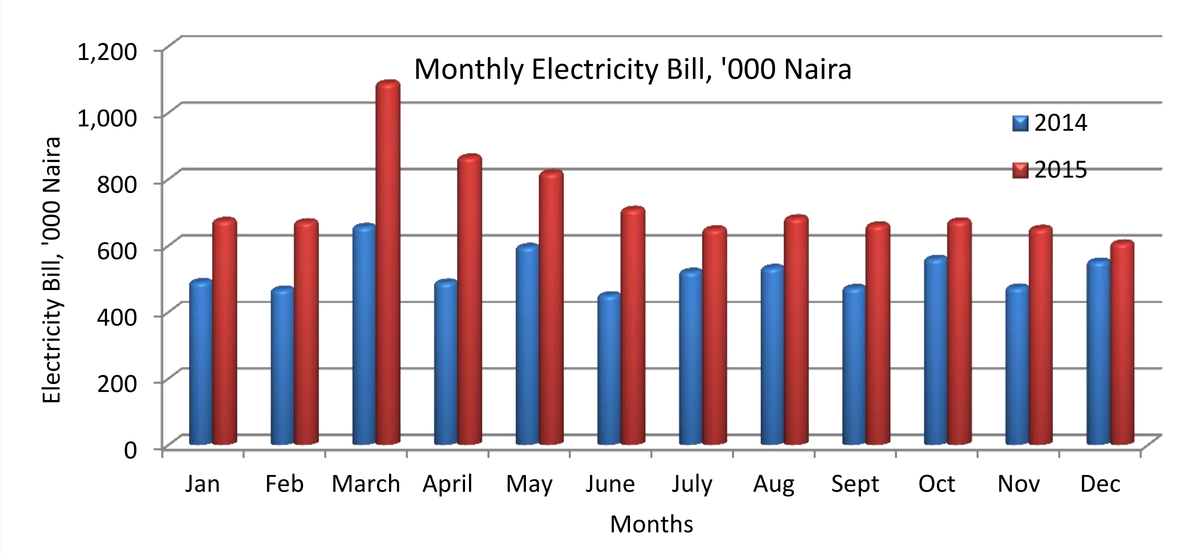


Chart 3.1.2: Monthly Electricity Bills in '000Naira for the Years 2014–2015

Standby Diesel Generator: Within the building, there is a 350kVA diesel generator set serving the entire building and the Annexes during power outages. The generator set was installed in 2005. From the most recent data made available by the Maintenance Unit of the ECN, the generator is estimated to consume an average of 43.79 litres of diesel per hour (Table 3.1.1). Going by the most recent price of diesel of₦262.5/litre, the estimated cost of running the generator for one hour is ₦11,494.88.

Table 3.1.1: Diesel Consumption of Generator Set per Hour

Quantity Supplied, liters	Hours of Use	Amount, ₦	Unit Cost/liter, ₦	Quantity consumed, Liters/ hour
5,000	110.00	1,008,000	201.6	45.45
5,000	106.11	1,008,000	201.6	47.12
5,000	137.22	1,008,000	201.6	36.44
15,000	263.07	3,024,000	201.6	57.02
5,000	127.08	1,312,500	262.5	39.35
5,000	133.92	1,312,500	262.5	37.34
40,000	**877.4**	**8,673,000**	**Average**	**43.79**

Solar Photovoltaic Plant: In addition to the conventional power supply, there is a 3.96kW Solar Photovoltaic roof-top stand-alone system installed by the GEF-UNDP supported energy efficiency programme to power the lighting equipment on the Fourth Floor of the building; this is however not functioning at the time of this report. Moreover, some of the outdoor lightings in the premises are stand-alone solar systems.

3.1.1.2 Measured Consumption

The total energy consumption, lighting and individual air conditioners in the building were measured using Multivoies System while Serial Wattmeters were used to measure the energy consumption of the Plug loads such as computers, printers, fans and the results are presented below:

3.1.1.2.1 The Measured Average Hourly Energy Consumption of ECN Building

Table 3.1.2: Measured Average Hourly Energy Consumption, Wh

Floor	Total	AC	Lighting	Plug Loads
Ground	10018.05	6152.62	1673.57	2191.86
First	29126.63	23488.91	3171.38	2466.35
Second	35891.77	31172.67	2250.70	2468.40
Third	33704.70	26485.58	2899.36	4319.75
Fourth	19703.03	17055.39	1898.59	749.05
Grand Total	**128,444.18**	**104,355.17**	**11,893.60**	**12,195.41**

The Measured Average Hourly Energy Consumption is 128.44kWh (Table 3.1.2); it should be noted that the back-up diesel generator manufacturer's power rating is 350kVA (297.50kW at power factor 0.85). Furthermore, variation in consumption from floor to floor is as a result of difference in occupancy and, types and quantity of appliances and equipment; despite that all the floors are of equal volume.

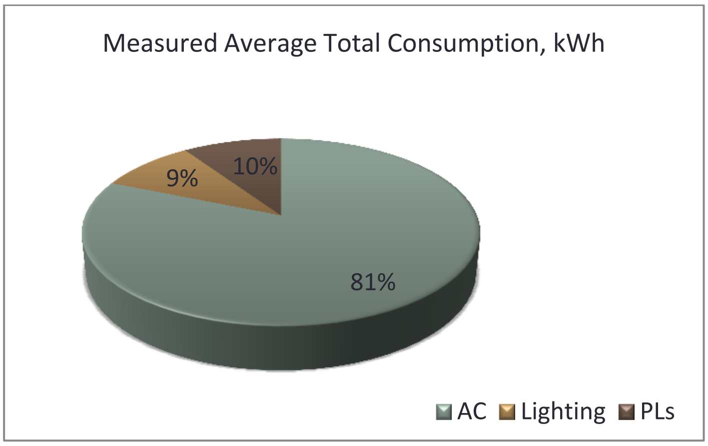


Chart 3.1.3: Percentage Total Energy Consumption in the ECN Building

3.1.1.2.2 Air Conditioners

Two types of air conditioners (ACs) were identified in the building; the Window Unit and the Split Unit. Going by manufacturers' rating, the Split Unit ACs consume less energy than the Window Units and generally rated to be more efficient. In the current study, a total of 78 ACs were identified, out of which 45 (58%) of them were Window Units ACs and 33 (42%) were Split Unit ACs (Table 3.1.3). The highest number of ACs was recorded in the Fourth Floor of the building, 15 Window Units and 10 Split Units making a total of 25 ACs. The Conference Room and the Director General's Conference Room are located on the Fourth Floor; this may explain the high number of ACs recorded on the Fourth Floor.

Declared Power Rating for Air Conditioners: In Nigeria, it is a common practice to rate air conditioner in Horsepower (1 Horsepower is equivalent to 745.7watts). Many end-users in Nigeria seem to be more familiar with the Horsepower unit for air conditioners.

The Audit Team could not read the power rating declared by manufacturers on 7 of the air conditioners. Out of the 71 air conditioners with manufacturers' declared power rating, a total of 34 air conditioners were rated 2Hp, while 30 air conditioners were rated 1.5Hp. All the air conditioners in the building have an average power rating of 1.9Hp (1,425 W).

Plate 3.1.2: Samples of Aged ACs in use in ECN

Table 3.1.3: Number of Air Conditioners with Their Power Rating, Hp

No of ACs	3	30	34	2	2
Power Rating, Hp	1	1.5	2	3	6

Measured Power Rating for Air Conditioners: The measured average energy consumption of most of the air conditioners in the Commission was discovered to be higher than the declared power rating by the manufacturers (Chart 3.1.4).

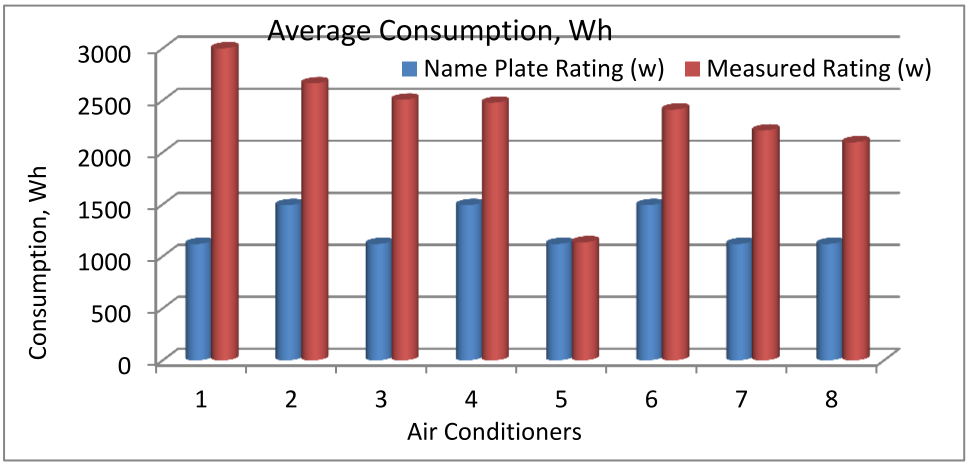


Chart 3.1.4: Comparison of Name Plate Rating (W) and Measured Average Hourly Consumption (Wh) for ACs

All the 71 ACs consume on the average 104,355.17Wh per hour representing 81% (Table 3.1.2 and Chart 3.1.3) of the total electricity consumption in the Commission. The difference between the declared rating by the manufacturers and the measured average energy consumption may be because of the age of the appliances. Many of the air conditioners were indicated to be over 10 years old (Plate 3.1.2).

3.1.1.2.3 Lighting Appliances

Five types of lighting equipment were found in the building during the study, they are indoor light emitting diodes (LED (CE)), compact fluorescent lamps (CFLs), linear fluorescent lamps (LFLs), incandescent lamps (ICLs) and outdoor light emitting diodes (LED (UL)); (see Appendix 27). As shown in Table 3.1.4, the highest number of lighting equipment was the LEDs, totaling 1,824 (91%) followed by LFLs totaling 93 (5%). The measured average hourly consumption of lighting in the Commission was 11,893.60Wh (Table 3.1.4).

Table 3.1.4: Number of Lighting Equipment in the Building

Floor	LED (CE)	CFLs	LFLs	ICLs	LED (UL)
Ground	236	53	50	5	20
First	360	-	-	-	-
Second	296	-	10	-	-
Third	488	-	1	1	-
Fourth	444	2	32	6	-
Total	1824	55	93	12	20

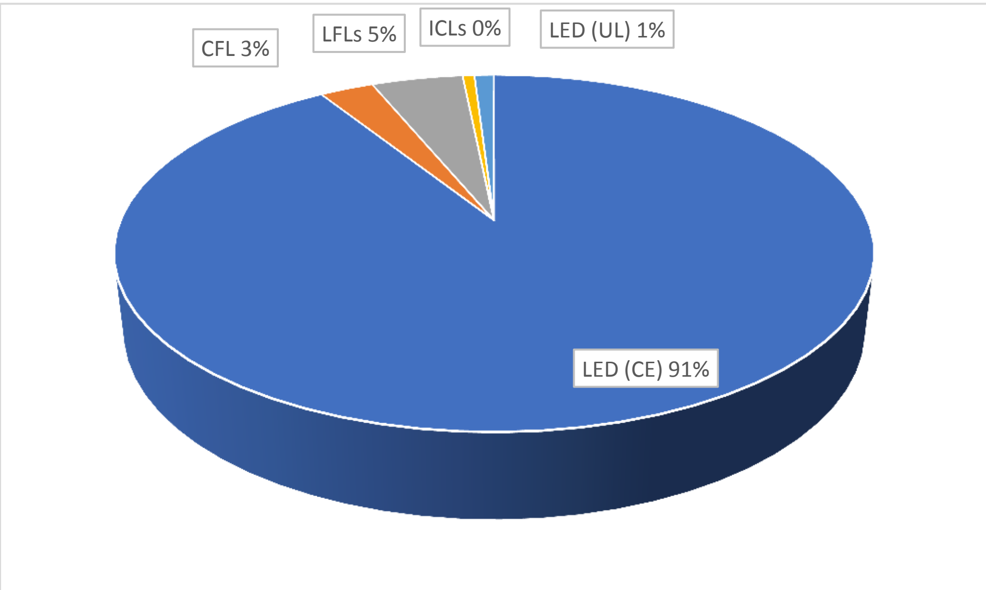


Chart 3.1.5: Percentage of Energy Consumption by Different Lighting Equipment in the ECN Building

3.1.1.2.4 Desktop Computers

Desktop computer is a system made-up of CPU and Display Monitor (LCD). The study revealed that there were 231 Desktop computers in the building. The highest number (104) was recorded on the Third Floor of the building making a total of 45% of the total number of computers. The Audit Team could not record the power rating of many of the Desktop computers as declared by the manufacturers; the manufacturers only declared the value of the electrical current passing through the equipment. From literature, an average desktop computer consumes between 60 and 300 watts of electricity; the exact consumption is difficult to determine, since it depends on the hardware configuration, video card, heavy gaming, 3D rendering etc. For some of the Desktop computers, the energy consumption of the central processing units (CPU) were measured separately from the liquid crystal display (LCD) monitors using the Serial Wattmeters. On the average, the annual energy consumption of (a) Desktop computer(s) is 96.4kWh/annum. It was estimated that the energy consumption of Desktop computers is highest on the Third Floor (10,046.4 kWh/annum), followed by the First Floor (5,796kWh/annum). The estimated total energy consumed by Desktop computers in the building is 22,214.6kWh/annum[3].

a. LCD Monitor

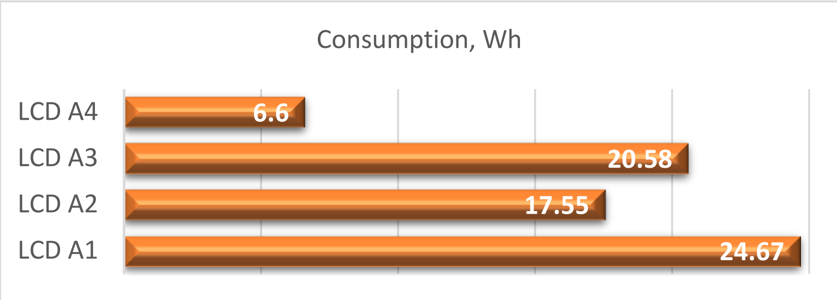


Chart 3.1.6: Measured Average Hourly Energy Consumption of Different LCDs in Wh

Different brands/models of the LCD monitor coded A1 – A4 were monitored (Chart 3.1.6). Data of the consumption obtained from the Serial Wattmeter showed that LCDs A1, A2, A3 and A4 consumed 24.67Wh, 17.55Wh, 20.58Wh and 6.6Wh respectively. LCDs A2 and A4 were of the same brand/model. The difference observed in average consumptions was as a result of the fact that LCD A2 was being actively used while LCD A4 was not in active use. The 6.6Wh consumption represented energy wastage that could be saved if the system were shut down when not in use.

b. Central Processing Unit (CPU)

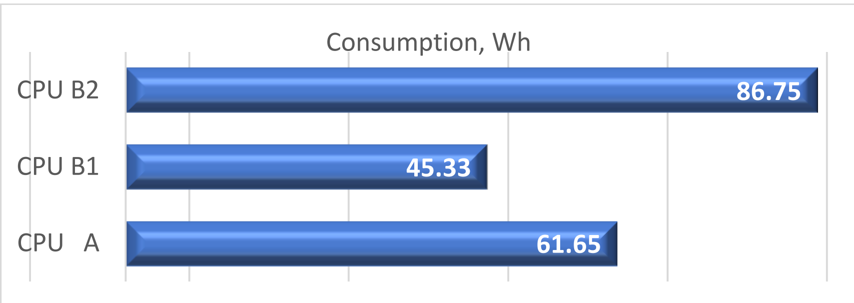


Chart 3.1.7: Measured Average Hourly Energy Consumption of Different CPU in Wh

[3] Here and similar places further, please refer to sub-section 2.4.2: Estimated Average Daily and Annual Consumptions

The result from Chart 3.1.7 shows that the measured average hourly energy consumption of CPU B1 was the lowest, possibly due to lesser activities by the user compared to other users, however, all of them are operating within the manufacturers' rating of CPU.

Since desktop computer is made up of a CPU and monitor (LCD); from the result obtained above, if the CPU and LCD that consume the highest average energy are assembled together, the system's energy consumption is still within the range of 60 to 300 watts and also comparable with the consumption of Smart Touch Computer (see chart 3.1.9 below).

3.1.1.2.5 Laptop Computers

A total of 51 laptop computers were recorded in the building within the study period. The highest number (20) was recorded on the Second Floor followed by the Fourth Floor which had 12 laptop computers. Most of the laptop computers were rated 65W by the manufacturers. From the measurement using the Serial Wattmeter, the annual energy consumption of laptop computers ranged from 18.5kWh/annum to 116.3kWh/annum. On the average, the laptop computer consumes 67.8kWh/annum. The estimated total energy consumption of laptops computers for the building was 3,457.8kWh/annum.

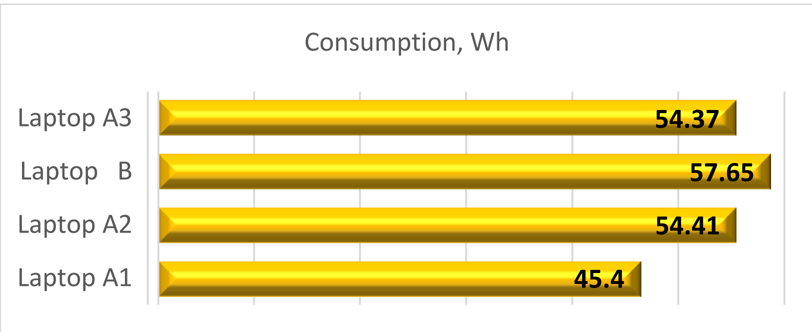


Chart 3.1.8: Measured Average Hourly Energy Consumption of Different Laptop in Wh

Chart 3.1.8 shows the measured average consumption per hour of the different brands/models of laptops coded A1, A2, A3 and B. The data obtained were all within the maximum plate label of 65W. The energy consumption of laptops also depends on the hardware configuration, video card, type of usage and whether the battery is fully charged or not. The energy consumption of any laptop where multiple activities goes on at the same time is expected to be higher but within the plate label rating.

3.1.1.2.6 Smart Torch Computers

The measured average consumption per hour of the three Touch Smart System coded A1 – A3 that were monitored is as shown in Chart 3.1.9. The readings indicate that, Systems A1 and A3 were actively used during the period of monitoring while system A2 was not in active use.

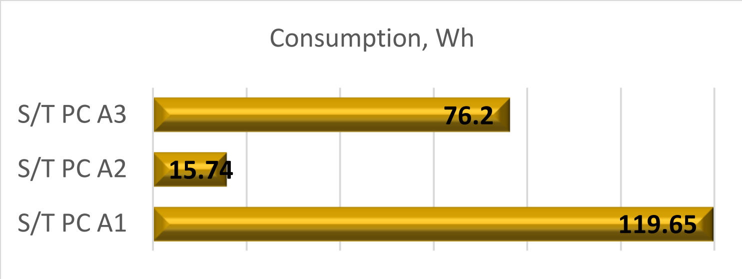


Chart 3.1.9: Average Measured Hourly Consumption of Different Smart Touch Computers in Wh

3.1.1.2.7 Printers

A total of 72 printers coded A1A, A1B and B were recorded in the building, the highest number (24) was found on the Second Floor. The energy consumption of the printers ranged from 2.07kWh/annum to 25.57kWh/annum. The total energy consumption of all the printers being used in the building during the period of the study was estimated to be 635.76kWh/annum.

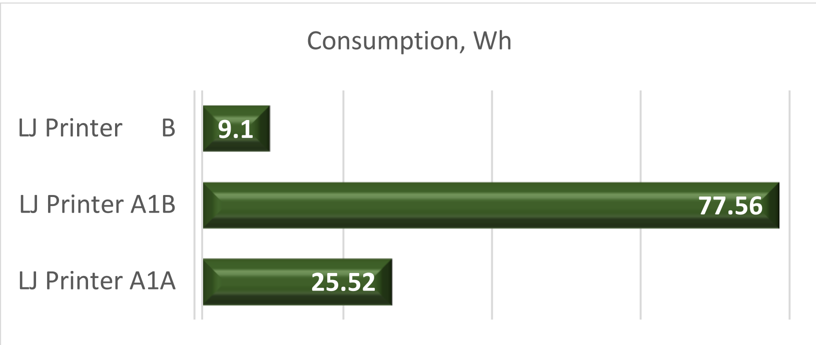


Chart 3.1.10: Measured Average Hourly Energy Consumption of Different Printers in Wh

Chart 3.1.10 shows the measured average energy consumption per hour of printers of two different models. Printer A1A and A1B are of the same brand and model. The difference in the average energy consumptions of the two printers may be as a result of the rate of their usage. It could be deduced from the readings that while printer A1B was in active use regularly, printer A1A was used occasionally.

3.1.1.2.8 Photocopier Machines and Scanners

There were 13 photocopier machines in the building; the highest number (5) was recorded on the Second Floor, followed by the Ground Floor where 3 photocopier machines were found. The total energy consumed by photocopier machines was estimated to be 107.9kWh/annum. Scanning machines were found only on the First Floor (2) and the Third Floor (4) making a total of 6 scanning machines in the entire building. The total energy consumption of all the scanning machines was estimated to be 43.6kWh/annum.

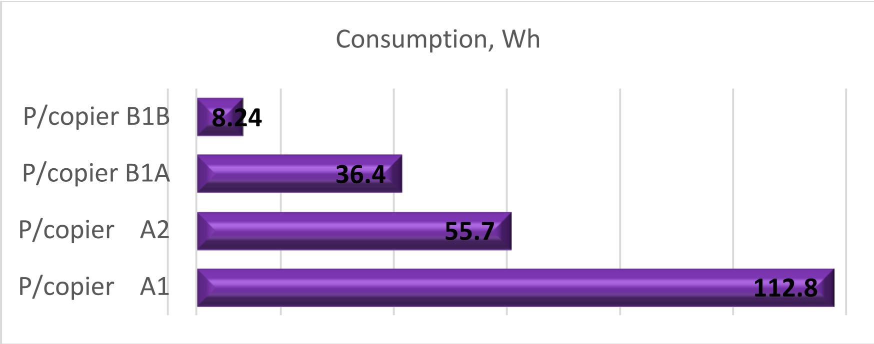


Chart 3.1.11: Measured Average Hourly Energy Consumption of Different Photocopiers in Wh

Chart 3.1.11 shows the measured average hourly energy consumption of different brands/models of photocopiers coded A1, A2, B1A and B1B. Photocopiers A1 and A2 are of the same brand but different models. Their plate labels were not available. Photocopier B1A and B1B are of the same brand and model. The data collected using Serial Wattmeter indicates that photocopier B1A on the average consumes 36.4Wh while its plate label rating is 40W. The consumption of photocopier B1B represented energy consumption that could had been saved if the photocopier was shut down while not in use.

3.1.1.2.9 Refrigerators

Four different types of refrigerators were found in the building; they included deep freezers, fridge-freezer, fridges and water dispensers. A total of 22 fridges were recorded in the buildings the highest number (8) was found on the Fourth Floor. The Second and Third Floors had equal number of fridges (Table 3.1.5). Deep freezers were found only on the Ground Floor, while the Water Dispensers were found only on the Fourth Floor. From the data collected using the Serial Wattmeter, the estimated energy consumption of refrigerators in the building ranged from 371.8kWh/annum to 1468.2kWh/annum. The total amount of energy used for powering refrigeration equipment in the building was estimated to be 19,341.3kWh/annum.

Table 3.1.5: Number of Fridge and Water Dispensers in the ECN

Floor	Fridge	Deep Freezer	Fridge Freezer	Dispenser
Ground	1	3	1	-
First	1	-	-	-
Second	6	-	-	-
Third	6	-	-	-
Fourth	8	-	2	2
Total	**22**	**3**	**3**	**2**

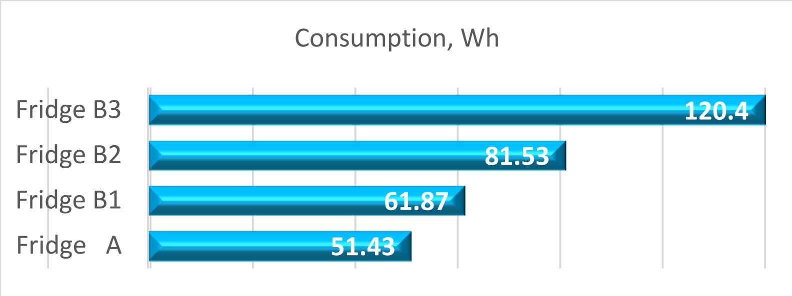


Chart 3.1.12: Measured Average Hourly Energy Consumption of Different Fridges in Wh

The energy consumption of some fridges that were monitored is presented in Chart 3.1.12. Fridges B1, B2, and B3 were of the same brand, but different models. Fridge A recorded 51.43Wh average energy consumption which is slightly above 50W plate label on the fridge. Fridge B1 and B2 recorded 61.87Wh and 81.53Wh which are slightly below their plate label of 70W and 83W respectively. Fridge B3 consumed 120.4Wh while the plate label is 145W.

3.1.1.2.10 Television Set, PAS, Radio/Compact Disk Play and Decoder

There were 8 television sets in the building; one of them was not functioning. The highest number (4) was recorded on the Fourth Floor (Table 3.1.6). A total number of 18 radio sets was recorded across the different floors except on the Third Floor, the highest number being found on the Fourth Floor. DSTV decoder machine was only found on the Fourth Floor. Similarly, Public Address System (PAS) was only found on the Fourth Floor of the building.

Table 3.1.6: Number of TV Set, PAS, Radio/CD Player and DSTV Decoder in ECN

Floor	TV	Radio	Decoder	PAS	DVD Play
Ground	2	1	-	-	-
First	1	2	-	-	-
Second	1	6	-	-	-
Third	-	2	-	-	-
Fourth	4	7	2	4	3
Total	**8**	**18**	**2**	**4**	**3**

Data obtained using the energy logger devices shows that the energy consumption of the television sets in the building ranged from 54.3kWh/annum to 437.2kWh/annum (Chart 3.1.13). The estimated total energy consumption of the TV sets was 1,420.7kWh/annum.

Television: The energy consumption per hour of the same brand but different models of Television is presented in Chart 3.1.13. Television A1 and A3 consumes 28.37Wh and 238.07Wh respectively, which is far less than their plate label of 85W and 552W. The gap between the average measured energy consumption and plate label of Television A3 was not wide. The plate label was 250W and the average measured energy consumption is 232.53Wh.

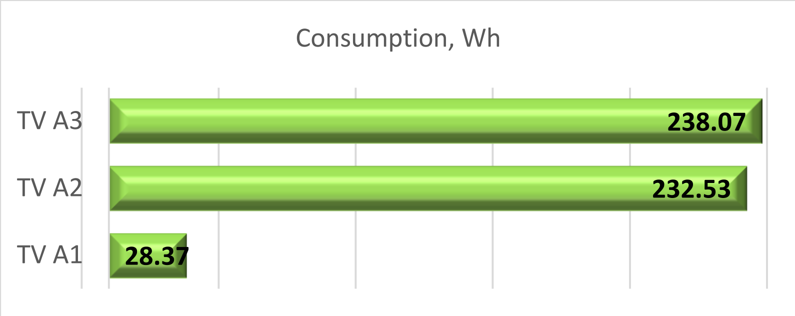


Chart 3.1.13: Measured Average Hourly Energy Consumption of Different Televisions in Wh

Others: The estimated energy consumption of the 18 radio sets in the building was 201.8kWh/annum. As shown in Table 3.1.6, there are only two DSTV Decoder machines in the building and both were estimated to consume 26.7kWh/annum and 7kWh/annum respectively making a total of 33.7kWh/annum. The total energy consumed by the DVD Player was estimated to be 55.2kWh/annum.

3.1.1.2.11Standing Fans

There were a total of 64 standing fans in the building; the highest number was recorded on the Third Floor. The least energy consuming electric fan was estimated to consume about 29.6kWh/annum while the highest energy consuming fan consumes 447.4kWh/annum. The total energy consumption of all the electric fans was estimated to be 8,281.6kWh/annum.

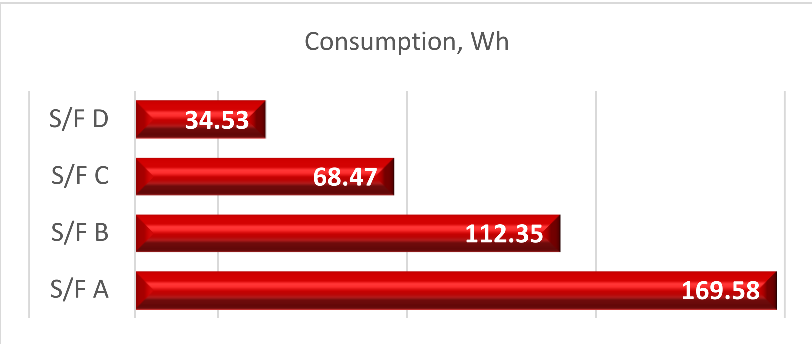


Chart 3.1.14: Measured Average Hourly Energy Consumption of Different Standing Fans in Wh

Chart 3.1.14 shows the measured average energy consumption per hour of different brands/models of standing fan. Standing fan B, C and D consumed less than their plate while standing fan A consumed 169.58Wh against the plate label of 54.5W.

3.1.1.2.12 Electric Kettle

A total of 14 electric kettles were found in the building, the highest was recorded on the Fourth Floor. The total energy consumption of all electric kettles in the building was estimated to be about 4,618.9kWh/annum.

3.1.1.2.13 Shredding Machines

A total of 8 shredder machines were recorded during the study and was found only on the Second and Fourth Floors. The estimated total energy consumed by shredding machines was estimated to be 28.3kWh/annum.

3.1.1.2.14 Other Electrical Appliances

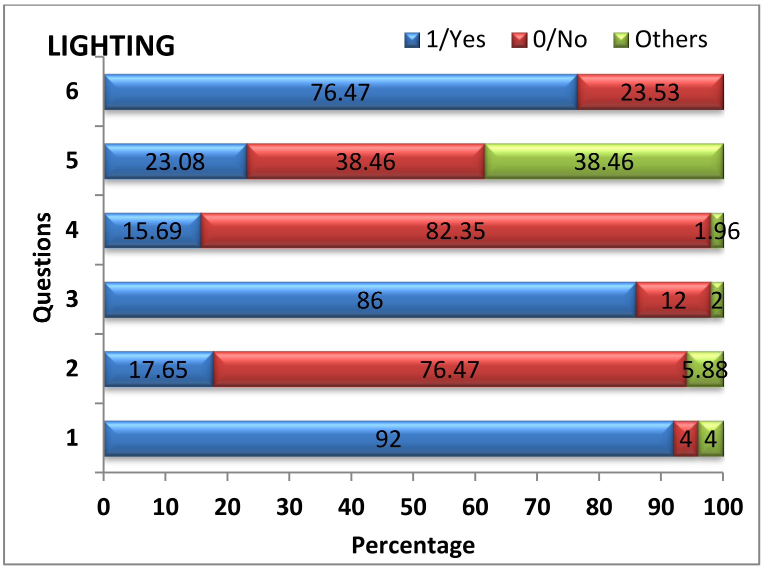
There were 120 Uninterruptible Power Supply (UPS) systems in the building, the highest number on the Second Floor. Also, there were 52 Automatic Voltage Regulator (AVR) found in some offices in the building. The water supply system in the building was powered by 3Hp submersible pumping machine. Similarly, there was only one microwave machine located on the ground floor of the building. The Second Floor and the Ground Floor; each had a set of battery bank and inverter machine.

NB. The Measured Average Hourly Energy Consumption in Wh of all the appliances monitored except very few was found to be within the manufacturer's rating (W) of the appliances contained in the plate label.

3.1.2 Behavioural Energy Audit

Out of the total 70 interviews planned, 51 were successfully completed, representing 73% of the total. The responses *yes, no, others were coded as 0, 1, 2 and others* were presented below in charts.

3.1.2.1 Occupants' Attitude to Lighting



Questions

1. Is lighting in your office off after working hours?
2. Is the toilet lighting in your floor always on even when not in use?
3. Is your office using the energy efficient lamps (CFLs, LEDs)?
4. Is the daylight in your office adequate without electric light?
5. If answer to 4 is yes, do you use the daylight instead of electric light at times? *(If answer to 4 is No, skip).*
6. Have you seen lighting management device such as dimmers, timers and sensors installed anywhere in this building?

Chart 3.1.15: Response of Occupants on their Attitude to Lighting

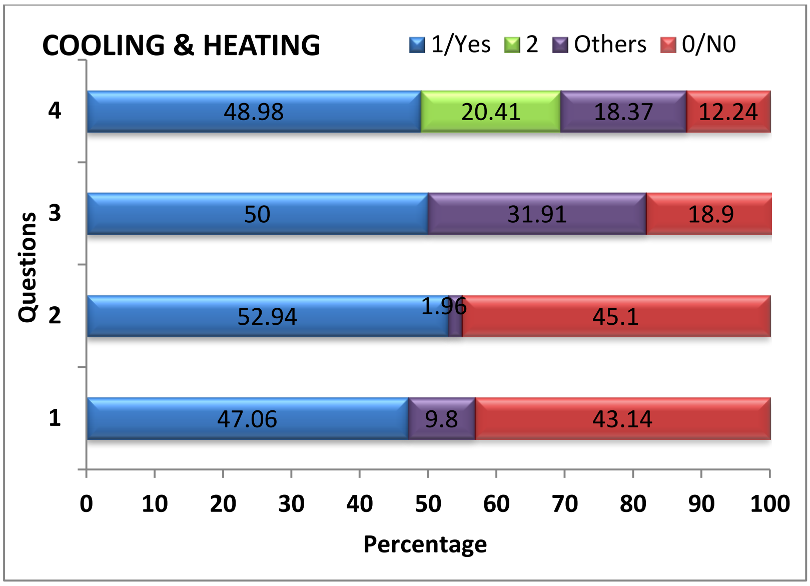
Chart 3.1.15 indicates that 92% of respondents had cultivated the habit of turning off the lighting in their offices after working hours. In respect of the toilet lighting, 76.47% of respondents said they turn off the switches when leaving the toilets.

The chart further indicates that 86% respondents answered that in their offices energy efficient lamps (LEDs) were in use; however, a small but significant percentage (2%) said they do not know the difference between the efficient and inefficient lamps.

When asked about adequacy of day lighting in the offices, 82.35% of respondents answered in the negative, while 38.46% of the respondents said they do not use it for office work and the same proportion were indifferent to the use of day light.

On the issue of energy management awareness, 76.47% said they are conscious of it and they had noticed promotion materials on the subject and devices in the Commission.

3.1.2.2 Occupants' Attitude to Cooling and Heating



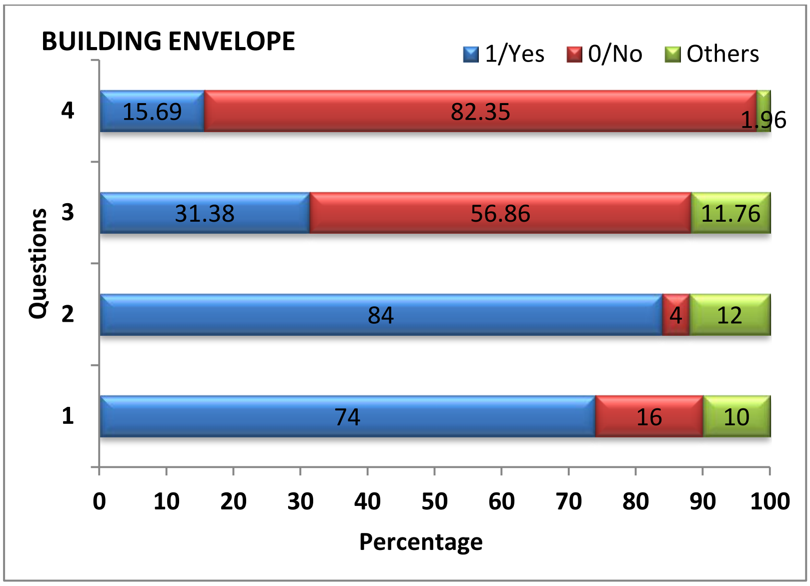
Questions

1. Is the AC in your office shut down when unoccupied during working hours?
2. Do you often use fan in place of AC?
3. Does the kettle in your office have functional thermostat?
4. How many times in a year is your AC serviced?

Chart 3.1.16: Response of Occupants on their Attitude to Cooling and Heating

47.06% of the respondents shut down the ACs in their offices when unoccupied during working hours, while 43.14% do not. 52.94% respondents often use fans in place of ACs while 45.1% do not. When asked about regularity of servicing of their ACs, 20.14% respondents noted that their ACs were serviced twice during the study year while 48.98% said their ACs were serviced once during the study year and 12.24% respondents said their ACs were never serviced while 18.37% respondents said their ACs were serviced only when the need arises.

3.1.2.3 Occupants' Perception about Office Building Envelope



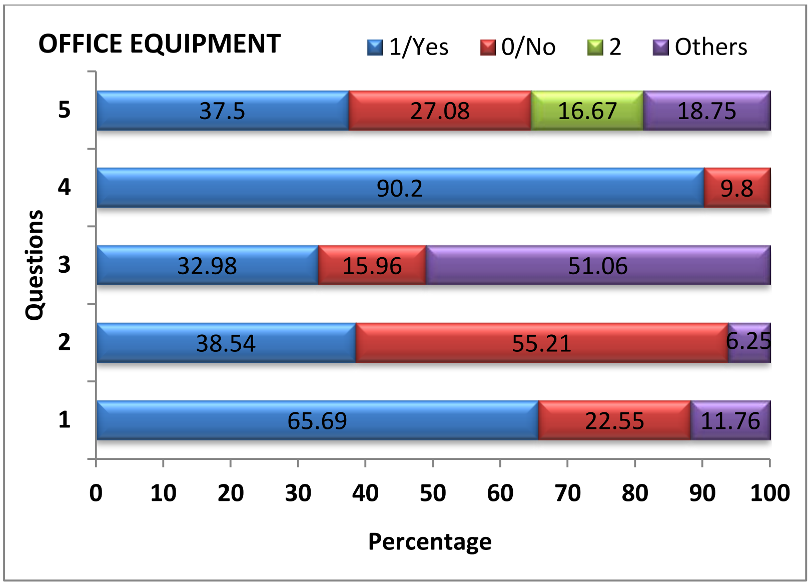
Questions

1. Is your office door always kept closed when AC is in Use?
2. Are your office windows always kept closed when AC is in Use?
3. Are the windows in your office in need of blinds to reduce/block the sun rays?
4. Is the daylight in your office adequate without electric light?

Chart 3.1.17: Response of Occupants on their Attitude to Office Building Envelope

Chart 3.1.17 reveals that 74% and 84% respondents ensured that the doors and windows of their offices were always closed when AC was in use respectively. Likewise, the same chart indicates that 10% and 12% respondents' offices had faulty doors and windows respectively. The chart further revealed that only 56.86% respondents were satisfied with their window blinds while 31.38% indicated that they do not have blind on their windows and 11.76% would like their window blinds replaced or re-fixed.

3.1.2.4 Occupants' Perception about Office Equipment



Questions

- Are your desktop and laptop set on hibernation? What is the timing?
- Are your desktop and laptop shut down during working hours when not in use *(for about 20mins and more)*?
- Is the copying machine shut down during working hours when not in use?
- Do you switch off the socket(s) in your office at the close of work?
- What is the regularity of service of your ICT equipment in a year?

Chart 3.1.18: Response of Occupants on their Attitude to Office Equipment

It was shown in chart 3.1.18 that 65.69% respondents set their laptops/desktops in hibernation mode during working hours and the remaining do not. Comparably, only about 40% said they do shut down their systems when not in use for about 20mins or more. Of the respondents that have photocopy machine under their care, only 32.98% of them shut down their copying machine during working hours when not in use. Furthermore, at the close of work 90.2% respondents switch off the sockets. Answering question on ICT service regularity, 37.5% said they had their system serviced once during the study year.

3.1.2.5 Summary of the Responses

The responses of the interviewees were summarized under three headings below:

Occupants' Awareness and Compliance

The level of occupant's consciousness and compliance to some energy management practices and requirements in the Commission was high; this was evident by the affirmative responses of the occupants to questions on shutting off light after work hour, use of fan in place of ACs and shutting off the sockets after closing hours. Also the high percentage of respondents that kept the doors and windows of their offices closed when AC was working, that set their laptop/desktop in hibernation mode are all indications of energy efficiency consciousness and compliance. This could be consequent upon the fact that promotion of energy efficiency is one of the functions of the Commission. However, the level of non-compliance in some cases for organizations like Energy Commission may be a course for concern. It is to be noted that the consequences of non-compliance will impact on the building's total energy consumption and bill, and GHG emission with devastating effect on the environment.

Management Responsiveness

Retrofitting of the lighting in the Commission to energy efficient ones (LEDs), usage of energy management devices and display of promotional materials in the building are evidences of management's responsiveness in ensuring compliancy to energy efficiency practices and requirements. However, non-prompt repair of faulty doors and windows evident from the responses of the interviewees are sources of leakages making the air conditions less effective; the results obtained from monitoring of the office room temperature using infra-red thermometer also validated this fact. Faulty switches, regular servicing of air-conditions, desktops and other office equipment are areas that require Management improved responsiveness.

Building Envelope

Issues of obvious attention and of particular concern in the building envelope of Energy Commission were window size, poorly insulated partitioning and office doors.

3.1.3 Renewable Energy and Bioclimatic Design Energy Audit

3.1.3.1 Section 1: Renewable Energy Audit

Solar PV Integration Assessment

As a first step in assessing the possibilities of integrating solar PV into a building, a pre audit of the building was conducted to ascertain if there is available space for both installation of solar PV array and power house. The results showed that there is adequate space for the installation of solar PV array and power house (Tables 3.1.7 and 3.1.8)

Plate 3.1.3: Existing Roof-top Solar PV

Table 3.1.7: Assessment of Space for Solar PV Array Installation

S/N	Item	Availability	Possibility	Angle of Inclination (o)	Orientation	Remark
1	Roof-top 1	Yes	Yes	≤ 30	North, South	
2	Roof-top 2	Yes	Yes	≤ 30	North	
3	Roof-top 3	Yes	Yes	≤ 30	-	
4	Parking lot 1	Yes	No	-	-	
5	Parking lot 2	Yes	No	-	-	

Key: Roof-top 1 – Main Building; Roof-top 2&3 – Annex 2&3; Parking lot (PL) 1 – Mgt. PL; PL 2 – Staff PL.

Table 3.1.8: Assessment of Space for Solar PV Power House

Item	Availability	Possibility	Size(m)
Mini Store at Centre of the Corridor on each floor	Yes	Yes	1.82 ×1.52

Solar Energy Resources

The importance of the available solar energy resource in the effective performance of the system cannot be over emphasized, on this basis, the irradiation, average sunshine hours, humidity and temperature were all measured at the audit location and values obtained were correlated to corresponding data from literature. The data is presented in Table 3.1.9.

Table 3.1.9: Solar Energy Resources

S/N	Parameter	Readings	
		Measured	Literature
1.	Irradiation	7.86kW/m^{2*}	5.337 kW/m^2
2.	Average Daily Sunshine	10 hours	6 hours**
3.	Humidity	39%	(36-46)%**
4.	Temperature	41^{0}C	

* Instrument: Solarimeter. ** NIMET data for the last 5 years

Transferable Load to Solar PV System

To ascertain the proportion of the electricity load that can be efficiently transferred to solar PV, an assessment of the power consumption in the building was carried out. The power consumption estimate was arrived at by computing all the lighting points, total fans, printers and personal computers in use in the Commission as shown in table 3.1.10.

Table 3.1.10: Quantity of Selected Appliance

S/N	Floor	Types and Quantity			
		Lighting	**PC**	**Fan**	**Printer**
1	Ground	167	11	17	3
2	First	90	28	7	9
3	Second	86	49	23	22
4	Third	207	70	7	5
5	Fourth	151	18	10	29
	Total	**701**	**176**	**64**	**68**

Energy Consumption and Cost

The energy consumption of the building on a monthly and annual basis was obtained. The total energy consumption in KWh and in naira for the last three years (2014–2016) was collected with respect to electricity from the grid and electricity from diesel generators. The data collected is presented in the table 3.1.11 below. The data is very important for cost benefit analysis of integrating solar PV into the building.

Table 3.1.11: Annual Electricity Consumption

S/N	**Parameter**	Consumption **Cost (₦)**			**Consumption, kWh**		
	Year	2014	2015	2016	2014	2015	2016
1	Grid	9,006,443	5,790,291	7,613,071	249,003	244,419	165,217
2	Generator	NA	10,140,000	14,710,500	NA	262,035	417,375

Diesel Generator: 350kVA, MIKANO

Existing Electricity Wiring

This is a very important aspect of the audit. An assessment of the existing circuitry in the building was carried out to ascertain the ease of solar PV integration. The result of this assessment can be seen in table 3.1.12.

Table 3.1.12: Electric Wiring

S/N	Parameter	Quantity	Description	Possibility Of Use	Modification required
1	Distribution Board	7	Mem (3)	Yes	Yes
2	Feeder pillar	1	Schneider (4)	Yes	No
3	Circuitry	-	Conduit	Yes	No

Note: the circuitry of lighting points and Plug loads are in ring form while ACs are in radial form.

3.1.3.1.2 Summary of the Cost of Integrating Solar PV into the Energy Mix

Below is the summary of Technical Specifications of Integrating Roof-Top Stand Alone Mini Grid to Energy Mix of ECN as alternative to Diesel Generator; the detailed calculations are in appendices Nos. 19 and 20.

Option A: Powering the Entire Electrical Loads

1. Load = 156.25kW
2. Energy (Wh/day) = 625,033.2Wh/day at 4 hours
3. Module = 695Nos. (300W, 24V)
4. Battery = 49Nos. (1000Ah, 2V)
5. Charge Controller = 37Nos. (60A, 24V)
6. Inverter = 190kVA=4Nos @ 50kVA each (48Vd.c, 230Va.c)
7. Space for 695 Modules: = 1,610m^2
8. Space for Battery Bank and Accessories = 12.96m^2
9. Total Cost = ₦184,037,053.00

Option B: Powering the Entire Loads Less ACs

1. Load = 28.91kW
2. Energy (Wh/day) = 115,625.25Wh/day at 4 hours
3. Module = 129Nos. (300W, 24V)
4. Battery = 9Nos. (1000Ah, 2V)
5. Charge Controller = 7Nos. (60A, 24V)
6. Inverter = 36.125kVA = 1No. @ 40kVA; (48Vd.c, 230Va.c)
7. Space for 129 Modules: = 298.84m^2
8. Space for Battery Bank and Accessories = 12.96m^2
9. Total Cost = ₦44,543,853.00

Cost of integrating Option A was estimated at ₦184,037,053.00 and it was designed to power the entire ECN loads for four (4) hours daily as alternative to diesel generator. At the time of the study, average annual cost of providing diesel to run the generator was ₦13.5million.

- Assuming the maintenance cost of both systems (RE and diesel generator) are equal, the simple pay-back period was calculated to be about fourteen (14) years; and it is expected to be shorter with time because the operational cost of diesel generator is expected to be higher as result of continuous increase in price of diesel per liter. Furthermore, the expected improvement in grid electricity should not shift the equation in favour of the diesel generator because of also continuous increase in electricity tariff according to Multi-Year Tariff Order (MYTO).

The cost of Integrating Option B was computed to be ₦44,543,853.00.00 and it was designed to power the entire lighting and plug loads for four (4) hours daily as a total replacement of diesel generator (back-up). From the result of the energy audit, the average total energy consumption of lighting and plug loads was measured to be 24.08kWh and the proportion (from the total) of cost of diesel to power the appliances was computed to be ₦2.53m.

- Going by the same assumptions as above, the simple pay-back period is eighteen (18) years. Also, as the price per liter of diesel goes up and prices of RE decreases, the pay back will become shorten.

NB. The pay-back periods of 13.5 and 17.6 years may seem not encouraging; however, with time the pay-back period will actually shorten. Furthermore, its advantages of GHG emission reduction and other environmental benefits and, conservation of petroleum resources are reasons why the economics of Solar PV electricity as viable alternative to diesel generator in public buildings must be given consideration to make it a reality.

3.1.3.2 Section 2: Bio-Climatic Design Energy Audit

Bioclimatic design is the foundation for an energy efficient building. The aim of a bioclimatic design is to optimize environmental conditions within a building mainly by controlling heat loss and gain from the building. This section presents the results of bioclimatic design energy audit undertaken to assess the level of the building compliancy with bioclimatic design requirement and also to identify the areas for further improvement.

Geographical Location of the Building

The building is located on the highland close to a perennial stream and oriented (the length of the building) to the N40^{0}E. The location of the building is at an angle to the sunpath as shown in table 3.1.13.

Table 3.1.13: Geographical Location of the Building

S/N	Parameter	Description
1	Topography	Hilly, close to perennial stream
2	Orientation	Front side: N40^{0}E; Backside: S40^{0}W

Architectural Design

The building is a storey building with five floors which are further partitioned into rooms using mostly plywood. The building has three (3) different types of windows but the dominant window type is the biggest with the size of (0.7×1.9) m. Doors are made of glass, wood and aluminum. The generated data is presented in tables 3.1.14 and 3.1.15.

Table3.1.14: Architectural Design of the Building

Parameter	Type of Building	No of Floors	No of Office Rooms	Remarks
Building	Detached Storey	5	147	• There is plywood partitioning • Most rooms are partitioned into two

Table 3.1.15: Architectural Design of the Building – Windows and Doors

S/N	Parameters	Size (metre)	Type/ Material	Qty.	Description	Remarks
1	Windows	0.79×1.09 0.66×0.76 0.61×0.61	Glass Glass Glass	149 6 5		• Most of the windows are faulty. (some are broken and some do not close properly)
2	Doors	0.79×2.04 0.79×2.04	Wooden Wooden/ Glass	42 105	Projected	• Some doors are wooden, some are wooden and glass. • Most doors do not close properly. • Most of the doors have gaps in between the frame and door pane.
3	Roof	26.24×16.1	Aluminum (Al)	NA	Roofs slanted to North and South at angle <30^0	• There is an existing solar installation on the roof.
4	Partition	NA	Wood, Glass, Al., & Louvers	NA		• Most of the partitions were not properly done.

3.1.3.3 Key Findings

Availability of Space for solar panels, batteries is a key consideration in the integration of solar PV in a building. The available spaces were identified the roof top for mounting of solar PV panels and the mini stores on each floor to serve as the power house and battery bank; however, an appropriate office-room can be converted to power house if need be.

Technical Capacity: The Commission has the capability of solar PV design, installation and maintenance.

Building Orientation with respect to the sun-path is very important in the aspect of minimizing heat gains. The location of the Commission's building is at angular to the sun-path which implies there is some heat gain into the building. The windows of the building are facing north and south which is the best orientation for this climate.

Building Form and Geometry: The various office rooms in the Commission are partitioned with plywood. There are gaps in the partitioning and also poor overlap of door frame and pane (see Plates 3.1.4 and 3.1.5). Poor functioning windows and doors also encourage heat gain within the building. The windows are old and do not have any coating. The poor building form and geometry affect the effective cooling of the office (Appendix 27).

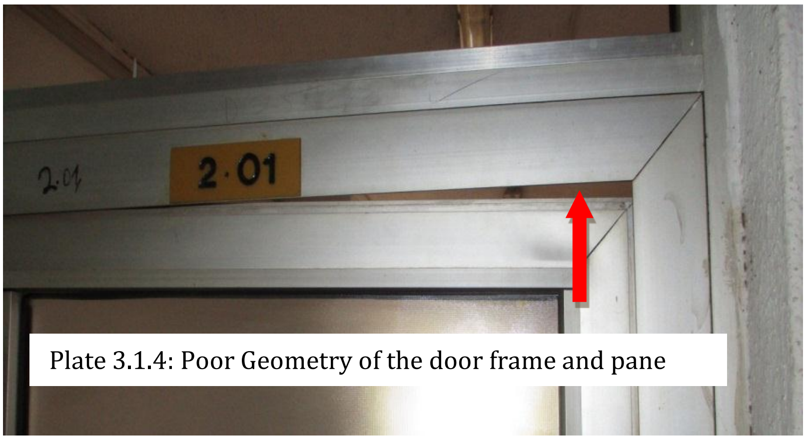


Plate 3.1.4: Poor Geometry of the door frame and pane

Building Envelope: There are no huge trees serving as shading to the solar radiation entering the building. The presence of sun breakers in the form of projected walls on the building however has helped by reducing the direct solar radiation from entering the building while not affecting the day-lighting effect, though the size of the windows is small to take maximum advantage of the daylight (see Plate 3.1.6).

Cost of Integration Solar PV System: The study revealed that it is possible and affordable to power all electrical appliance and equipment in ECN using Solar PV System, however, the challenge may be the fourteen (14) to eighteen (18) years simple pay-back period; See Appendices Nos. 19 and 20.

Plate 3.1.5: Small Window Size

3.2 Consumers Protection Council

Mandate: The Consumer Protection Council (CPC) is an agency of the Federal Government of Nigeria, under the Federal Ministry of Trade and Investment. The Council was established by Act No. 66 of 1992. The agency however commenced operations in 1999. The CPC is mandated to eliminate hazardous products from the market; provide speedy redress to consumers' complaints; undertake campaigns that will lead to increased consumer awareness; ensure that consumers interest receive due consideration at the appropriate forum; and encourage trade, industry and professional associations to develop and enforce in their various fields quality standards designed to safeguard the interest of consumers.

Building Description: The headquarter of the CPC is located at Plot 1105, Dar-es-Salam Street, Wuse II, Abuja (Plate 3.2.1). The building consists of two Blocks; A and B. Block A has been occupied for about 12 years while Block B just for only 2 years. The walls are concrete walls and the floor is made up of ceramic tiles.

Plate 3.2.1: CPC Headquarters

Activities: The building comprises of offices except for the laboratory, Television and Radio studios. In addition to the office of the Director-General, the Council has seven departments occupying the building. They are: Administrative Department; Account Department; Consumer Education Department; Surveillance and Enforcement Department; Quality Assurance Department; Planning Research and Statistic Department; Legal Department. There are three units directly under the Office of the Director-General; they are the Public Relation Unit, Audit Unit and the Procurement Unit. The energy management activities are under the Maintenance Unit. The study revealed that no member of staff had been trained on energy efficiency and conservation. There was a previous energy audit conduct on the Block B in 2010; however the report of the audit could not be accessed during this audit. There are about 130 occupants of the building. Like most public service, CPC operates from Monday to Friday between the hours of 8am and 4pm.

3.2.1 Electrical Energy Audit

3.2.1.1 Sources of Power Supply

There are two main sources of power supply to the CPC building – electricity from the utilities and standby generators. In addition, there is a battery bank and an inverter machine installed to ensure uninterrupted power supply to the Server Room.

Public Utility: Table 3.2.1 shows the monthly and annual electricity bill of the CPC from 2013 to 2016. The highest electricity bill was recorded in the year 2015. In the year 2013, the highest electricity bill was paid in the month of December (₦266,859.87), while in the year 2014, electricity bill was highest in the month of July (₦468,468.24), the electricity bill was highest in month of October in the year 2015 (₦392,051.56) and in the year 2016, the highest bill was paid in the month of March (₦551,965.43). It should be noted that the amount of energy consumed and consequently electricity bill in a particular month depends on the supply by the utility company.

Table 3.2.1: Monthly Electricity Consumption for Years 2013–2016 in Naira

Month	Electricity Bills, Naira			
	2013	**2014**	**2015**	**2016**
Jan.	167,799.87	266,859.87	254,725.68	228,535.17
Feb.	144,094.00	219,972.87	215,603.19	100,321.20
March	147,491.14	265,049.19	215,554.15	551,965.43
April	144,094.00	200,321.20	244,244.22	287,074.43
May	128,485.38	250,210.42	324,644.62	287,074.43
June	128,485.38	315,769.15	167,402.95	261,298.90
July	19,250.62	468,468.24	323,317.93	210,573.03
Aug.	176,043.43	219,972.87	157,612.98	210,573.03
Sept.	170,526.66	265,049.19	323,317.93	262,852.22
Oct.	138,535.88	200,321.20	392,051.56	319,985.57
Nov.	255,532.06	250,210.42	350,989.29	231,882.69
Dec.	266,859.87	254,725.68	350,989.29	231,882.69
Total	**1,887,198.29**	**3,176,930.30**	**3,320,453.79**	**3,184,018.79**

Standby Generator: There are two diesel-powered private generators serving the entire office complex – they are 150 KVA (GMJ) and 250 KVA (FG Wilson) generators. From the information made available during the study, it was difficult to determine the unit cost of energy charged to the building by the utilities and the quantity of diesel used by each generating set.

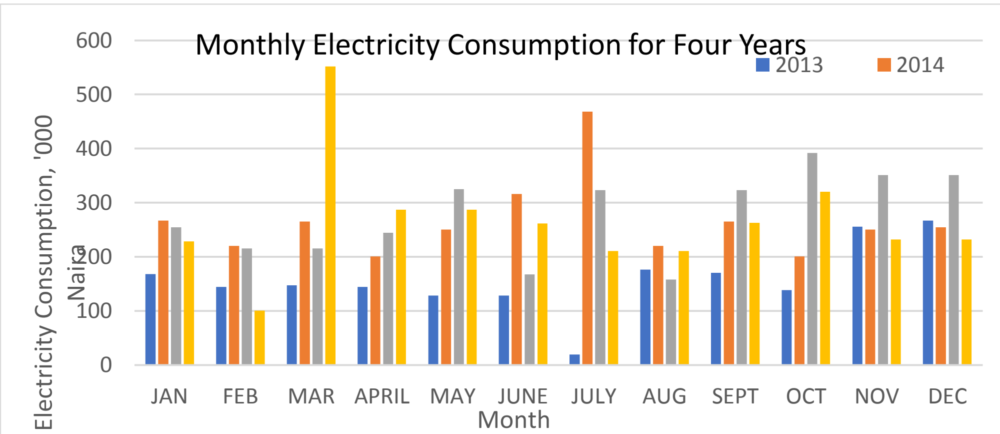


Chart 3.2.1: Monthly Electricity Consumption for Years 2013–2016 in '000 Naira

3.2.1.2 Measured Consumption

3.2.1.2.1 The Measured Average Hourly Energy Consumption of CPC Building

The Measured Average Total Energy Consumption is 76.46kWh per hour (Table 3.2.2); it should be noted that the back-up diesel generators manufacturer's power rating are 150kVA and 250kVA though they work alternatively.

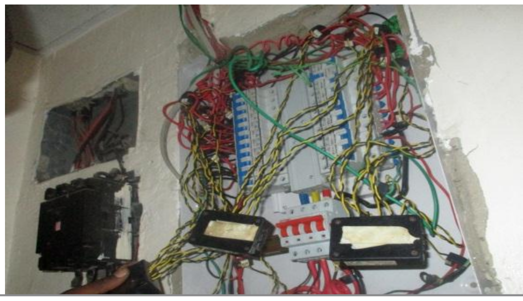
Table 3.2.2: Average Measured Total Consumption, Wh

ANNEX A	Total	ACs	Others
Ground Floor	5,654.23	3,315.83	2,338.40
1st Floor	17,556.57	11,089.29	6,467.28
2nd Floor	15,448.86	7,208.14	8,240.72
ANNEX B			
Ground Floor	6,715.79	4,171.64	2,544.14
1st Floor*	12,500.00	8,000.00	4,500.00
2nd Floor	11,575.09	7,498.36	4,076.73
Lab	2,623.79	2,604.36	19.43
Studio	4,387.43	3,980.14	407.29
Grand Total	**76,461.75**	**47,867.76**	**28,593.99**

- The DB on the floor was faulty at the time of the audit, hence the consumptions were interpolated on the basis of floor with similar occupancy and appliances

3.2.1.2.2 Air Conditioners

Unlike the ECN building, there were very few window unit air conditioners in CPC building, 91% of the air conditioners in the building were split unit air conditioner while only 9% were window unit air conditioners. The highest number of split unit air conditioners (23) was recorded on the Ground Floor, followed by the First Floor where there are 20 split unit air conditioners and 17 split unit air conditioners on the Second Floor. The energy consumed by air conditioner ranged from 1,286kWh/annum to 5516kWh/annum. The total estimated energy consumed by air conditioners was estimated to be 164,908.26kWh/annum.



Measured Power Rating for Air Conditioners: The measured average energy consumption per hour of significant numbers of air conditioners in the buildings was higher than the declared power rating by the manufacturers (Chart 3.2.3). Of the 66 ACs in the building only the 26 ACs that were working at the time of the study were measured and they consume an average of 47,867.76Wh per hour representing 63% (Table 3.2.2 and Chart 3.2.2) of the total electricity consumption in the buildings. The difference between the declared rating by the manufacturers and the measured rating may be because of the age of the appliances.

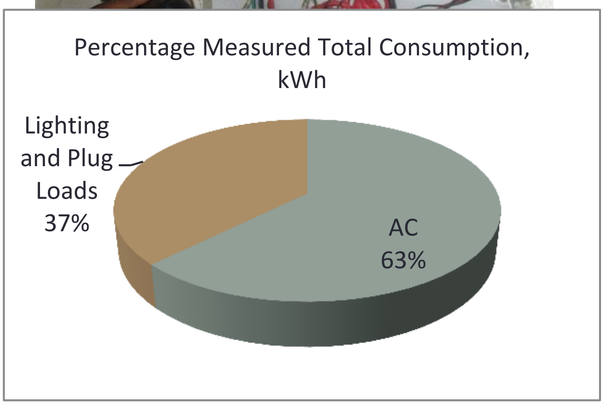


Chart 3.2.2: Total Energy Consumption in CPC in Percentage

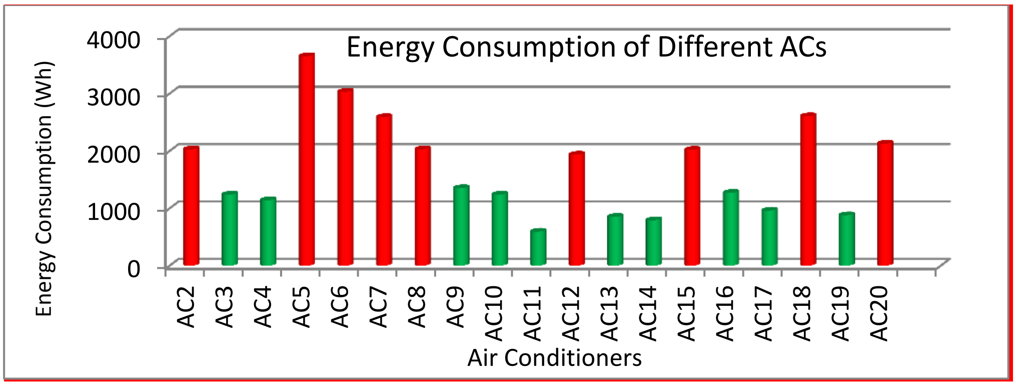


Chart 3.2.3: Measured Average Energy Consumption per Hour of Different ACs in Wh.

3.2.1.2.3 Lighting Appliances

Three types of lighting equipment were found in the building, they include the linear fluorescent lamps (LCLs), the compact fluorescent lamps (CFLs) and the light emitting diodes (LEDs). The most abundant of the lighting equipment was LFLs (544), followed by the CFLs (135) and the LED (1). The highest number of LFLs was recorded on the First Floor, while the highest number of CFLs was recorded on the Second Floor. See Appendices Nos.26 and 27.

3.2.1.2.4 Desktop Computers

Desktop computer is a system made-up CPU and Display Monitor (LCD). The study revealed that there are 65 Desktop computers in the building, out of which 33 were recorded on the First Floor, 17 on the Second Floor and 15 on the Ground Floor.

a. LCD Monitor

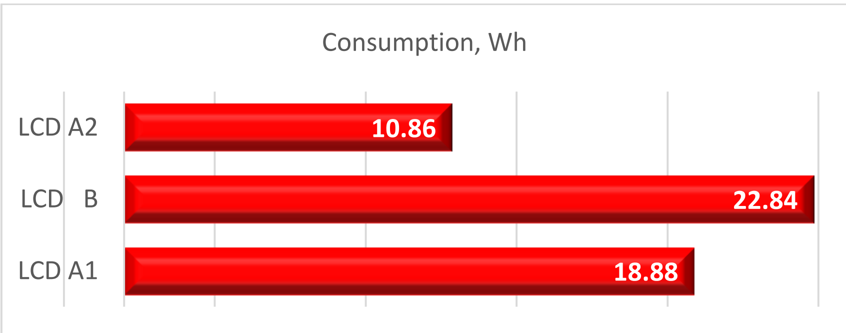


Chart 3.2.4: Measured Average Hourly Energy Consumption of Different LCDs in Wh

The serial wattmeter readings for the three LCDs sampled is depicted in the chart 3.2.4. LCD A1 and A2 are of the same brand but different models while LCD B is a completely different brand. Based on the readings, average energy consumption per hour of LCDs were established as indicated in the chart and were found to be within the monitor's standard ratings of 20W to 60W. The difference in the values may be due to difference in usage.

b. Central Processing Unit (CPU)

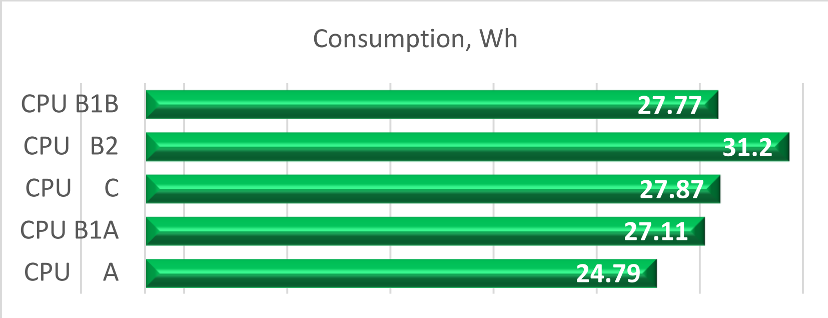


Chart 3.2.5: Measured Average Hourly Energy Consumption of Different CPU in Wh

CPUs A, B1A and B1B are of the same brand but different models. The power consumption pattern for a CPU is majorly determined by the nature of tasks it performs. From the chart above, CPU B2 consumes 31.2Wh while CPU A consumes 24.79Wh. All the above readings are within the manufacturers' ratings for CPU.

3.2.1.2.5 Laptop Computers

Out the 26 laptop computers found in the building, 14 (54%) were found on the First Floor, 7 (27%) on the Ground Floor and 5 (19%) on the Third Floor. It was estimated that all the laptop computers in the building consume 987kWh/annum.

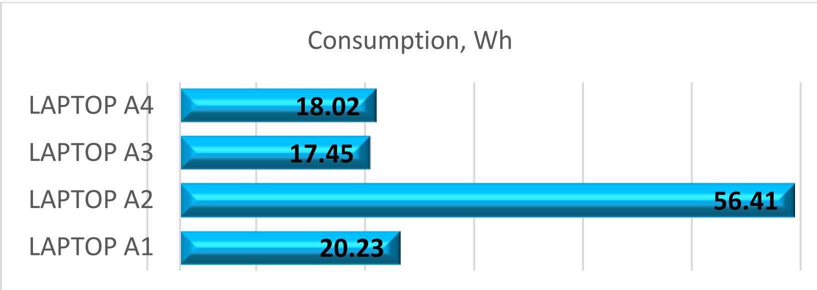


Chart 3.2.6: Measured Average Hourly Energy Consumption of Different Laptops in Wh

All the Laptops considered were of the same brand but different models. The consumption of 56.41Wh for Laptop A2 suggests that this Laptop was been used to perform quite a number of tasks while the lower values of 18.02Wh for Laptop A4, 17.45Wh for Laptop A3 and 20.23Wh for Laptop A1 implies that the Laptops were been used for lesser tasks.

3.2.1.2.6 Smart Touch Computers

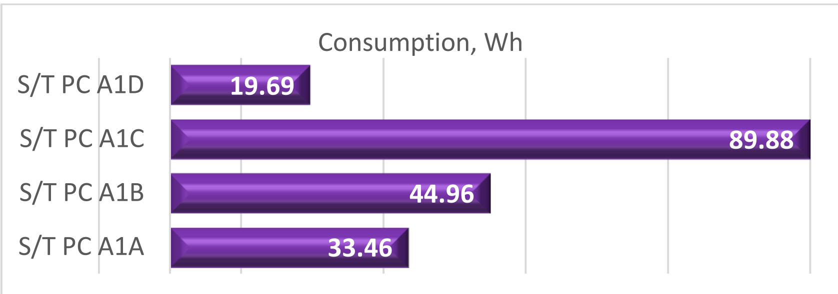


Chart 3.2.7: Average Measured Consumption of Different Smart Touch Computers in Wh

The Smart Touch PC A1C with a power consumption of 89.88Wh per hour was in active use for the period been considered during the study. The level of usage of the other Smart Touch PCs was not as high as that of A1C.

3.2.1.2.7 Printers

There are 30 printers found in use in the office complex, 11 were recorded each on the First and Second Floor while 8 were recorded on the Third Floor. The total electricity consumed by all the printers was estimated to be 475.50 kWh/annum.

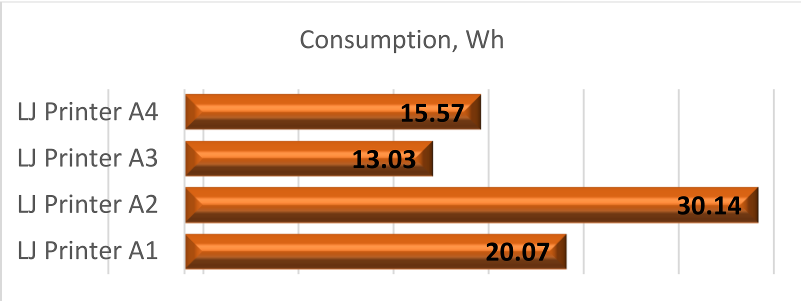


Chart 3.2.8: Measured Average Hourly Energy Consumption of Different Printers in Wh

All the printers were of the same brand. LaserJet Printer A2 consumed the most amount of power due to its frequency of use followed by LaserJet Printer A1, A4 and A3 in that order.

3.2.1.2.8 Photocopier Machines

There are 9 photocopier machines in the entire office complex, 5 on the First Floor and 2 each on the Ground Floor and Third Floor.

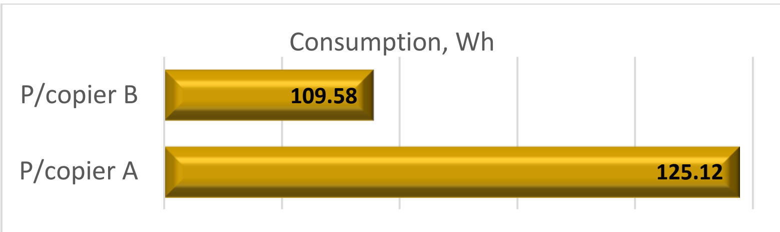


Chart 3.2.9: Measured Average Hourly Energy Consumption of Different Photocopiers in Wh

The two photocopiers were of different brands and with a per hour power average consumption of 125.12Wh for Photocopier A while its plate label is 1400W and 109.58Wh for Photocopier B while its plate label is 1200W.

3.2.1.2.9 Refrigerators

During the study, a total of 13 fridges and 5 water dispensers were recorded in the building. The highest number of fridges (5) was found in the Second Floor while the Ground Floor and the First Floor had the highest number of water dispenser that is 2 on each floor

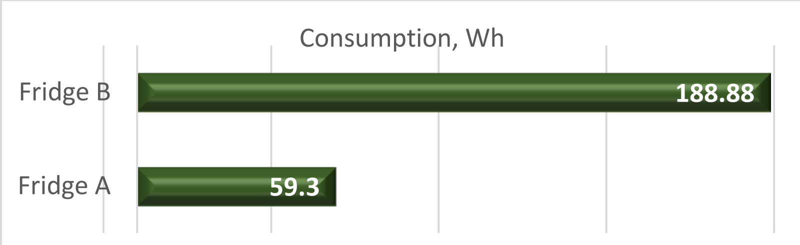


Chart 3.2.10: Measured Average Hourly Energy Consumption of Different Fridges in Wh

Both Fridges were not of the same brand but however, Fridge A recorded 59.3Wh while its plate label is 150W and Fridge B recorded 188.88Wh per hour against the plate label of 150W (Chart 3.2.10).

3.2.1.2.10 Television Set

A total of 19 television sets were found during the study with highest number (8) found on the Ground Floor, followed by the Second Floor (6) and the Third Floor (5). From the measured values using the serial wattmeters, the least power rating of the television sets is about 40W while the highest power rating was about 100W. The total energy consumed by the TV sets is estimated to be 2002.03kWh/annum.

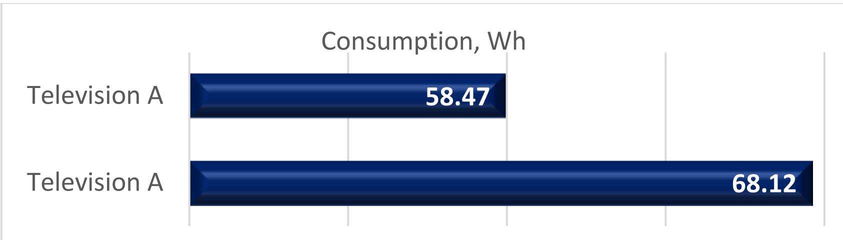


Chart 3.2.11: Measured Average Hourly Energy Consumption of Different Televisions in Wh

Television A recorded 68.12Wh against it plate label of 58W while Television B recorded 58.47W which was less its plate label of 108W.

3.2.1.2.11 Electric Fans

A total of 18 electric fans were recorded during the study, 9 recorded on the Ground Floor, 7 on the First Floor and 2 on the Second Floor. The total energy consumption of all the electric fans was estimated to be 2,329.2kWh/annum.

3.2.1.2.12 UPS and Automatic Voltage Regulator

The study revealed that there is a total of 25 uninterruptible power supply (UPS) machine in the building and 7 automatic voltage regulator machine. The highest number of UPS machine was recorded on the First Floor and lowest number was recorded on the Second Floor.

3.2.1.2.13 Other Equipment

The other equipment in the building during the study included one microwave machine on the Second Floor, an electric stove popularly call "hot plate" found on the Ground Floor and one paper shredder machine found on the First Floor.

3.2.2 Behavioural Energy Audit

A total of 27 interviews (25% of the population) were planned while 23 Nos. of those interviews were successfully completed. The responses of the interviewees were coded yes, no, others; 0, 1, 2 and others; and presented in the following charts:

3.2.2.1 Occupants' Attitude to Lighting

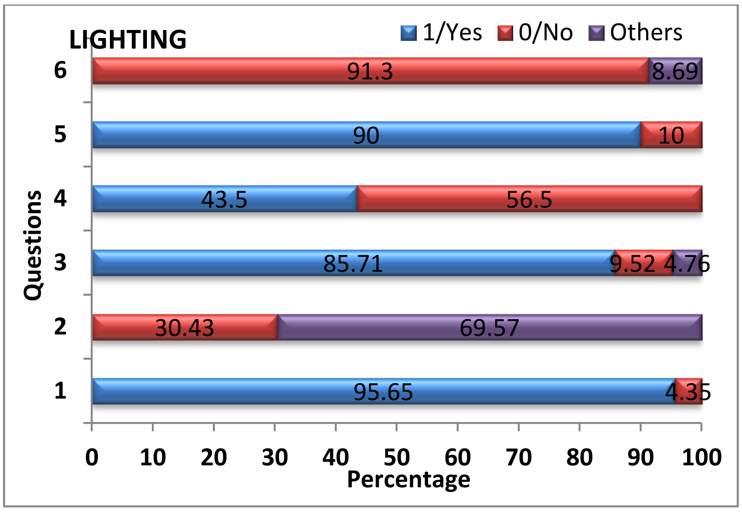


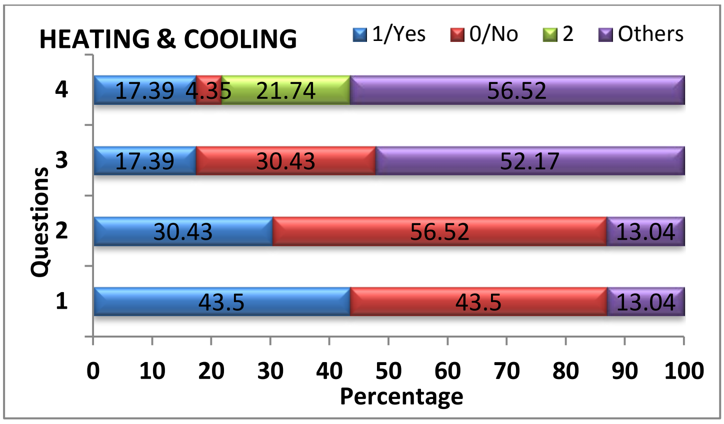
Chart 3.2.12: Response of Occupants on their Attitude to Lighting

Questions

1. Is lighting in your office off after working hours?
2. Is the toilet lighting in your floor always on even when not in use?
3. Is your office using the energy efficient lamps (CFLs, LEDs)?
4. Is the daylight in your office adequate without electric light?
5. If answer to 4 is yes, do you use the daylight instead of electric light at times? *(If answer to 4 is No, skip).*
6. Have you seen lighting management device such as dimmers, timers and sensors installed anywhere in this building?

It can be deduced from the above chart that 95.65% of respondents put off lights in their offices after working hours, while 30.43%put off light when leaving the toilet, possibly due to the fact that 69.57% of toilet lighting was not functional. The chart also revealed that the lighting in the CPC offices was efficient; 85.71% respondents confirmed that CFLs was in use. On the issue of adequacy of day lighting 43.5% respondents said the day light in their offices was adequate without electric light while 56.5% responded in the negative. 90% respondents that considered the day light adequate said that they use day light in their offices instead of electric light. Over 90% respondents do not know and have never seen energy management devices installed anywhere in the building, whereas about 9% do not know what sensors or dimmers were.

3.2.2.2 Occupants Attitude to Cooling and Heating



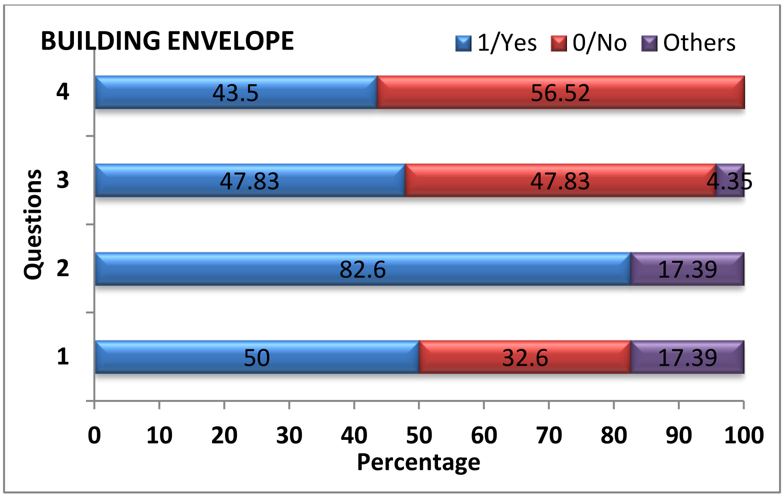
Questions

1. Is the AC in your office shut down when unoccupied during working hours?
2. Do you often use fan in place of AC?
3. Does the kettle in your office have functional thermostat?
4. How many times in a year is your AC serviced?

Chart 3.2.13: Response of Occupants on their attitude to cooling and heating

Chart 3.2.13 above shows that 43.5% respondents turned off their ACs in their offices when unoccupied during working hours, while 43.5% respondents do not and about 13% respondents reported that their ACs were faulty. 56.52% said they do not use fans in place of ACs while 30.43% do, partially because some have faulty ACs. Only 17.39% of respondents with access to electric kettle reported that their kettles have functional thermostat. 56.52% respondents said their ACs were serviced only when the need arises during the study year.

3.2.2.3 Occupants' Perception about Office Building Envelope



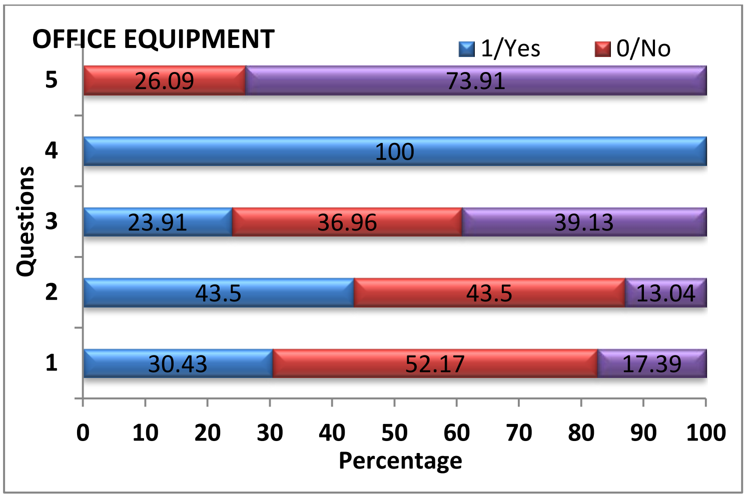
Questions

1. Is your office door always kept closed when AC is in Use?
2. Are your office windows always kept closed when AC is in Use?
3. Are the windows in your office in need of blinds to reduce/block the sun rays?
4. Is the daylight in your office adequate without electric light?

Chart 3.2.14: Response of Occupants on their Attitude to Office Building Envelope

According to chart 3.2.14, 50% respondents shut their doors when AC is in use while 32.6% do not for various reasons; however, 82.60% respondents closed their office windows when their AC is in use. Equal percentage (47.83%) said that they want blinds fixed on their windows and 47.83% said they do not need window blinds.

3.2.2.4 Occupants' Perception about their Office Equipment



Questions

- Are your desktop and laptop set on hibernation? What is the timing?
- Are your desktop and laptop shut down during working hours when not in use *(for about 20mins and more)*?
- Is the copying machine shut down during working hours when not in use?
- Do you switch off the socket(s) in your office at the close of work?
- What is the regularity of service of your ICT equipment in a year?

Chart 3.2.15: Response of Occupants on their Attitude to Office Equipment

Chart 3.2.15 shows that 52.17% respondents do not put their laptops/desktops on hibernation during working hours when not in use and 43.5% respondents said they do and they do not shut down their laptops/desktop during working hours when not in use. Only 23.91% respondents having copying machine under their care shut down their machines during working hours when not in use, while 36.96% do not, about 40% had no machine under their direct control. The chart further revealed that 100% respondents switch off sockets in their offices at the close of work. It could be deduced from the chart that 73.91% respondents usually call for maintenance of the ICT equipment only when the need arises.

3.2.2.5 Summary of the Responses

The responses of the interviewees were summarized under three headings below:

Occupant's Awareness and Compliance

The level of occupants' consciousness and compliance to some energy management practices and requirements in Consumer Protection Council (CPC) was considered high based on the affirmative responses of the interviewees to questions on shutting off light after working hours, shutting down of light and sockets at the close of work, closing of office windows and doors when ACs are in use and shutting down of ACs when the offices are unoccupied during working hours. Contrarily, the audit also revealed non-compliance of the staff to some energy management practices and standards as manifested by low number of electric kettles with functional thermostat, significant number of ACs that were not shut down when the offices are unoccupied during working hours and number of the laptop/desktop users that have not cultivated the habit of setting their systems in hibernation mode. It should be noted that any non-compliance will have consequence on the building's total energy consumption and bills and CO_2 emission with devastating effects on the environment.

Management Responsiveness

The use of energy efficient lighting (Compact Fluorescent Lamps) in the building as affirmed by the respondents is an indication of management responsiveness in ensuring compliance to energy efficiency practices and requirements. However, absence of energy management devices and promotional materials in the building and non-prompt fixing of faulty lights and doors are pointers to the low responsiveness.

Building Envelope

Areas of particular concern in the building envelope of Consumer Protection Council were the inadequate daylight in some offices, excess number and size of windows in others, partition style and materials of some offices and non-partition of other large office rooms; from what was observed during the energy audit all the above can hinder energy efficiency in one way or the other.

3.2.3 Renewable Energy and Bioclimatic Design Energy Audit

3.2.3.1 Section 1: Renewable Energy Audit

Solar PV Integration Assessment

Table 3.2.3: Assessment of Space for Solar PV Array Installation

S/N	Assessment parameter	Availability	Possibility	Angle of Inclination (º)	Orientation	Remark
1	Roof-top 1	Yes	Yes	≤ 60	North, South	
2	Roof-top 2	Yes	Yes	-	North West, South East	
3	Roof-top 3	No	No	-	-	
4	Parking lot 1	Yes	No	-	-	
5	Parking lot 2	Yes	No	-	-	

Roof- top 1: Main Building, Roof-top 2,3: Annex Building, Parking lot 1 (PL): Management PL, Parking lot 2: Staff PL.

Table 3.2.4: Assessment of Space for Solar PV Power House

Item	Availability	Possibility	Size(m)
Lobbies/Unused Toilets Space	Yes	Yes	Not quantified.

The assessment as presented in tables 3.2.3 and 3.2.4 show that the Council has three roof tops with two of them available and possible for integration of Solar PV. Also, two parking lots are available but do not meet required criteria for possible use. Table 3.2.4 shows that the lobbies and unused toilets can be used as power house for the solar PV (i.e. storage for batteries, inverter and controllers).

Transferable Load to Solar PV System

Table 3.2.5: Quantity of Selected Appliance

S/N	Floor	Types & Quantity			
		Lighting	PCs	Fans	Printers
1	Ground	30	1	1	-
2	First A&B (1st Building)	52	10	3	5
	C&D (2nd Building)	83	12	3	4
3	Second A	32	5	1	1
	DG	4	5	-	2
	Total	201	33	8	12

Table 3.2.5 shows the quantities of different appliances in each floor were carefully computed for assessment, estimation and design.

Solar Energy Resources

Table 3.2.6: Solar Energy Resources

S/N	Assessment Parameter	Readings	
		Measured	Literature
1	Irradiation (kW/m^2)	5.57kw/m^2	5.337 kw/m^2
2	Average sunshine daily hours (Hr)	10hours	6hours
3	Humidity of the area (%)	38.5%	(36 - 46)%
4	Temperature (Degree Celsius)	39.5^{0}C	(19-45)^{0}C

Instrument: Solarimeter; NIMET data for the last 5 years

Table 3.2.6 shows the values for irradiation, average sunshine hours, humidity and temperature were all measured as against the values available from literature.

Energy Consumption and Cost

Table 3.2.7: Annual Electricity Consumption

S/N	Assessment Parameter	Cost (₦)			Kwh		
	Consumption	2014	2015	2016	2014	2015	2016
1	Grid	3,176,930.3	3,320,453.78	3,184,018.79	34,906	64,734	56,950.4
2	Generator	NA	7,470,000	3,600,000	NA	41,500L	20,000L

L= Litre of Fuel, Generators: 250kVA FG Wilson, 150kVA MIKANO Sperkins, NA: Not Available.

The energy consumption in the year 2014, 2015 and 2016 in Naira and kWh for the grid and diesel generator is computed; for cost benefit and technical-economic analysis, See table 3.2.7.

Existing Electricity Wiring

Table 3.2.8: Electric Wiring

S/N	Assessment Parameter	Quantity	Description	Possibility Of Use	Modification required
1	DB	6		Yes	Yes
2	Electrical Feeder Pillar	1		Yes	Yes
3	Circuitry	NA	Conduit	Yes	Yes

Note: Lighting points are in ring form. Air Conditioners are in radial form.

Table 3.2.8 shows that the building has six numbers of Distribution boards and one electrical feeder pillar. All these can be integrated without any modification required. The circuitry is in conduit and is possible for integration.

3.2.3.1.1 Summary of the Cost of Integrating Solar PV into the Energy Mix

Below is the summary of Technical Specifications and cost of Integrating Roof-Top Stand Alone Mini Grid to Energy Mix of CPC as alternative to Diesel Generator; the detailed calculations are in appendices Nos. 21 and 22.

Option A: Powering the entire electrical loads

1. Load (Mini Grid Capacity) = 91.754kW
2. Energy (Wh/day) = 367,016.4Wh/day at 4 hours
3. Module = 408Nos. (300W, 24V)
4. Battery = 29Nos. (1000Ah, 2V)
5. Charge Controller = 22Nos. (60A, 24V)
6. Inverter = 115kVA=3Nos @ 40kVA each (48Vd.c, 230Va.c)
7. Space for 408 Modules: = 945.17m^2
8. Space for Battery Bank and Accessories = 9.26m^2
9. Total Cost = ₦110,768,403.00

Option B: Powering the entire loads less air conditioners

1. Load (Mini Grid Capacity) = 34.312kW
2. Energy (Wh/day) = 137,251.152Wh/day at 4 hours
3. Module = 129Nos. (300W, 24V)
4. Battery = 11Nos. (1000Ah, 2V)
5. Charge Controller = 8Nos. (60A, 24V)
6. Inverter = 45kVA = 1No. @ 45kVA; (48Vd.c, 230Va.c)
7. Space for 129 Modules: = 354m^2
8. Space for Battery Bank and Accessories = 9.26m^2
9. Total Cost = ₦43,886,588.00

Cost of integrating Option A was estimated at ₦110,768,403.00 and it was designed to power the entire CPC loads for four (4) hours every day as complete alternative to diesel generator. At the time of the study, average annual cost of providing diesel to run the generator was ₦5.5million.

- Assuming the maintenance cost of both systems (RE and diesel generator) are equal, the simple pay-back period was calculated to be about twenty (20) years; and it is expected to be shorter with time because the operational cost of diesel generator is expected to be higher as result of continuous increase in price of diesel per liter. Furthermore, the expected improvement in grid electricity should not shift the equation in favour of the diesel generator because of also continuous increase in electricity tariff according to Multi-Year Tariff Order (MYTO).

The cost of Integrating Option B was computed to be ₦43,886,588.00 and it was designed to power the entire lighting and plug loads for four (4) hours daily as a total replacement of diesel generator (back-up). From the result of the energy audit, the average total energy consumption of lighting and plug loads was measured to be 28.593kWh and the proportion (from the total) of cost of diesel to power the appliances was computed to be ₦2.06m.

- Going by the same assumptions as above, the simple pay-back period is twenty one (21) years. Also, as the price per liter of diesel goes up and prices of RE decreases, the pay back will become shorten.

NB. The pay-back periods of 20 and 21 years may seem not encouraging; however, with time the pay-back period will actually shorten. Furthermore, its advantages of GHG emission reduction and other environmental benefits and, conservation of petroleum resources are reasons why the economics of Solar PV electricity as viable alternative to diesel generator in public buildings must be given consideration to make it a reality.

3.2.3.2 Section 2: Bio-Climatic Design Energy Audit

Geographical Location of the Building

Table 3.2.9: Geographical Location of the Building

S/N	Assessment Parameter	Description
1	Topography	Shaded (Adjacent building may impede air circulation)
2	Orientation	Front side: SE; Backside: NW

The topographical location of the building is noticed to be shaded with orientation having front side facing SE and back view to NW (table 3.2.9).

Architectural Design

Table 3.2.10: Architectural Design of the Building

Assessment Parameter	Type of Building	Floors/Building	No of office rooms	Remarks
Building	Detached Storey	3	47	• CPC is an office with (2) detached two story buildings

Table 3.2.11: Architectural Design of the Building – Windows and Doors						
S/N	**Assessment Parameters**	**Size (m)**	**Type/Material**	**Quantity**	**Description**	**Remarks**
1	Windows	2.405×1.46	Glass	48		
		1.20×1.20	Glass	11		
		1.72×1.05	Glass	6		
		0.52×0.52	Glass	197		
2	Doors	1.82×2.00	Glass	6	Projected	
		1.35×2.00	Glass	8	Projected	
		1.22×2.00	Glass	36	Projected	
		0.92×2.00	Wood and Metal	36	Projected	
3	Roof 1 Roof 2	25.3×10.66 25.3×10.66	Aluminium	2	Roof 1 slanted (<60^{O}) to the North and South while Roof 2 slanted (<60^{O}) to North West and South West	
4	Partition	NA	Wood, Aluminium, Glass and Louvers	NA	Office rooms partitioned with glass/ aluminum	Partitions not properly done.

CPC building is a detached story building with three floors and forty seven rooms. The roof, windows and doors are shown in table 3.2.11 with their different sizes, material and quantity. The partition was done with wood, aluminum, glass and louvers. The data is presented in table 3.2.10 and 3.2.11.

3.2.3.3 Key Findings

Availability of Space: This is a key consideration in the integration of solar PV in a building. The available spaces for mounting the solar panels were identified as the roof top and the lobby on each floor. The roof top for mounting of solar PV panels and the mini stores to serve as the power house and battery bank. The available space is very important as it determines the amount of solar panels that can be mounted which in turn determines the amount of solar energy that can be generated.

Technical Capacity: The Council will either train the maintenance unit personnel to handle operation and maintenance of the Plant or employ qualified technicians for the job.

Building Orientation: This is very important in the aspect of minimizing heat gains. The orientation of the building with respect to the sun path is very important. The location of the Council's two building is an angular to the sun path which implies there is some heat gain into the building. The majority of windows in the two buildings are facing north and south which is the best orientation for this climate. However, some windows are located on the east and west side of the building which allows some solar radiation directly into the building.

Building Form and Geometry: The various office rooms in the council are partitioned using aluminum and glass materials. The partitioning in the office is well done and there are very little leakages of air.

Building Envelope: There are no huge trees serving as shading to the solar radiation entering the building.

Cost of Integration Solar PV System: The study revealed that it is possible to power all electrical appliance and equipment minus ACs in CPC using Solar PV System. However, the challenge is the cost of integration with about 21 to 22 years simple pay-back period.

3.3 Rural Electrification Agency

Mandate and Activities: Rural Electrification Agency (REA) was established through Section 88 of the Electric Power Sector Reform Act 2005 in March 2006. It is a Federal Government Agency saddled with the responsibility of providing electricity to rural communities in Nigeria; undertaking basic planning and preparation of projects in line with the Indicative Rural Electrification Masterplan (IREMP). The agency came into existence as a result of the commitment of the Federal Government to aggressively implement rural electrification as dictated in some policy documents that outlined the principle for Rural Electrification. These documents include the: National Energy Policy in 2003, Electric Power Sector Reform Act in 2005, Rural Electrification Policy in 2005, and the National Electric Power Policy in 2001. The agency is vested with capacity to mobilize investible capital for sustained public and private-sector investment in rural electrification development in Nigeria for improved living conditions in the rural areas through enhanced agricultural, commercial, industrial and domestic activities, thereby providing access to reliable electric power supply for rural dwellers irrespective of where they live and what they do, in a way that would allow for reasonable return on investment through appropriate tariff that is economically responsive and supportive of the average rural customer.

Plate 3.3.1: REA Headquarters

Building Description: The headquarter is located at No. 22, Freetown Street, Off Adetokunbo Ademola Street, Wuse 2, Abuja. It is on the longitude$7^{o}29^{1}18.74^{11}$E and latitude $9^{o}4^{1}23.01^{11}$N. The property is occupied solely by the Agency as a tenant. The property is a two identical story building (block of flats) consisting of three floors each. The two buildings were labeled Block A and Block B; and each floor consisted of two flats each, making a total of six flats per block; the building was designed for residential purpose. The office building is not fully occupied. Most offices/rooms have air conditioners and at the same time well ventilated.

The Block A is occupied by the Project, Development departments, as well as the Audit, ICT, Human Resources/Admin, Legal and Audit Units. Block B is occupied by the Managing Director’s Office, and four departments: Fund Management, Procurement, Promotion, Planning and Research departments. The agency operates between the hours of 8:00am to 5:00pm daily.

3.3.1 Electrical Energy Audit

3.3.1.1 Source of Power Supply

There are two sources of power supply – power supply from the national grid and the use of standby generator during power outages. Chart 3.3.1 shows the monthly electricity consumption of the REA building from 2014 to 2016 in kWh. The electricity consumed in the building was highest in the year 2014 followed by the year 2016. From the data made available to the Energy Audit Team, the electricity consumed in kWh was the same from July 2014 to February 2015. These values seem to suggest that the building was placed on estimated billing as it is not possible to have same value for six consecutive months.

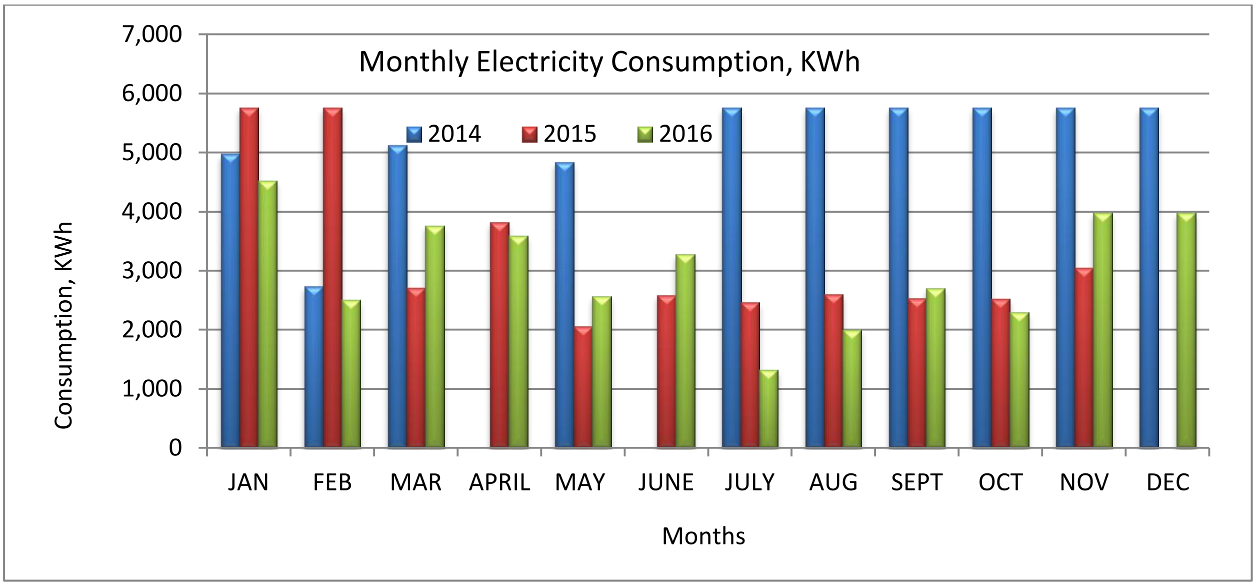


Chart 3.3.1: Monthly Electricity Consumption for Years 2014–2016 in kWh

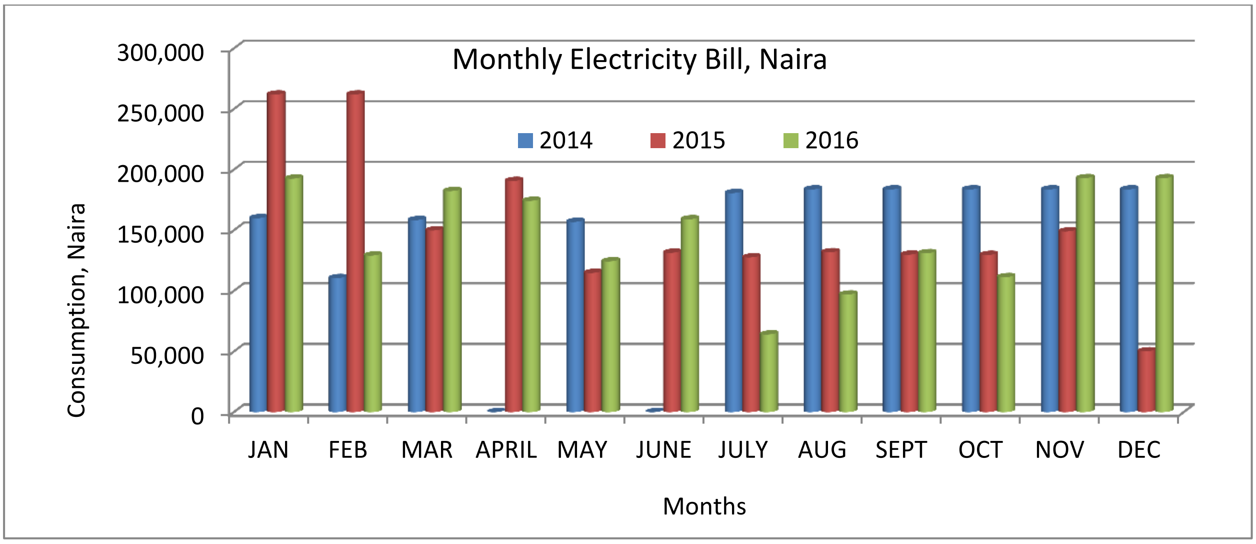


Chart 3.3.2: Monthly Electricity Bill for the Years 2014–2016 in Naira

Conversely, the total electricity bill was highest in the year 2015 followed by the year 2016 (Chart *3.3.2*). The inverse relationship between the total energy consumed and the total cost is due to the difference in the unit cost of electricity. The unit cost for electricity in the year 2014 was about ₦32/kWh, while the unit cost for electricity in the year 2015 was about ₦50/kWh and the unit cost of electricity for the year 2016 was ₦48/kWh.

Standby Generator: REA building has two generator sets each rated 110KVA (pf=0.8) and each supply power to a block separately.

Table 3.3.1: Electricity Bill for the Years 2014 to 2016

Month	Electricity Bill, Naira		
	2014	**2015**	**2016**
Jan.	159,993.98	262,022.04	192,634.55
Feb.	110,575.58	262022.04	129,172.86
March	158,420.61	149,911.98	182,370.42
April	NA	190,702.71	174,312.53
May	156,924.65	114,881.42	124,411.86
June	NA	131,502.34	159,070.50
July	180,699.36	127,661.90	64,123.32
Aug.	183,699.96	131,880.08	97,034.46
Sept.	183,699.96	129,896.91	131,110.59
Oct.	183,699.96	129,676.55	111,354.20
Nov.	183,699.96	149,077.11	193,001.00
Dec.	183,699.96	50,160.60	193,001.00
Total	**1,685,113.98**	**1,829,395.68**	**1,751,597.29**

3.3.2 Measured Consumption

3.3.2.1 Measured Average Hourly Energy Consumption

The total energy consumption, lighting and individual air conditioners in the building were measured using multivoies system while serial wattmeters were used to measure the energy consumption of the Plug loads such as computers, printers, fans and the results are presented in the table below:

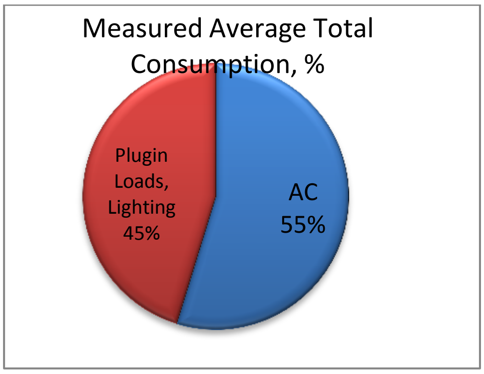


Chart 3.3.3: Percentage of Total energy Consumption of REA Building

Plate *3.3.2*: Installation of Logger Device on DB at REA

Table 3.3.2: Measured Average Hourly Consumption, Wh

	Total	**AC**	**Lighting & Plug Loads**
Annex A			
Flat 1	3803.5	2384.4	1419.1
Flat 2	4142	2688	1454
Flat 3	2999.9	1627.9	1372
Flat 4	3023.5	2592.9	430.6
Flat 5	2167.3	1650.5	516.8
Flat 6	5565	2370.2	3194.8
Annex B			
Flat 1	4369.75	2220.5	2149.25
Flat 2	5395.25	1732.75	3662.5
Flat 3	5207.6	3884.25	1323.35
Flat 4	4881	1639.87	3241.13
Flat 5	4474.25	2345.12	2129.13
Flat 6	3273.25	1852.75	1420.5
Total	**49,302.3**	**26,989.14**	**22,313.16**

The Measured Average Total Consumption is 49.30kWh per hour (Table 3.3.1)

3.3.2.1.1 Air Conditioners

All the 65 air conditioners recorded in the building are split unit air conditioners. They were distributed across the floors thus: 21 AC units on the Ground Floor, 15 units and 14 units on the second and first floors respectively.

From the measured values using the Multivoies System, the energy consumed by air conditioners in REA building ranged from 535.1kWh/annum to 2513.6kWh/annum. The total energy consumed by all air conditioners in the building was estimated to be 71,696.6 kWh/annum.

Measured Average Hourly Energy Consumption for Air Conditioners: The measured average energy consumption per hour of many air conditioners in the Agency are within plate label rating specified by the manufacturers except one of the many monitored (Chart *3.3.4*), possibly because they are new and also split units.

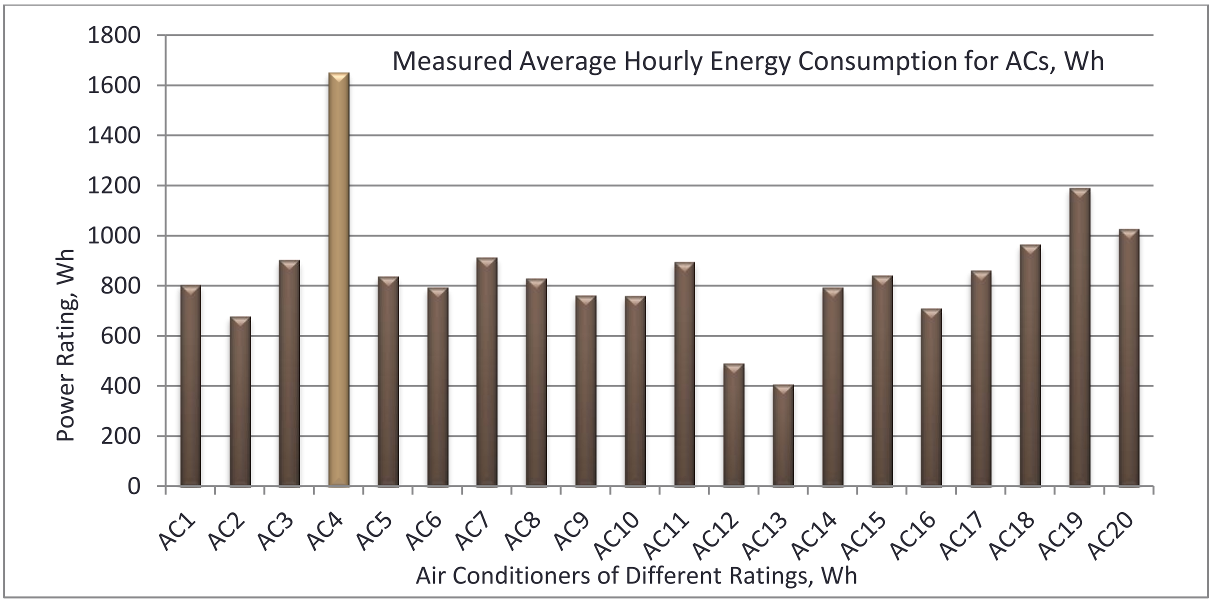


Chart 3.3.4: Measured Average Hourly Energy Consumption of Air Conditioners

3.3.2.1.2 Lighting Appliance

There were two types of lighting lamps/bulbs found in the building – the CFLs and the LED. The CFLs make up the larger number (431) and LED (1). The highest number of CFLs (178) was recorded on the Second Floor. The only LED lamp founded was recorded on the Ground Floor. The total energy consumed by all lighting appliances was estimated to be 4505.28kWh/annum. See Appendices Nos 26 and 27.

3.3.2.1.3 Desktop Computers

A desktop computer system consists of monitor (LCD) and CPU. In this audit most LCD monitors and CPU were measured separately, however, a total of 13 desktop computers were recorded in the building. The total energy consumption of all desktop computers was estimated to be 1322.1kWh/annum.

a. LCD Monitor

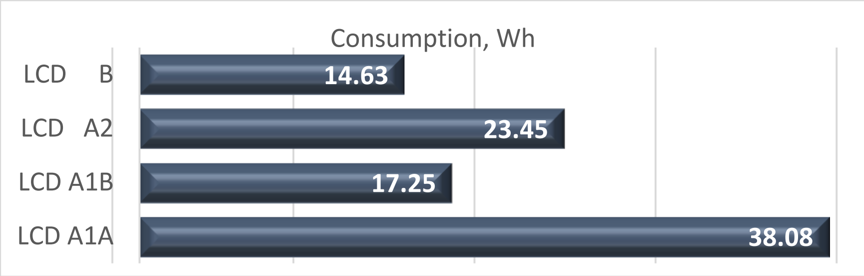


Chart 3.3.5: Measured Average Hourly Energy Consumption of Different LCD in Wh

Real time energy consumption per hour of two brands and different models of LCD coded A1A, A1B, A2 and B are presented in Chart 3.3.5. LCD A1A and A1B are of the same brand and model. The difference in average energy consumption per hour of LCD A1A and A1B was as a result of the fact that LCD A1A was in active use while LCD A1B was not in active use. LCD A2 is of the same brand with LCD A1A and A1B, but different models and its average energy consumption per hour was 23.45Wh while LCD B is of different brand and model and it consumes 14.63Wh.

b. Central Processing Unit (CPU)

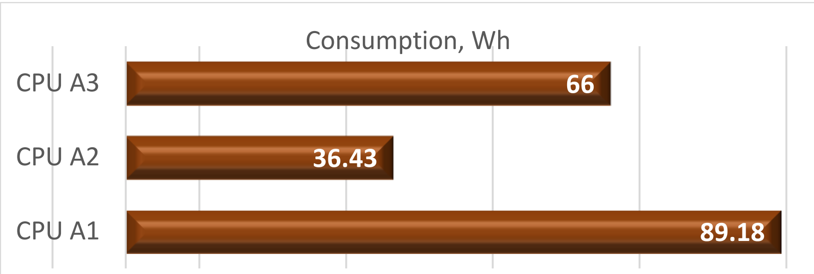


Chart 3.3.6: Measured Average Hourly Energy Consumption of Different CPU in Wh

CPU A1 and A2 are of the same brand and model, yet there was a sharp difference in their energy consumption per hour. The difference in energy consumption between CPU A1 and A2 may be due to the fact that CPU A1 was put into active use during the period of monitoring while CPU A2 was not actively used during the same period.

3.3.2.1.4 Laptop Computers

During the study, 8 laptop computers were recorded in the building and the highest was recorded on the Ground Floor. The total energy consumed by the laptop computers was estimated to be 623.6kWh/annum.

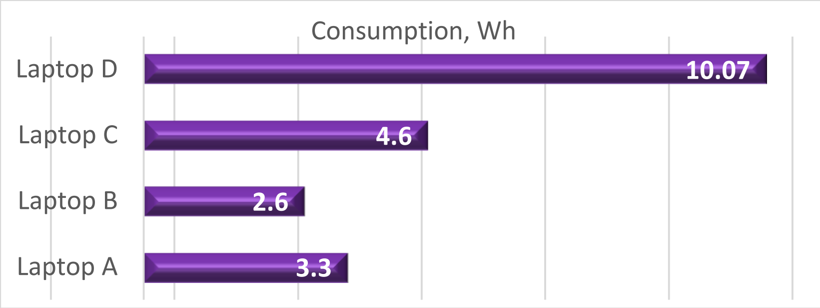


Chart 3.3.7: Measured Average Hourly Energy Consumption of Different Laptops in Wh

Chart 3.3.7 shows the energy consumption per hour of the different brands/models of laptops coded A – D. The data captured monitoring of laptops A, B and C indicated that the laptops were probably in sleep mode, while laptop D might have been left idle, which perhaps represent energy that could partially have been saved if sleep mode was activated.

3.3.2.1.5 Touch Smart System

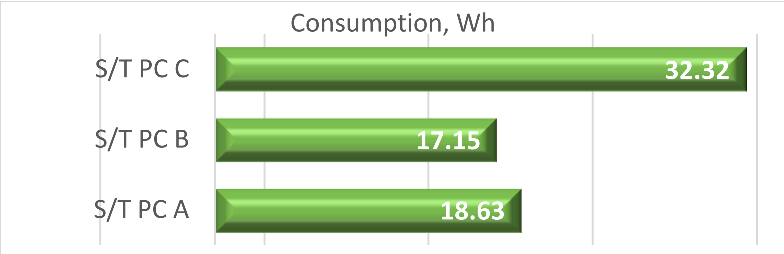


Chart 3.3.8: Measured Average Hourly Energy Consumption of Different Smart Touch Computers in Wh

The average energy consumption per hour of the three Smart Touch Systems that were monitored is shown in Chart 3.3.8. The systems are all of the same brand and model. The difference in their energy consumption per hour may be as a result of the task performed and duration of active usage.

3.3.2.1.6 Printing and Photocopier Machines

At the time of data collection, there were 3 photocopier machines in the entire office complex – one on each Floor; on the other hand, there were 32 printing machines in the building. The total energy consumed by all the printing machines in the building was estimated to by 403.2 kWh/annum.

a. **Printers**

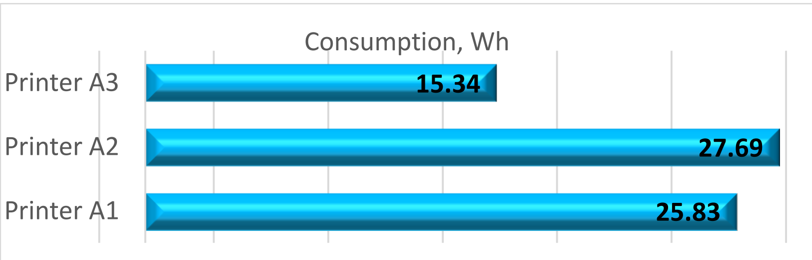


Chart 3.3.9: Measured Average Hourly Energy Consumption of Different Printers in Wh

The real time energy consumption per hour of three printers of the same brand but different models are presented in Chart 3.3.9. Printer A1 consumes 25.83Wh, printer A2 consumes 27.69Wh, while printer A3 consumes 15.34Wh.

b. Photocopiers

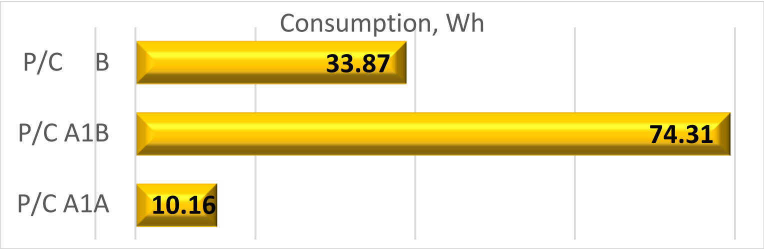


Chart 3.3.10: Measured Average Hourly Energy Consumption of Different Photocopiers in Wh

Chart 3.3.10 shows the measured average hourly energy consumption of the same brand but different models of photocopiers. Photocopiers A1A and A1B are of the same brand and model. The energy consumption of photocopier A1A represented energy that could have been saved if it was shut down. Photocopiers A1B and B consumes 33.87Wh and 74.31Wh respectively.

3.3.2.1.7 Refrigeration Equipment

A total of 19 fridges and 3 water dispensers were recorded during the study. The highest number of fridges (10) was found on the Ground Floor and the least (4) was recorded on the First Floor. The water dispensers (3) recorded during the study were located on the First Floor.

The energy consumed by the refrigeration equipment ranged from 355.7kWh/annum to 630.2kWh/annum. The total energy consumed by all refrigeration equipment was estimated to be 8,790.16kWh/annum.

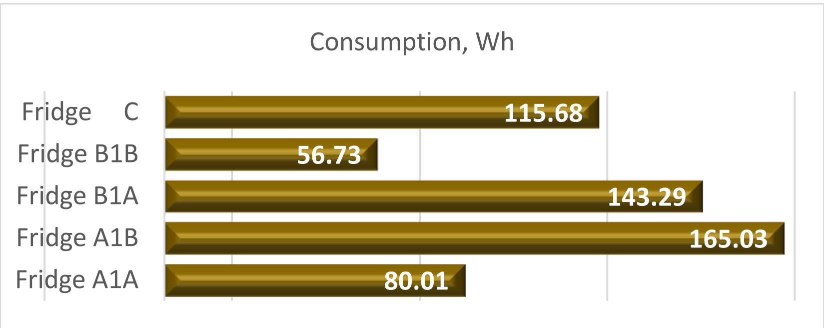


Chart 3.3.11: Measured Average Hourly Energy Consumption of Different Fridges in Wh

The energy consumption per hour of some refrigerators that were monitored was presented in Chart 3.3.11. Fridge A1A and A1B are of the same brand and model. Fridge A1A consumes 80.01Wh against the plate label of 85W, while Fridge A1B consumes 165.63Wh against the plate label of 85W. Also, Fridge B1A and B1B are of the same brand and model. Fridge B1A and B1B consumes 143.29Wh and 56.73Wh respectively against the plate label of 83W. Fridge C consumes 115.68h while its plate label is 110W.

3.3.2.1.8 Television Sets

Out of a total of the 34 television sets recorded in the building, 12 each were recorded on the Second and Ground Floor while 10 were recorded on the First Floor. The total energy consumed by all the television set was recorded to be 4,245.92kWh/annum.

The energy consumption per hour of the same brand but different models of Televisions is presented in Chart 3.3.12. Television A1A and A1B are of the same model. They consume 119.7Wh and 108.95Wh, values which are higher than their plate label of 80W. Also, Television B1A and B1B are of the same model and they both consumed below their plate label of 116W.

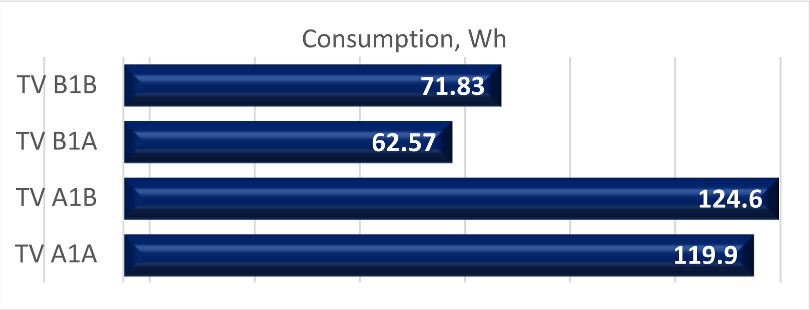


Chart 3.3.12: Measured Average Hourly Energy Consumption of Different Televisions in Wh

3.3.2.1.9 Standing Fans

The audit reveals that there are 17 electric fans in the building, the highest number was found on the Ground Floor (10), followed by the First Floor (6) and the Second Floor (1). Energy Consumption of the electric fans measured using the serial wattmeters, indicates estimated consumption from 64.3kWh/annum to 130.9kWh/annum. The total energy consumption by all the fans in the building was estimated to be 1645.6kWh/annum.

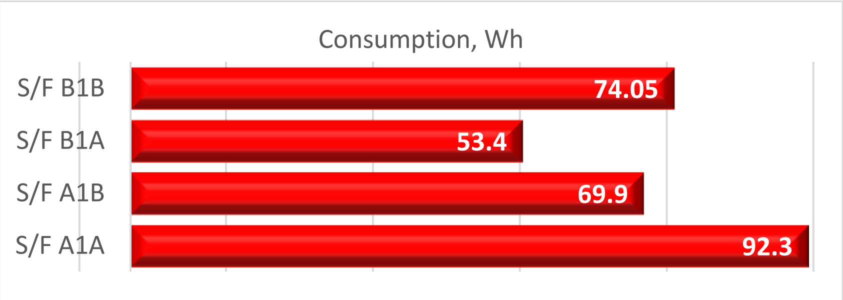


Chart 3.3.13: Measured Average Hourly Energy Consumption of Different Standing Fan in Wh

Chart 3.3.13 shows the measured average energy consumption per hour of different brands/models of standing fan. Standing fan coded A1A, A1B, B1A and B1B are of the same brand and model. The difference in their energy consumption per hour may be as a result of the frequency of rotation. Also, standing fan B1A and B1B are of the same brand and model. Standing fan B1A consumes 53.4Wh while its plate label is 54.5W. But standing fan B1B consumes 74.05Wh per hour against its plate label of 54.5W, this may be as a result of the age of the fan.

3.3.2.1.10 Electric Kettles

Seventeen (17) electric kettles were recorded in the building, with the highest number occurring on the Ground Floor. The total energy consumption of electric kettles in the building was estimated to be 4100.2kWh/annum.

3.3.3 Behavioural Energy Audit

Behavioural energy audit was planned at the Rural Electrification Agency for 37 interviewees, but only 32 were administered. The responses (yes, no, others; 0, 1, 2 and others) are presented below in the charts

3.3.3.1 Occupants' Attitude to Lighting

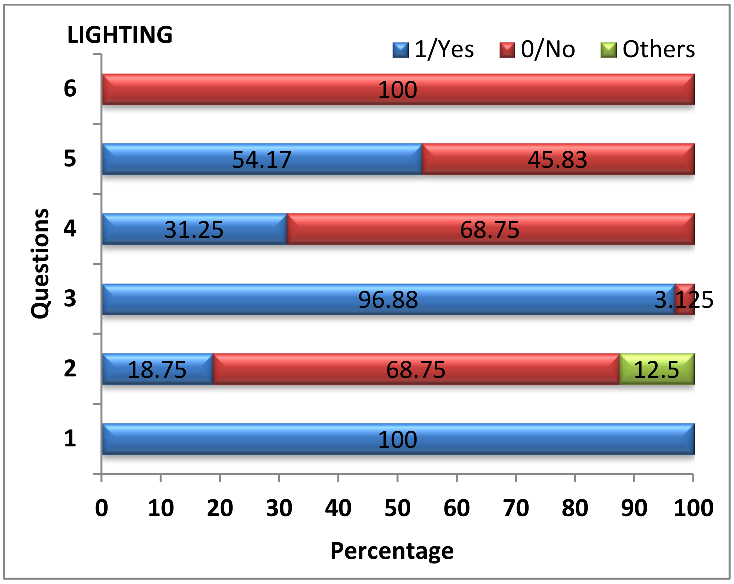


Chart 3.3.14: Response of Occupants on their Attitude to Lighting

Questions

- Is lighting in your office off after working hours?
- Is the toilet lighting in your floor always on even when not in use?
- Is your office using the energy efficient lamps (CFLs, LEDs)?
- Is the daylight in your office adequate without electric light?
- If answer to 4 is yes, do you use the daylight instead of electric light at times? *(If answer to 4 is No, skip).*
- Have you seen lighting management device such as dimmers, timers and sensors installed anywhere in this building?

Chart 3.3.14 indicates that 100% of the respondents had formed the energy efficient habit of turning off light switches in their offices after working hours, while 68.75% affirmed that they switched off the light in the toilets. Furthermore, 96.88% respondents said that lighting bulbs/lamps in their offices were energy efficient. In responding to adequacy of day lighting in the offices, only 31.25% respondents said it was enough without electric light and 54.17% of them use the day light in the absence of electricity. Responding to the question on awareness or usage of energy management devices in the building, 100% of the respondents said they are not aware of and have never seen such installed in the building.

3.3.3.2 Occupants' Attitude to Cooling and Heating

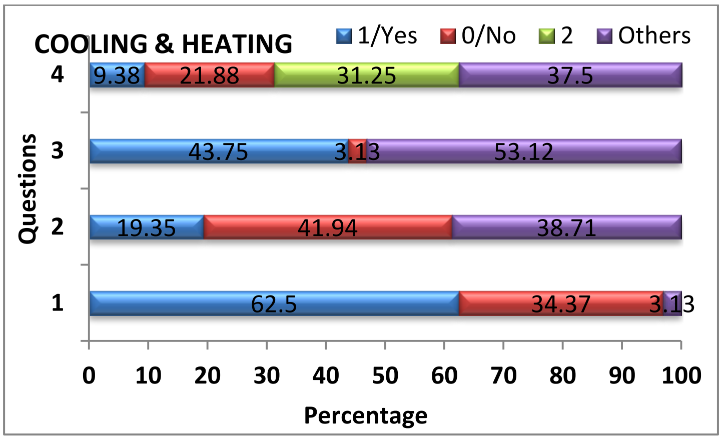


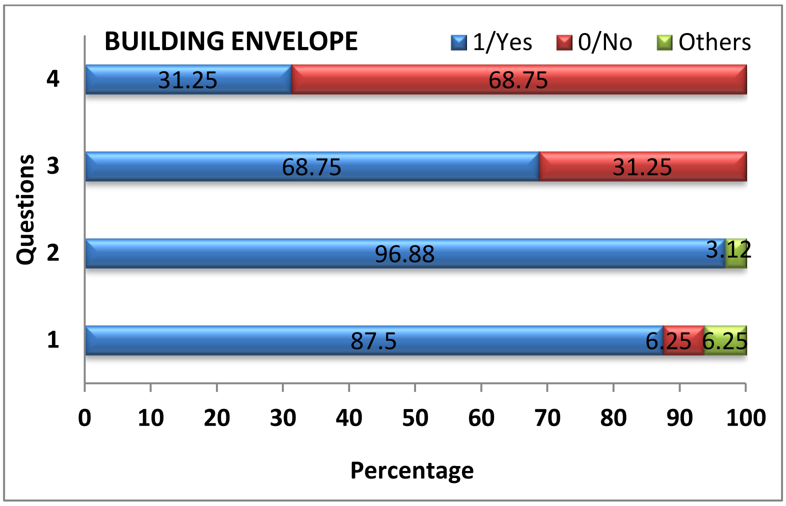
Chart 3.3.15: Response of Occupants on their Attitude to Cooling and Heating

Questions

- Is the AC in your office shut down when unoccupied during working hours?
- Do you often use fan in place of AC?
- Does the kettle in your office have functional thermostat?
- How many times in a year is your AC serviced?

It can be deduced from chart 3.3.15 that 62.5% respondents turn off their ACs when not in use during working hours. Only 19.35% of respondents use fan in place of AC for different reasons. 53.12% do not have electric kettle while 3.13% respondents who use electric kettles said their kettle did not have functional thermostat. 31.25% respondents said their ACs were serviced twice during the study year while 37.5% said their ACs were serviced only when faulty or when the need arose.

3.3.3.3 Occupants' Perception about Office Building Envelope



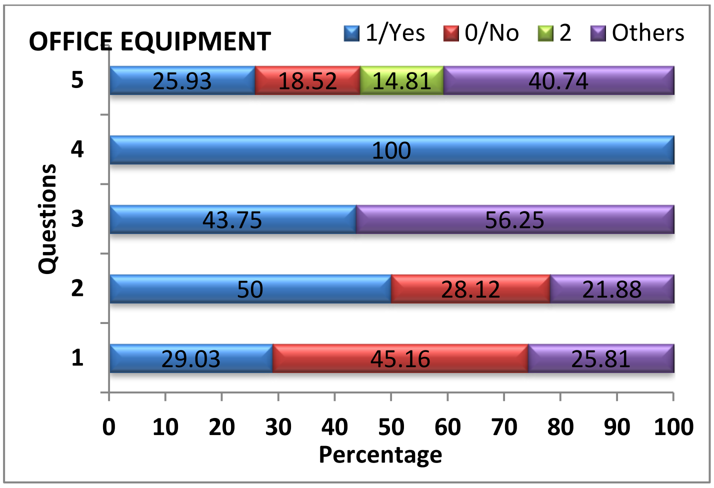
Questions

- Is your office door always kept closed when AC is in Use?
- Are your office windows always kept closed when AC is in Use?
- Are the windows in your office in need of blinds to reduce/block the sun rays?
- Is the daylight in your office adequate without electric light?

Chart 3.3.16: Response of Occupants on their Attitude to Office Building Envelope

Chart 3.3.16 above reveals that 87.5% and 96.88% respondents respectively were in the habit of closing the door and windows of their offices respectively when ACs were in use, while 6.25% said their office's doors are faulty. Furthermore, 68.75% respondents said they are in need of window blinds.

3.3.3.4 Occupants' Perception about Office Equipment



Questions

1. Are your desktop and laptop set on hibernation? What is the timing?
2. Are your desktop and laptop shut down during working hours when not in use *(for about 20mins and more)*?
3. Is the copying machine shut down during working hours when not in use?
4. Do you switch off the socket(s) in your office at the close of work?
5. What is the regularity of service of your ICT equipment in a year?

Chart 3.3.17: Response of Occupants on their Attitude to Office Equipment

Chart 3.3.17, indicates that 29.03% respondents were in the habit of setting their desktop/laptop in hibernation mode while 45.16% do not; 50% respondents shut down their desktop/laptop when not in use during working hours and 28.12% do not. Of those that have copying machine in their care only 43.75% respondents shut them down when not in use during working hours. Furthermore, 100% respondents were in the habit of switching off their sockets at the close of work. On regularity of services of ICT equipment, 25.93% respondents said their equipment were serviced once during the study year while 40.74% respondents said theirs was serviced only when faulty.

3.3.3.5 Summary of the Responses

The responses of the interviewees are summarized under three headings below:

Occupants' Awareness and Compliance

Affirmative responses of the occupants to questions on turning off light switches after working hours, shutting down ACs when the office was unoccupied during working hours, closing the doors and windows of their offices when AC is in use, shutting down their desktop/laptop when not in use during working hours showed that most occupants are conscious of and comply with some energy management practices and requirements. Low culture of using desktop/laptop hibernation mode was the major non-compliance deduced from the energy audit results.

Management Responsiveness

The strong affirmative response on the use of energy efficient lighting in the Agency is an indication of management responsiveness. Contrary to this is non-availability of energy management devices, absence of window blinds. The building could make substantial gains by taking advantage of energy efficiency opportunities in the areas of efficient use of computers, laptops, and ACs; these will lead to cost savings and reduction in greenhouse gases (GHG) emissions.

Building Envelope

REA occupies a residential estate meaning the buildings were originally not designed for office accommodation hence the inadequacy of the day light in many office rooms. Fixing of window blinds as requested by many respondents will increase occupants comfort and productivity.

3.3.4 Renewable Energy and Bioclimatic Design Energy Audit

3.3.4.1 Section 1: Renewable Energy Audit

Solar PV Integration Assessment

Table 3.3.3: Assessment of Space for Solar PV Array Installation

S/N	Assessment parameters	Availability	Possibility	Inclination (º)	Orientation	Remarks
1	Roof-top 1	Yes	Yes	≤ 30	North, South	S40W, N40E
2	Roof-top 2	Yes	Yes	≤ 30	North, South	S40W, N40E
3	Roof-top 3					
4	Parking lot 1	Yes	Yes	-	-	Uncovered
5	Parking lot 2	Yes	Yes	-	-	Uncovered

Roof- top 1: Main Building, Roof-top 2,3: Annex Building, Parking lot (PL) 1: Management PL, Parking lot 2: Staff PL.

Table 3.3.4: Assessment of Space for Solar PV Power House

Item	Availability	Possibility	Size(m)
Space for control room	Yes	Yes	Vacant Plot Unquantified.

Energy assessment for possible integration of solar PV was carried out on the building and the results are presented in table 3.3.3 showing the possibility and availability of space for solar PV integration on the roofs and the parking lots. Table 3.3.4 shows the assessment of space for solar PV power house.

Transferable Load to Solar PV System

Table 3.3.5: Quantity of Lighting and Plug Loads

S/N	Floor	Type and Quantity							
		Lighting		PCs		Fans		Printers	
		Annex A	Annex B	Annex A	Annex B	Annex A	Annex B	Annex A	Annex B
1	Ground	16	70	1	5	4	3	7	7
2	First	24	10	5		4		5	
3	Second	62	17	2	2	2			5
Total			199		15		13		24

The total number of appliances (lighting, personal computers, fans and printers) are shown in table 3.3.5.

Solar Energy Resources

Table 3.3.6: Solar Energy Resources

S/N	Assessment Parameter	Readings	
		Measured	Literature
1.	Irradiation (kW/m^2)	7.80kw/m^2	5.337 kw/m^2
2.	Average sunshine daily hours (Hr)	10hours	6hours
3.	Humidity of the area (%)	38.5%	(36 - 46)%
4.	Temperature (Degree Celsius)	41.3^{0}C	(19-45)^{0}C

Instrument: solarimeter; NIMET data for the last 5 years

The irradiation, average sunshine hours, humidity and temperature for the location were all measured in relation with available values from literature as shown in table 3.3.6 this is to enhance effective design and optimum performance of solar PV system.

Energy Consumption and Cost

Table 3.3.7: Annual Electricity Consumption

S/N	Assessment parameter	Cost (₦)			kWh		
	Consumption	2014	2015	2016	2014	2015	2016
1	Grid	1,685,113.98	1,826,395.68	1,751,597.29	52,234	35,857	36,491
2	Generator	-	-	-	-	-	-

Two (2) generator sets of 110kVA JMG each.

Table 3.3.7 shows the total yearly grid energy consumption in the last three years both in Naira and kWh. The information is meant for comparison with the generator consumption.

Existing Electricity Wiring

Table 3.3.8: Electric Wiring

S/N	Assessment Parameter	Quantity	Description	Possibility Of Use	Modification required
1	DB	-		Yes	Yes
2	Electrical Feeder Pillar	-		Yes	No
3	Circuitry	-	Conduit	Yes	No

Note: Lighting points are in ring form. Air Conditioners are in radial form.

The entire building circuitry is made up of conduit system and integrating Solar PV System into it is possible. The building is made up of six flats each flat with separate distribution board, and all of them are available for use and require no modification, the electrical feeder pillar can equally be used but will require modification. See table 3.3.8.

3.3.4.1.1 Summary of the Cost of Integrating Solar PV into the Energy Mix

Below is the summary of Technical Specifications and cost of Integrating Roof-Top Stand Alone Mini Grid to Energy Mix of REA as alternative to Diesel Generator; the detailed calculations are in appendices Nos. 23 and 24.

Option A: Powering the Entire Electrical Loads

1. Load (Mini Grid Capacity) = 59.162kW
2. Energy (Wh/day) = 236,651.04Wh/day at 4 hours
3. Module = 263Nos. (300W, 24V)
4. Battery = 19Nos. (1000Ah, 2V)
5. Charge Controller = 14Nos. (60A, 24V)
6. Inverter = 75kVA=1Nos @ 75kVA each (48Vd.c, 230Va.c)
7. Space for 263 Modules: = 609.26m^2
8. Space for Battery Bank and Accessories = 12.056m^2
9. Total Cost = ₦65,644,792.51

Option B: Powering the Entire Loads Less ACs

1. Load (Mini Grid Capacity) = 26.78kW
2. Energy (Wh/day) = 107,103.25Wh/day at 4 hours
3. Module = 120Nos. (300W, 24V)
4. Battery = 9Nos. (1000Ah, 2V)
5. Charge Controller = 7Nos. (60A, 24V)
6. Inverter = 35kVA = 1No. @ 35kVA; (48Vd.c, 230Va.c)
7. Space for 120 Modules: = 277.992m^2
8. Space for Battery Bank and Accessories = 12.056m^2
9. Total Cost = ₦31,983,053.00

Cost of integrating Option A was estimated at ₦65,644,792.51 and it was designed to power the entire REA loads for four (4) hours every day as complete alternative to diesel generator. The Energy Audit Team could not access the cost of supplying diesel for running the generators. However, going by the literature, a generator of 110kVA/88kW at half load consumes an estimated quantity of 12liters per hour. The two generators in REA operate below half load, hence, a 10litres per hour consumption was assumed; and at prevailing price of ₦260 per liter during the time of the study, it was computed that about ₦5.14million would be expended to run the two (2) generators four hours daily for 247 official working days.

- Assuming the maintenance cost of both systems (RE and diesel generator) are equal, the simple pay-back period was calculated to be about thirteen (13) years; and it is expected to be shorter with time because the operational cost of diesel generator is expected to be higher as result of continuous increase in price of diesel per liter. Furthermore, the expected improvement in grid electricity should not shift the equation in favour of the diesel generator because of also continuous increase in electricity tariff according to Multi-Year Tariff Order (MYTO).

The cost of Integrating Option B was computed to be ₦31,983,053.00 and it was designed to power the entire lighting and plug loads for four (4) hours daily as a total replacement of diesel generator (back-up). From the result of the energy audit, the average total energy consumption of lighting and plug loads was measured to be 22.3kWh and the proportion (from the total) of cost of diesel to power the appliances was computed to be ₦2.29m.

- Going by the same assumptions as above, the simple pay-back period is fourteen (14) years. Also, as the price per liter of diesel goes up and prices of RE decreases, the pay back will become shorten.

NB. The pay-back periods of 13 and 14 years may seem not encouraging; however, with time the pay-back period will actually shorten. Furthermore, its advantages of GHG emission reduction and other environmental benefits and, conservation of petroleum resources are reasons why the economics of Solar PV electricity as viable alternative to diesel generator in public buildings must be given consideration to make it a reality.

3.3.4.2 Section 2: Bio-Climatic Design Energy Audit

Geographical Location of the Building

Table 3.3.9: Geographical Location of the Building

S/N	Assessment Parameter	Description
1	Topography	Hilly
2	Orientation	N40W, S40E

The location of the building was on a hilly topography with orientation of N40^{0}W, S40E.

Architectural Design

Table 3.3.10: Architectural Design of the Building

Assessment Parameter	Type of Building	Floors/Building	No of office rooms	Remarks
Building	Detached Storey	3	60	REA is an office with (2) detached two storey buildings

Table 3.3.11: Architectural Design of the Building – Windows and Doors

S/N	Assessment Parameters	Size (m)	Material	Quantity	Description	Remarks
1	Windows	1.46×1.18	Glass	12		Room partitioning were done with wood and Aluminum frames
		1.80× 0.90	Glass	12		
		1.80×1.15	Glass	68		
		3.00×1.15	Glass	4		
		0.58×0.6	Glass	48		
		0.89×0.48	Glass	12		
2	Doors	1.32×1.97	Metal	12		Efficient doors
		0.82×1.97	Wood	24		
3	Roof1 Roof (Annex)	24.4×20.6 24.1×22.8	Aluminum	2	Both roofs slanted to North and South directions	REA is an office with 2 buildings
4	Partition	NA	Wood and Aluminum	NA		Partitions give room for ventilation leaking.

The agency has two fully detached storey buildings with three floors and sixty (60) rooms which were partitioned with wood and aluminum frames. The windows and doors are made of different sizes, materials and the quantity varies as shown in table 3.3.11.

3.3.4.3. Key Findings

Availability of Space: This is a key consideration in the integration of solar PV in a building. Is there space for the solar panels, batteries etc. The available space were identified as the roof top and the lobby on each floor; the roof top for mounting of solar PV panels and the lobby to serve as the power house and battery bank. The available space is very important as it is one of the factors that determine the number of solar panels that can be mounted which in turn determines the amount of solar energy that can be generated.

Technical Capacity: The some staff of the agency have the capacity to participate fully in the integration of solar PV into the building. And with adequate training, they should be able to operate and maintain the system. REA is an engineering based organization.

Building Orientation: This is very important in the aspect of minimizing heat gains. The orientation of the building with respect to the sun-path is very important. The location of the agency's two building is at angular to the sun-path which implies there is some heat gain into the building. The majority of windows in the two buildings are facing north and south which is the best orientation for this climate. However some windows are located on the east and west side of the building which allows some solar radiation directly into the building; however, the presence of large balconies (buffer spaces) and sun breakers completely and partially respectively prevented solar radiation entering into the building.

Building Form and Geometry: The building is residential converted to office space; hence most of the partitioning are permanent and made of blocks.

Building Envelope: There are no huge trees serving as shading to the solar radiation entering the building. The building has some buffer spaces and sun breakers.

Cost of Integration Solar PV System: The study revealed that it is possible to power all electrical appliance and equipment minus ACs in REA using Solar PV System. However, the challenge is the cost of integration with about 13 to 14 years simple pay-back period.

Chapter 4: Recommendations and Conclusion

4.1 Highlight of the Results

This section of the report focuses on the identified energy waste streams in all the three buildings under this study. The identified waste streams represent the energy saving opportunities; therefore, the need to devise appropriate measures to eliminate or reduce them to barest minimum. Reading this part with appropriate sections in chapter three will give a better understanding on how to achieve the savings.

a. *Inappropriate Sizing of Back-up Diesel Generator*

When carrying out generator sizing the normal practice is to add an additional 25% of the total calculated load due to the fact that appliances such as AC, Inverters, UPS and refrigerator requires a high starting current, some times as high as 1.4 to 2 times their template value.

The optimum power to pull from a generator is 70 to 90% of the machine's rated capacity. This range provides efficiency and leaves some flexibility if more power should be required. When the load is less than 50% of the rated capacity, the generator is considered to be oversized.

Energy Commission of Nigeria has a generator with a capacity of 350kVA/280kW and measured average total power consumption is 128.4kWh. Taking into consideration an addition of 25%, the estimated total consumption is 160kWh. It can be concluded that the 350kVA/280kW generator currently in use is not oversized since the estimated total consumption is 57% (above 50%); however a generator of 250kVA/200kW could have been ideal cost-wise and for optimal operation and efficiency. And also the issues of premature servicing would be eliminated.

At **Consumers Protection Council** the measured total average load is 76,461.75kW, and 95,625kWh with an addition of 25%. The installed generator capacities are 120kW/150kVA (old) and 200kW/250kVA (new) which are operated at different time cycle. The ideal generator size is 120kW/150kVA; the 200kW/250kVA capacity generator is oversized with a small margin. Using the 120kW/150kVA over 200kW/250kVA would give an estimated saving of about 4.5 liters of diesel per hour. Currently, the generator is operated for an average of six hours daily, hence, about 6920 litres per annum (22.5%) of diesel is wasted amounting to about ₦1.2million. If the generator set is replaced with 120kW/150kVA to eliminate the waste, it will take less than 13 years to pay back (see Appendix 33).

Rural Electrification Agency has two building and two generators with a capacity of 110kVA/88kW for each building. Each building consumes a measured average of about 25kWh. Putting into consideration an addition of 25% we have an estimated total consumption of about 32kWh (36.36%), which is not up to 50% of the installed generator capacity and these can be considered to be oversized. A 40kW/50kVA or 60kW/75kVA would be an ideal generator size. Though when comparing the savings on diesel consumption, the currently installed generator and the suggested generator size is minimal. But, proper generator sizing for REA would eliminate problem of wet stacking or diesel slobber that reduces the life and performance of the prime mover and usually causes premature servicing (see Appendix 7).

b. ***Inefficient Air Conditioners***

Inefficient ACs are huge source of energy wastage. Age of AC relative to its specified life span is a factor that can result in wastage. ECN and CPC can achieve significant savings by taking appropriate measures to ensure that its air conditioners are energy efficient.

Energy Commission of Nigeria building has 71 air conditioners; out of which 63 were in use and consequently measured during the study period. The measured average total hourly consumption of the 63 ACs is 104,355.17Wh, 90% of which are either 1.5Hp or 2Hp; but from the measured value, 95% are consuming above their template value. If the 63 ACs were to be retrofitted with 1.5Hp efficient ACs, the estimated consumption per hour would be about 70,497Wh; leading to a total saving of about 33,859.17Wh (which can power an extra 15, 1.5Hp AC's). On an annual basis, a saving of 50,178kWh (₦2.36million) could be achieved representing 32.45% and 12.35% of total annual energy consumption by ACs and the total annual cost of electricity supply to the building respectively (see Appendix 34). The payback period of the retrofit should be less than 7 years.

Consumers Protection Council has a total of 60 ACs, out of which a total of 26 ACs were measured. Other not measured were either faulty or not in use during the course of measurement. A consumption of 41,667.76Wh per hour was recorded for 26 ACs, which represents 63% of the total buildings' energy consumption. From the measurement taken, about 50% of the ACs consumed energy above their template value. It was estimated that, retrofitting the 50% inefficient ACs with efficient 1.5Hp, a saving of about 12,573.76Wh per hour can be achieved, translating to a saving of about 18,634kWh (about ₦880,000) per annum representing about 30% and 10% of the total annual energy consumption by ACs and the total annual cost of electricity supply to the building respectively. The proposed retrofitting will take less than 8 years to pay back (see Appendix 35).

At the **Rural Electrification Agency** a total of 50 ACs were measured with a consumption of 26,989.14Wh which is 55% of the total power consumption of the building, however, 99% of the ACs measured is within their rated template value. The 55% ACs consumption of the total electricity consumption can thus be considered to be within the range of the benchmark of air conditioners' consumption of the total for the public buildings.

c. ***Lighting***

Generally, lighting in all the building surveyed are efficient; LEDs and CFLs dominate in ECN and REA; however, considerable amount of energy could be saved if the remaining LFLs and ICLs recorded in some of the buildings during the study could be replaced with LEDs or CFLs. Furthermore, reducing the number of lighting fittings in offices where luminosity is more than required is also energy saving opportunity; limiting the number of lighting points controlled by a switch will allow efficient management of lighting energy consumption in a multiple-occupant office when it is sparsely occupied.

Energy consumption of lighting at the Consumer Protection Council can be reduced by an average of 7.07kWh (₦333.03/kWh) in one hour if all the 544Nos 18W LFLs were to be retrofitted to 5W LEDs

(Appendix 26). Furthermore, it can reduce the non-ACs consumption by 13.974kWh (₦658,048) per annum representing 24.7% of non-ACs total annual consumption in the building. In Energy Commission of Nigeria, if all the 12Nos ICLs were to be replaced with 10W LEDs, saving of 0.6kWh (₦28.25/kWh) in an hour can be made; and also, replacing the 61Nos 32W LFLs with 20W LEDs will results to savings of about 0.976kWh (₦45.96/kWh) in one hour (see Appendix 32).

d. *Plug Loads - Appliances and Equipment*

Plug loads were sampled and measured average energy consumption in Wh per hour was established for the major and dominant appliances vis-à-vis quantity and consumption. The result showed that all the sampled appliances except five were consuming energy within the limit of their plate label ratings. The five were two fridges and TV Sets each and a Standing Fan. Computer systems were the dominant appliances and there are three different types (desktop, laptop and smart touch computer systems) in use in the study areas; all the three systems have measured average energy consumption lesser than their manufacturers' rating. Going by the activities that the computers are used for in the buildings no serious gain can be made replacing a system with another one; and if that is to be done as a means of saving energy, it has to be both tactical and selective. Importantly, it was observed that area that needs serious attention is the users'/occupants' interface with the technology; many plug loads especially desktop computers and laptops were left running in active or idle modes during working hours. By simply setting the systems to sleep mode, 15Wh and above of energy could be gained thus from every system. To save energy, the users must be educated on how the appliances consume energy and encouraged to practice the energy savings tips peculiar to each of the plug load. In addition, in allocating appliances to staff, their job schedules among other factors should be considered.

e. Total Quantity of Appliances and Equipment

Some of the buildings studied seem to have more than required quantity of appliances/equipment; if so this is a license to waste energy. In order to minimize wastages and at the same time not compromise users'/occupants' efficiency and productivity appliances-user's activities should be rationalized and optimized.

f. Users'/Occupants' Attitude

The users' ignorance and/or neglect of the energy saving mechanisms and procedures inbuilt in appliances observed during the study were found to be other major energy waste stream in public buildings. This also included disregard for operational procedures of some electrical appliances and violation of standards of electrical circuitry and accessories in buildings. For example, the cumulative percentage of the users/occupants in the three buildings (ECN, 43.14%; CPC, 43.5% and REA, 34.37%) that are in the habit of leaving the ACs on when their office is un-occupied during working hours for an average of 30 minutes weekly wastes 195,309kWh or over ₦9,197,078 per annum (see Appendix 30).

g. Management Responsiveness

Reported delays in attending to repairs, maintenance and replacement of appliances/equipment and various other components such as doors, windows, partitioning etc. in a building that relate to energy consumption are sources of energy wastage. Timely Top Management's decision and approval on these matters will save significant amount of energy. Other findings were reported delays in attending to repairs, maintenance and replacement of appliances/equipment and various other components such as doors, windows, partitioning etc. It was confirmed that timely management's decision and approval on these matters will save significant amount of energy. For instance, a faulty switch in an office room in ECN that was not fixed promptly wastes 407kWh of electricity or over ₦19,167.51 annually; if there were to be a number of such instances, the bill will be high. It takes less than N2000 to fix a switch! (see Appendix 29).

h. Renewable Energy Integration

To integrate Solar PV electricity as back-up to the supply from the national grid system, the **Energy Commission of Nigeria** will need an estimated amount of ₦184,037,053.00 and ₦44,543,853.00.00 to power the entire load (156.25kW) and less ACs (28.91kW) with pay-back period of fourteen (14) and eighteen (18) years respectively.

In the **Consumer Protection Council** the costs of integrating Solar PV to carry the entire load (91.75kW) and less ACs (34.312kW) was estimated at ₦110,768,403.00 and ₦43,886,588.00 28.593kWh with simple pay-back period of twenty (20) and twenty one (21) years respectively.

The **Rural Electrification Agency,** to integrating Solar PV to carry the entire load (59.162kW) and less ACs (26.78kW) will need and estimated amount of ₦65,644,792.51 and be ₦31,983,053.00 22.3kWh with simple pay-back period of thirteen (13) and fourteen (14) years respectively.

The pay-back period is expected to be shorter with time because the operational cost of diesel generator is expected to be higher as result of continuous increase in price of diesel per liter. Furthermore, the expected improvement in grid electricity should not shift the equation in favour of the diesel generator because of also continuous increase in electricity tariff according to Multi-Year Tariff Order (MYTO). If ECN and CPC replace their inefficient ACs with efficient ones, the total loads should reduce significantly and hence, the cost of integrating the Solar PV and the pay-back period. In addition, the availability of power from the national grid to these buildings ranges from three (3) hours in CPC and REA to six (6) in ECN including off-working hours, therefore, effectively, it is less available. Having a noiseless, non-pollution and continuous power supply for four (4) hours will easy the current helplessness energy situation in most of the public buildings.

The pay-back periods for all the three buildings may seem not encouraging; however, with time the pay-back period will actually shorten. Furthermore, its advantages of GHG emission reduction and other environmental benefits and, conservation of petroleum resources are reasons why the economics of Solar PV electricity as viable alternative to diesel generator in public buildings must be given consideration to make it a reality.

i. Bioclimatic Design

One of the buildings studied has many windows with small area square meters hence; it seems impossible taking maximum advantage of day lighting and ventilation. Furthermore, design and materials of partitioning, geometry of doors and windows were factors that rendered ACs ineffective.

4.2 Policy Directions: Recommendation

Consequent upon the completion of the pilot energy audit of the three (3) public buildings in Abuja; the results obtained seem to lead to a number of policy and planning directions that need to be researched further in a more comprehensive and representative energy audit study. Results of further studies may help in adopting and advancing the concept of energy efficiency and conservation in Public Buildings in Nigeria. The major policy directions are grouped into two: the Priority Areas and the Enablers as follows:

4.2.1 Priority Areas

i. Institutionalizing the Position of Energy Manager in Public Buildings

The findings of the energy audits have virtually shown that almost nobody was saddled with the responsibility for monitoring of how energy is being used in a public building. The maintenance units (MUs) of most organisations are mostly concerned with the supply of fuel for the back-up generator sets, their maintenance and, payment of utility bills[4]. Therefore, detailed records of energy flows in organization are not kept. International best practices have proven that the presence of an energy manager in a building makes it more energy efficient and better managed in terms of energy consumption. Advancing further, energy manager could be a member or head of energy team having easy access to the Top Management of the organisation.

ii. Equipment/Appliances

Because, equipment/appliances are usually found in large numbers in any organization; some of them have individual users while others are found in the pool, ensuring energy efficiency compliance in their utilization is demanding, therefore certain measures have to be put in place to guarantee avoidable wastages. Some of these measures could be: periodic activity-based assessment to determine functionality in relation to efficiency performance; incorporation of energy efficiency standards in the procurement, operation and maintenance procedures; maintaining record/log book energy efficiency reporting; adherence to energy labeling and minimum energy performance standards (MEPS) as well as the life span of the appliance.

iii. Building Envelope

The existing building codes and practices in the country and in particular the recently published "Buildings Energy Efficiency in Nigeria" by the Federal Ministry of Power, Works and Housing (Housing Division) adequately addressed this issue of building envelop. Issues on window types and sizes for effective ventilation, use of daytime lighting, heat exchange and transfer, type and size of doors as well as the geometry of the doors and windows are sufficiently captured; the challenge may be compliance. More study is needed to provide convincing data on the disadvantages of not complying with the guidelines.

[4]Previous study "Survey of Availability of Energy Manager" (Manuscript) carried out by Energy Commission Nigeria, 2011 confirmed this fact.

iv. Energy Users (Office Occupants)

The energy users or occupants of public buildings are key to the success of any energy efficiency programme or activity therein. If the buy-in of this critical factor –the users or occupants – is not secured, it is certain that efficient appliances and energy efficient complaint building envelop may not achieve the expected results. It is therefore pertinent to adequately and particularly address the users/occupants in areas of thorough awareness and education, creating supportive environment for them that will facilitate their compliancy, motivating responsiveness and sanctioning where otherwise.

v. On Site Energy Generation

Public buildings like others are electricity dependent, therefore, incessant power outage in them cannot be tolerated. The global trend in solving this challenge is by having diverse energy mix including on the site energy generation to compliment the supply from the grid, efficient consumption and building design and envelop and, conscious effort of the users to comply. Therefore, there is need to put in place necessary measures to generate energy on the site of public building where possible using solar photovoltaic technology and possibly wind and where necessary solar water heater.

vi. The Top Management

All major decisions in an organization are taken by the Top Management; level of available information, concerns and conviction will influence quality of decision and speed of response to approval of request to repair, maintain and replace alliances/equipment. This is very important because delay in such cases can have serious consequence on the energy equation of the organization leading to wastages and reduced productivity. To avoid this situation, Top Management of organization of different levels should ensure the following: existence of in-house energy policy and guidelines, availability of energy manager and team, routine awareness of the personnel, energy action plan built on Plan-Do-Check-Act Cycle, energy matters are part of Management meeting Agenda, energy reporting, prompt approval or directive on O&M of energy system.

vii. Buy-in of the Federal Government

This is a very important priority which must be given all the necessary attention and priority, without it, it is possible no meaningful progress can be made in making the Nation's Public Service efficient, highly productive and competitive. The Public Service cannot tolerate even few minutes of power outages contrary to what is currently happening. There is need for the Federal Government to approve energy efficiency policy and programme for the Public Buildings, put in place mechanisms of its actualization including financing schemes. These buildings are owned by FG; therefore it is logical and effective to have a coordinated strategy than leaving the matter to the individual MDA or organization. Supervisory and regulatory bodies like National University Commission, Ministry of Health, Nigerian Electricity Regulatory Commission, Central Bank of Nigeria with large number of organisations under their purview can also adopt this strategy.

4.2.2 Enablers

The enablers are to create supportive environment for the actualization of the priority areas. Within the scope of this recommendation few enablers are hereby proposed:

a. Energy Efficiency Education and Awareness

This enabler builds energy efficiency consciousness in the priority areas. It is target specific and multi-stakeholder. It engages and combines different media.

b. Financing Scheme

Financing enabler should be conceived as a multi-layer system of financing energy efficiency programme in each public building. It is a check and balance algorithm involving public and private financial institutions, technical organisations, focal organisation etc. The beneficiaries-buildings are Federation Account budget based organisations; therefore the adoption of such scheme will simplify the process, especially, the pay back process.

c. Capacity Building and Manpower Development

There is need for institutional certificated courses for energy auditors, energy managers, solar PV technicians and other critical professionals for energy efficient buildings. Also, other professional stakeholders such as builders, architects, engineers, building designers need to be continually trained and retrained to factor the concept of energy efficiency in their various works.

d. Baseline Data

Reliable, comprehensive and representative data is important for planning. Establishment of national and individual energy efficiency baseline data is paramount for actionable energy efficiency programme in public sector. Baseline Data is a critical enabler for all the priority areas.

4.3 Conclusion

The study was completed within the planned scope, objectives and timeframe and the interim report was presented at a workshop to the stakeholders for inputs and some of them were considered in this final report.

In line with the study's scope, all the three components, namely, electrical energy audit (real time measurement of energy consumption of appliances/equipment), behavioural energy audit and, renewable energy and bioclimatic design energy audit were successfully conducted in all the three selected public buildings: Energy Commission of Nigeria, Consumers Protection Council and Rural Electrification Agency.

Evaluating achievement of the study's objectives; the energy consumption pattern in public buildings was assessed and major energy waste streams identified, attitude of energy users or building occupants was linked to energy consumption and wastages, impacts of bioclimatic design of building on its energy consumption were assessed and viability of solar photovoltaic electricity as alternative to age-long diesel generator was established. Furthermore, a workshop to disseminate the result of the study was organized on Thursday, 16th February, 2016 in Abuja with over 140 participants representing about 60 organisations in the energy sector (public and private) and copies of the report planned for wider circulation after printing will form solid platform for continuous and targeted promotion of energy management in public buildings in Nigeria. To align with the policy planning mandate of the Commission, general policy directions on measures for reducing wastages and consequently energy consumption, and for entrenching energy efficient culture in public buildings were recommended on the basis of the key findings and international best practices. The study gathered information that will guide development of implementation plan of relevant sections on public buildings in different national policy documents on energy efficiency.

The study successfully covered all the planned scopes and objectives though it is not exhaustive, further researches on the findings of the present study using the integrated energy audit approach (adopted in this study) in public buildings in Abuja and other cities around the country will avail the nation the opportunity of generating comprehensive and representative baseline data that would be used in defining the general energy use/consumption pattern in public buildings. Such baseline data will assist the government as the owner of the buildings to develop remedying policies, implementation plan and regulations geared towards reduction of energy consumption in public buildings. This is paramount for energy efficiency compliant public buildings and consequently, highly effective, productive and competitive public service – the administrative hub of governance and national development.

References

1. Capehart B. L, Turner W. C., Kennedy W. J. Guide to Energy Management. Fourth Edition. The Fairmont Press, Inc. 2003.
2. Fuller S. K and Petersen S. R. Life-Cycle Costing Manual for the Federal Energy Management Program. U.S. Department of Commerce Technology Administration National Institute of Standards and Technology. NIST Handbook 135 1995 Edition.
3. GEF (2011). *Promoting Energy Efficiency in Residential and Public Sector in Nigeria*. Project Document.www.thegef.org.
4. Thumann A, and W. J. Younger. Handbook of Energy Audits. Seventh Edition. The Fairmont Press. 2008.
5. UNEP Sustainable Buildings and Climate Initiative Website: http://www.org/sbci/About SBCI/Background.asp.
6. How to Calculate Watts for Analyzing Energy Efficiency Projects: http://www.hoveyelectric.com/hovey-electric-power-blog/bid/55242/How-To-Calculate-Watts-For-Analyzing-Energy-Efficiency-Projects)
7. LED Light.com: https://www.ledlight.com/LED-Information.aspx
8. Greengoods4U.com: http://www.newenergyco-op.co.uk/blog/blog-36.html
9. ABLE SALES: www.ablesales.com.au
10. How to choose energy saving light bulbs: https://www.bunnings.com.au/diy-advice/home-improvement/lighting/how-to-choose-energy-saving-light-bulbs

Appendices

Appendix 1:

Energy Audit of Public Buildings: Questions to Guide the Focused Group Discussion

Energy Commission of Nigeria
Energy Management Training and Manpower Development

Energy Audit of Public Buildings: Questions to Guide the Focused Group Discussion

1. History of the Building i.e. the year of construction
2. Location of the building – the geographical coordinates, district, street name, inclination in respect to the four cardinal points etc.
3. Description of the building – wall type, floor type, roof type, ceiling materials, type of painting, landscaping, number of floors, window type etc.
4. The ownership of the building – is it owned by the agency or it rented
5. What are the activities going on the building – is the building mainly used as offices or there are other activities
6. A brief description of the different departments/units in the agency or ministry
7. What is the overage number of occupants in the building per day with male to female ratio
8. Overview of the energy sources – utilities, backup generator, PV
9. Brief description of the backup generator – in terms of energy capacity, type of fuel (petrol or diesel), year of purchase, manufacturer, model number
10. Provide a brief overview of daily or weekly or monthly or yearly fuel consumption of the backup generator
11. What is the monthly/annual expenditure on diesel or petrol?
12. Provide information on the monthly electricity bill (request for copies of the monthly electricity bill for a year)
13. Provide information on the annual expenditure on energy
14. Where available, a brief overview of previous energy audit and to provide any documentations of previous energy audit
15. Provide a brief overview of the electrical appliances in the building
16. Do the agency have staff or department dedicated to energy efficiency and energy management
17. Do they have previous training on energy efficiency and energy management?
18. Is there any organization policy on energy efficiency or energy management
19. Time of usage of the generator
20. Information on the Log Book for the generator

Appendix 2: Concentrator Serial Number Data Sheet

THE ENERGY COMMISSION OF NIGERIA

CONCENTRATOR SERIAL NUMBER DATA SHEET

Concentrator serial number:		Module*serial number:*		
Multivoies system installation below				
	Appliances	Protection/Fuse(Amps)	Phase	Remarks
Channel 1				
Channel 2				
Channel 3				
Channel 4				
Channel 5				
Channel 6				
Comments:				
Comments:				
Concentrator serial number:		Module*serial number:*		
Multivoies system installation below				
	Appliances	Protection/Fuse(Amps)	Phase	Remarks
Channel 1				
Channel 2				
Channel 3				
Channel 4				
Channel 5				
Channel 6				
Comments:				
Comments:				
Concentrator serial number:		Module*serial number:*		
Multivoies system installation below				
	Appliances	Protection/Fuse(Amps)	Phase	Remarks
Channel 1				
Channel 2				
Channel 3				
Channel 4				
Channel 5				
Channel 6				
Comments:				
Comments:				

SITE…………………………………………………………………………………………….DATE/TIME…………………………………..

FLOOR……………………......TYPE OF DB…………………………………..NUMBER OF PHASE……………………………..

Appendix 3: Walk-Through Energy Audit – Office Appliance Inventory Questionnaire

ENERGY COMMISSION OF NIGERIA

ENERGY MANAGEMENT, TRAINING AND MANPOWER DEVELOPMENT DEPARTMENT

WALK-THROUGH ENERGY AUDIT

Office Appliance Inventory Questionnaire (Form EA/002)

Form Serial No.______

Name of Building____

Floor Number______________________ Room Number_____________________

Room Type_________________________ Date_____________________________

S/N	Equipment	Brand Name and Model	Qty	Power Rating (W)	Age	Hours of Use	Status
e.g.	Fan	Panasonic	2	25	2 years	8	Functioning
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							

Name of Officer:_______________________________________ Designation:________________

Signature:______________________________ Date:_______________________________________

Appendix 4: Serial Wattmeter Installation Sheet

ENERGY COMMISSION OF NIGERIA

ENERGY MANAGEMENT, TRAINING AND MANPOWER DEVELOPMENT DEPARTMENT

ENERGY AUDIT

Serial Wattmeter Installation Sheet (Form EA/002B)

SN	Appliances: Name, Brand and Model	Serial numbers	Remarks (model/Type)
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			

Comments:

`

Name of Officer:______________________________________

Designation:________________

Signature:_____________________________

Date:______________________________________

Appendix 5: Behavioural Energy Audit Questionnaire

ENERGY COMMISSION OF NIGERIA

ENERGY MANAGEMENT, TRAINING AND MANPOWER DEVELOPMENT DEPARTMENT

BEHAVIOURAL ENERGY AUDIT

Questionnaire (Form EA/001)

Form Serial No.______

TABLE 1: LIGHTING					
S/N	Check Point Description	RESPONSE			
		Yes	No	Others	Remarks
1	Is lighting in your office off after working hours?				
2	Is the toilet lighting in your floor always on even when not in use?				
3	Is your office using the energy efficient lamps (CFLs, LEDs)?				
4	Is the daylight in your office adequate without electric light?				
5	If answer to 4 is yes, do you use the daylight instead of electric light at times? *(If answer to 4 is No, skip).*				
6	Have you seen lighting management device such as dimmers, timers and sensors installed anywhere in this building?				

TABLE 2: COOLING & HEATING					
S/N	Check Point Description	RESPONSE			
		Yes	No	Others	Remarks
1	Is the AC in your office shut down when unoccupied during working hours?				
2	Do you often use fan in place of AC?				
3	Does the kettle in your office have functional thermostat?				
4	How many times in a year is your AC serviced?	0	1	2	Others

TABLE 3: BUILDING ENVELOPE					
S/N	Check Point Description	RESPONSE			
		Yes	No	Others	Remarks
1.	Is your office door always kept closed when AC is in Use?				
2.	Are your office windows always kept closed when AC is in Use?				
3.	Are the windows in your office in need of blinds to reduce/block the sun rays?				
4.	Is the daylight in your office adequate without electric light?				

TABLE 4: OFFICE EQUIPMENT					
S/N	Check Point Description	RESPONSE			
		Yes	No	Others	Remarks
1	Are your desktop and laptopset on hibernation? What is the timing?				
2	Are your desktop and laptop shut down during working hours when not in use*(for about 20mins and more)*?				
3	Is the copying machine shut down during working hours when not in use?				
4	Do you switch off the socket(s) in your office at the close of work?				
5	What is the regularity of service of your ICT equipment in a year?	0	1	2	Others

Name of Officer:___________________________________ Designation:_______________

Signature:___________________________ Date:___________________________________

Appendix 6: Sample of the Data Captured Using Multivoies Logger Device

Concentrator		Phases					Module 3261						Module 3387						Module 3392		
1000752		Volts(V)					Watts(W)						Watts(W)						Watts(W)		
Time	Ph 1	Ph 2	Ph 3	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
11/21/2016 12:44	0	0	0	95.5	1900	0	485.5	0	536.5	12	351.5	154.5	0	619	0	0	1	59	0	0	334.5
11/21/2016 12:50	221.7	224.7	225.6	24	1542	0	288.5	0	4	15.5	313.5	61	0	158	0	0	0	84	0	3.5	199.5
11/21/2016 13:00	221.6	225.5	227.2	55.5	2759.5	0	2824.5	0	265	108.5	469.5	544	0	2047	0	0	0	582.5	0	20	362.5
11/21/2016 13:10	222.2	227.7	228.9	0	2823.5	0	2955	0	0	108	474	536.5	0	2031	0	0	0	603	0	20.5	259.5
11/21/2016 13:20	222.5	227.6	228	0	1997.5	0	2972	0	0	108	471	547	0	2058	0	0	1	579	0	20	235
11/21/2016 13:30	222	226	226.2	0	125.5	0	2935.5	0	0	107.5	471	588.5	0	2020	0	0	1	573	0	32	258
11/21/2016 13:33	0	0	0	0	96.5	0	1099	0	0	39.5	174.5	204.5	0	740	0	0	0	189.5	0	64	40
11/21/2016 14:02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11/21/2016 14:10	229.5	230.3	229.8	0	1532	0	1814.5	0	0	76.5	275.5	609.5	0	1412	0	0	0	319	0	96	202.5
11/21/2016 14:20	229.3	230.5	229.7	0	2567	0	2794	0	0	108.5	369	706	0	129	0	0	1	345.5	0	22	886
11/21/2016 14:30	229.6	230.2	230.8	0	2723.5	0	2896	0	0	109	367.5	615.5	0	0	0	0	0	325.5	917.5	22.5	456.5
11/21/2016 14:40	229.6	230.1	230.5	0	2729	0	2869	0	1	109	362.5	1226.5	0	0	0	0	0	333	1203	22.5	493.5
11/21/2016 14:50	229.4	230.9	229.3	0	2829.5	0	2788.5	0	0	109	412.5	2346.5	0	0	0	0	1	329	0	22	427
11/21/2016 15:00	229.5	231	230.6	0	2792	0	2610	0	0	109.5	471	2362.5	0	0	0	0	1	327.5	0	22.5	427
11/21/2016 15:10	229.6	231	231.3	0	2758	0	2573.5	0	1	109.5	468.5	2460.5	0	0	0	0	0	324	0	22	364.5
11/21/2016 15:20	229.6	231.1	231	0	2875.5	0	2750.5	0	0	110.5	466.5	863.5	0	0	0	0	0	337	0	22.5	263.5
11/21/2016 15:30	229.8	230.6	231.1	0	2936.5	0	2907	0	0	110	465.5	461	0	0	0	0	0	340.5	0	22.5	189
11/21/2016 15:40	230.1	230.3	230.3	0	226	0	2980	0	0	109.5	519.5	450.5	0	0	0	0	0	343	0	22	185
11/21/2016 15:50	230.4	229.7	229.2	0	630.5	0	2968	0	0	109.5	469.5	452	0	0	0	0	1	270.5	0	22	182
11/21/2016 15:59	0	0	0	0	2539	0	1827	0	0	107	404.5	387.5	0	0	0	0	0	241	0	21.5	321.5
11/21/2016 17:15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11/21/2016 17:20	226	229.2	230.6	0	0	0	0	0	0	51.5	45	96	0	0	0	0	0	47.5	0	9	123.5
11/21/2016 17:30	225.8	228.8	230.5	0	0	0	0	0	0	109	86	176.5	0	0	0	0	0	88.5	0	19.5	352.5

Appendix 7: Diesel Generator Fuel Consumption Chart in Litres

The table below outlines an approximation of the diesel generator fuel consumption per hour in litres and also the usage at various load levels across a range of generators from 10kVA to 500kVA. Please note this table should only be used as an approximate to give you an indication of fuel usage at various load levels. Actual usage may vary slightly due to various factors.

Table ???: Diesel Generator Fuel Consumption in litres				
Generator size	Approximate Diesel Fuel Consumption			
	¼ Load (litres/hour)	½ Load (litres/hour)	¾ Load (litres/hour)	Full Load (litres/hour)
8kW/10kVA	0.9	1.2	1.7	2.1
10kW/12kVA	1.0	1.4	2.1	2.6
12kW/15kVA	1.3	1.8	2.6	3.2
16kW/20kVA	1.7	2.4	3.5	4.3
20kW/25kVA	2.1	3.0	4.3	5.4
24kW/30kVA	2.6	3.6	5.2	6.4
32kW/40kVA	3.4	4.8	7.0	8.6
40kW/50kVA	4.3	6.0	8.6	10.7
60kW/75kVA	6.4	9.0	12.7	16.1
80kW/100kVA	8.3	11.9	16.1	21.4
120kW/150kVA	10.9	17.3	24.1	32.1
160kW/200kVA	14.1	22.9	32.7	42.8
200kW/250kVA	17.4	28.6	40.8	53.5
280kW/350kVA	23.7	39.3	56.0	74.9
400kW/500kVA	33.3	55.6	79.6	107.0
Source: www.ablesales.com.au				

Appendix 8: Ratings of Different Lighting Equipment

Table:					
		Type of Lighting			
		LEDs	**CFLs**	**HALOGEN**	**ICLs**
	Lifespan	10,000 – 50,000 Hours	6,000 – 15,000 Hours	2,000 Hours	1,200 Hours
Dimmer-Brighter	**Lumens**	**Watts**			
	220	4W	5-7W	18W	25W
	420	6W	7-8W	28W	40W
	720	10W	11-12W	42W	60W
	930	13W	13-18W	52W	75W
	1,300	18W	18-23W	70W	100W
		More efficient ……………………………………………………………………Less efficient			
Source. https://www.bunnings.com.au/diy-advice/home-improvement/lighting/how-to-choose-energy-saving-light-bulbs					

Appendix 9: Walk-Through Energy Audit Data, ECN

Energy Commission of Nigeria											
Walk-Through Energy Audit Data Collation Sheet											
S/N	Equipment’s	Brand Name	Model	Qty Ground floor	Qty first floor	Qty Second floor	Qty Third floor	Qty fourth floor	Total Qty	Power Rating (W)	Total Power Rating (W)
1	Lighting bulb	LED	Schneider	59	90	76	205	111	541	20	10820
		Incandescent		5			1	6	12	60	720
		4 Ft Flr Tube		50		10	1		61	36	2196
		2 Ft Flr Tube						32	32	18	576
		CFL						2	2	18	36
		CFL	Philip	26					26	15	390
		CFL	AKT	8					8	32	256
		CFL	AKT	19					19	100	1900
											16894
2	Ceiling Fan			1					1	110	110
3	Standing Fan	OX		3	1	1		5	10	135	1350
		OX		1					1	250	250
		KDK	P40U			10		3	13	54.5	708.5
		KDK	F-409V				2		2	53.76	107.52
		KDK		5					5	80	400
		Panasonic	F-407X	5	3	12	5	1	26	54.5	1417
		Panasonic	F-407Y		3				3	54.5	163.5
		National						1	1	53.76	53.76
		National		2					2	85	170
											4730.28
4	Television	LG	LG 10 Series					1	1	552	552
		LG		1					1	85	85
		LG		1					1	250	250
		Panasonic			1				1	250	250
		Panasonic						1	1	136	136
		Sharp		1					1	80	80
		Samsung				1			1		0
		Samsung						1	1	110	110
5	CCTV Monitor	Samsung						1	1	95	95
6	Decoder	DSTV						2	2	18	36
		Startimes		1					1		0
											1594
7	AC Window Unit	National	CW-C120VC-M	2	8	11	1		22	1492	32824
		National						7	7	1119	7833
		Panasonic		1	1	6	1	4	13	1119	14547
		LG Gold			1	1	3	4	9	1119	10071

8	AC Split Unit	West Point	WSZ-187S					5	5	1492	7460
		LG	CP-K3063CW					2	2	900	1800
		LG Gold					2		2	1119	2238
		Panasonic		1			2	1	4	1492	5968
		Panasonic		2					2	4800	9600
		Sanyo				2			2	1492	2984
		National					4	2	6	1492	8952
		National					1		1	1119	1119
		Midea		1					1	1119	1119
											106515
9	Refrigerator	LG		1	1	7	1	4	14	70	980
		LG					4		4	83	332
		LG					1		1	145	145
		LG	Expresscool	1		1			2	600	1200
		AKAI		1					1	800	800
		Haier Thermocool	HTF-66H					1	1	110	110
		New castle	R1340					1	1	50	50
		Haier Thermocool						1	1	150	150
		West Point	WRK-558G					1	1	600	600
		LG						1	1	145	145
		Sharp						1	1	74	74
10	Deep Freezer	Ocean		1					1	500	500
		GHT		1					1	500	500
		Haier Thermocool		1					1	500	500
											6086
11	LCD Monitor	HP	L1710	11	26	49	32	10	128	240	30720
		HP	S2031a				23	3	26	192	4992
		HP	L1706				3	2	5	240	1200
		HP	w17e		1		4	1	6	240	1440
		HP	L1908W		2		8	1	11	240	2640
		HP	W1972a		1				1	240	240
12	CPU	HP	Compaq Dx600MT					15	15	480	7200
		HP	XD/MS/MS Pro	11		49		1	61	480	29280
		HP	XT390EA#B13					1	1	480	480
		HP	COMPAQ DX-2290MT				27		27	300	8100
		HP					1		1	1200	1200
		HP					4		4	300	1200
		HP COMPAQ	DS3420				14		14	280	3920
		HP COMPAQ					10		10	690	6900
		HP					4		4	600	2400
		HP					8		8	552	4416
		HP	368817270M				1		1	480	480
		HP	Compaq Dx1000		20				20	480	9600

		HP	Compaq Dc7600		2				2	480	960
		HP	Compaq Dx2390		4				4	480	1920
13	Touch Smart System	HP	PC310		2				2	150	300
		HP	PC610					2	2	150	300
											119888
14	DJ Printer	HP	4625					1	1	96	96
		HP	F4283			1		3	4	20	80
		HP	F4282	1					1	60	60
		HP	960C			1		1	2	400	800
		HP	F2280					1	1	12	12
		HP	D4163		3				3	400	1200
15	LJ Printer	HP	4250	1	4	2	3	5	15	800	12000
		HP	4350			4	1	1	6	800	4800
		HP						1	1	400	400
		HP	P3015					1	1	672	672
		HP	2600n	1		5		1	7	400	2800
		HP	M476DN					1	1	320	320
		HP	P20SSDN					1	1	660	660
		HP	M125A					1	1	480	480
			CP1515N			4			4	400	1600
		HP						3	3	704	2112
		HP	4350N					2	2	800	1600
		HP	P2055		2				2	800	1600
		HP	2055dn			2			2	480	960
		HP	2420			3			3	640	1920
16	Office Jet Printer					1			1	20	20
17	Printer	HP	D4163					2	2	23.04	46.08
		HP	1200D					1	1	880	880
		HP	2420N					2	2	800	1600
		HP	C3183					1	1	40	40
			2600				1		1	575	575
											37333.08
18	Photocopier	Sharp	AR5520	2		1		1	4	1200	4800
		Xerox		1				1	2	1760	3520
		Duplo				1		1	2	253	506
		SHARP	AR 5316		1		1		2	1200	2400
		SHARP	AR 5618				1		1	1200	1200
		SHARP	AR 55161				1		1	1200	1200
		Sharp	AR5623N			1			1	1200	1200
		Sharp	PAR-5620			1			1	1200	1200
											16026
19	Radio	Panasonic	RX-ES29		2	4		3	9	33	297
		Sony	CFO-S03CP	1		1		1	3	12	36

		Sony		2					2	80	160
		Waxiba	XB-2081URT			1			1	10	10
		PANASONIC					1		1	33	33
		KCHIBO	KK 8120			1	1		2	66	132
											668
20	Paper Shredder	Sanyo	SBS 650			4		2	6	26	156
		Sanyo	C22CC/650					1	1	26	26
											182
21	Laptop	HP	530, GC2			17		8	25	65	1625
		Dell	Inspiron			1		2	3	65	195
		Dell	Vestro	1					1	44	44
		Toshiba	Satellite	1					1	44	44
		Toshiba				1			1	65	65
		HP COMPAQ	CQ61-310SA				3		3	65	195
		HP					3		3	65	195
		HP	250				1		1	65	65
		HP		1					1	42	42
		HP	DV51-2000				1		1	65	65
		LG	LGW56				1		1	40	40
									0		0
		DELL	DELPP18L				1		1	65	65
		HP	HP665		2				2	65	130
		HP	HP4510S		1				1	65	65
		ACER			1				1	45	45
		Asus				2			2	65	130
22	Electric Calculator	Casio	DR-1401			8			8	19.2	153.6
											3163.6
23	Heater (Kettle)	Sanyo				3		4	7	2400	16800
		EMEL	AP12				1		1	750	750
		Binatone	CEJ-1730				1		1	2000	2000
		Sanyo	AP12		1				1	2000	2000
		Philip		1					1	2400	2400
		Beverley		1					1	3000	3000
		ASDA		2					2	2200	4400
24	Heater (Jug)	ASDA			1				1	1500	1500
25	Microwave Oven	Midea		1					1	800	800
26	Hot Plate			1					1	1000	1000
											34650
27	Water Dispenser	CWay						2	2	300	600
28	3 DVD Changer System	LG						1	1	70	70
29	Video Cassette Player	Sharp						1	1	10	10
30	Central Amplifier	Ahuja	CMA-3400					1	1	136	136
31	Digital Video Recorder	Chloride						1	1		0

32	Wireless Micro	Ultimate Sound						1	1		0
33	Microphone	Ahuja	CMD-3200					33	33	3	99
34	Phone Receiver	LY-382	SM-1000						0		0
35	Professional Sound System	JBL						2	2	1200	2400
36	Speaker System	LG						2	2	260	520
											3235
37	Switch/router	D-link		2				3	5	16	80
		D-link		1					1	8	8
		CISCO			4				4	2800	11200
		D-LINK			9				9	200	1800
		CISCO/D-LINK			2				2	100	200
38	Server				3				3	500	1500
39	SJ Scanner	HP	5530		1				1	2.5	2.5
		HP	4600		1				1	2.5	2.5
		HP	G2410				1		1	1.5	1.5
		MECURY	1200CU				1		1	2.5	2.5
											14797
40	Water Pumping Mchine	DAB		1					1	2238	2238
41	Inverter	Luminous		1					1	154000	154000

Appendix 10: Walk-Through Energy Audit Data, CPC (A)

Consumer Protection Council - Building A											
Walk-Through Energy Audit Data Collation Sheet											
S/N	Equipment’s	Brand Name	Model	GROUND FLOOR (Admin & Corridor)	FIRST FLOOR (1A &1B)	First FLOOR (1C &1D)	SECOND FLOOR (wing A)	SECOND FLOOR (DG)	Total Qty	Power Rating (W)	Total Power Rating (W)
1	Lighting	CFL		2	4	6	4		16	40	640
		CFL						2	2	18	36
		CFL						82	82	14	1148
		2 Ft Flr. Tube		28	48	76	28	20	200	18	3600
		Lamp BP led Light	LED/663			1			1	3.2	3.2
											5427.2
2	Standing Fan	Lucky	WF-11109		1				1	80	80
		OX	FS-50X		1		1		2	135	270
		OX	FS-66X	1	1	2			4	125	500
		QASA				1			1	60	60

											910
3	Television	LG	21FG5RD			1			1	85	85
		LG SMART TV	43LH50					1	1	35	35
		Panasonic	TC-21FX2ORG		1				1	58	58
		SONY TRINITRON	COLOR TV					1	1	108	108
4	Decoder	DSTV						1	1	18	18
											304
5	AC Split Unit	New Clime	SSAC-7G12-R22	1	2	3	1	1	8	1119	8952
		New Clime	SSAC-8G18-R22		1	2		1	4	1119	4476
		LG SPLIT	HS-C1264NAB					3	3	1492	4476
		LG SPLIT	HS-C1264543				1		1	1119	1492
		New Clime	AUS-12C53F					1	1	1119	1119
		Panasonic						2	2	1492	2984
		Sanyo	SAP-K124G				1	1	2	1492	2984
											26483
6	Refrigerator	Haier Thermocool	HR-137		1			3	4	100	400
		Haier Thermocool	250		1				1	150	150
		LG	GC-131SQ					1	1	90	90
		Midea Tabletop				1			1	150	150
											790
7	All in one PC	HP	ProOne400		9	5		2	16	120	**1920**
8	LCD Monitor	HP	L1702		1				1	240	240
		HP	S2031a	1					1	35	35
		HP	2011X			1			1	22	22
		HP	L1908W			1		1	2	50	100
		DELL	E2013HC			3	1		4	14	56
		DELL	E173FPI				1		1	22	22
		DELL	E1914H					1	1	22	22
											497
9	CPU	HP	PRO 3400 MT			1	1		2	146	292
		HP						1	1	528	528
		HP COMPAQ	NA			1				690	0
		DELL	OPTIPLEX 7010				1		1	275	275
		HP	Compaq Dx2390				1		1	480	480
											1575
10	Printer	HP DESKJET	5525		1				1	14.64	14.64
		HP LASERJET	C19525N		1				1	880	880
		HP LASER JET	P2035		1				1	550	550
		HP 3in 1 laserjet Pro	MFP M127fn		1	1			2	480	960

		HP 3in 1 laserjet Pro	MFP M175A					1	1	310	310
		HP LASERJET	1022		1				1	300	300
		HP LASERJET	MFP M1132			1			1	375	375
		HP LASERJET	P2015			1	1	1	3	350	1050
		HP OFFICEJET	430			1			1	60	60
											4499.64
11	Photocopier	Sharp	AR5620		1				1	1200	1200
		Xerox	PE 120i		1				1	400	400
		KONICA MINOLTA	bizhub C224e					1	1	1400	1400
		Xerox	6015					1	1	880	880
											3880
12	Radio	Panasonic	RX-ES29			1			1	33	33
											33
13	Paper Shredder	Silicon	PS-800c			1			1	26	26
14	Laptop	Toshiba Satellite	p875-s7200		1				1	65	65
		APPLE						1	1	45	45
			7300					1	1	120	120
		HP	530		1				1	65	65
		HP	350		1				1	45	45
		HP	15-D053CI					1	1	65	65
											405
15	Microwave Oven	LG	MS2021F/00					1	1	700	700
16	Water Dispenser	Cway				1		1	2	500	1000
17	Stabilizer	century	CVR-TUP		1				1	800	800
		AMS	AMS-2066					1	1	2000	2000
											4500

Appendix 11: Walk-Through Energy Audit Data, CPC (B)

Consumer Protection Council - Building B											
Walk-Through Energy Audit Data Collation Sheet											
S/N	Equipment's	Brand Name	Model	GROUND FLOOR (Admin, HR, Registry, Cash Office)	GROUND FLOOR (LABS, studio)	GROUND FLOOR (General, DD FIN, DD ACC.)	FIRST FLOOR (DIRECTOR, GENERAL, BOARD-RM)	SECOND FLOOR (PRO, IT, Co-Edu., LIBRARY)	Total Qty	Power Rating (W)	Total Power Rating (W)
1	Lighting	CFL			3	4	2	2	11	40	440
		CFL		12	3				15	18	270
		CFL			3				3	14	42

		CFL			2				2	26	52
		CFL			4				4	5	20
		2 Ft Flr Tube		100	12	64	72	96	344	18	6192
									0		**7016**
2	Standing Fan	lucky	WF-7409b					1	1	144	144
		OX	FS-50X				1		1	135	135
		OX	FS-66X					1	1	135	135
		OX	FS-45X	1					1	125	125
		KDK	A40W	1					1	40	40
		Binatone					1		1	15	15
		Binatone	A-1692			1			1	70	70
		Binatone	Vseries			2			2	65	130
		LG	LIFES BAUER			1			1	60	60
		GOLDEN				2			2	60	120
											974
4	Television	LG	21FG5RD	3					3	85	255
		LG			3	1			4	300	1200
		LG	21FG5RV-T7			1			1	85	85
		Panasonic	TC-21FX2ORG				1	1	2	58	116
		Sharp	AQUOS				1		1	80	80
6	Decoder	GO	DVT32			1	1		2	18	36
7	DVD Player	Sony				1			1	25	25
		LG	DV482				1		1	8	8
											1805
7	AC Window Unit	National						1	1	1119	1119
		National	CW-C180EFM		3	1			4	1492	5968
		LG Gold						1	1	1119	1119
8	AC Split Unit	NewClime	SSAC-7G12-R22	7					7	1119	7833
		NewClime	SSAC-8G18-R22	4					4	1119	4476
		LG SPLIT	HS-C1264NAB			2			2	1119	2238
		LG SPLIT	HS-C1264NA8					1	1	1530	1530
		LG SPLIT	HS-C1264NAH			1	2		3	1492	4476
		LG SPLIT						1	1	2020	2020
		LG SPLIT	HS-C1264543			1			1	1119	1119
		Sanyo	SAP-K124G			1	4	3	8	1119	8952
		Samsung			1				1	1492	1492
		Samsung	AS09UUFN		1				1	980	980
		Sanyo	ASP-KI84GJL				1		1	1119	1119
		Westpoint	VUAT-60				1		1	369	369
		Haier Thermocool				1		1	2	1119	2238
											47048
9	Refrigerator	Haier Thermocool	HR-137	2			1	1	4	100	400
		Haier Thermocool	250				1		1	150	150

		Haier Thermocool	HRF-351		1				1	140	140
		LG Table top	GC-15ISA				1		1	67	67
		Haier Thermocool			1				1	160	160
											917
11	All in one PC	HP	ProOne400					1	1	120	**120**
12	LCD Monitor	HP	L1706		1			3	4	240	960
		HP	S2031a			2			2	192	384
		HP	2011X	1					1	240	240
		HP	L1908W			1		3	4	240	960
		DELL	E2013HC	2				1	3	264	792
		DELL	E1914HEF				1		1	264	264
		Dell	S2340M		1				1	264	264
		HP COMPAQ	LE1711			1	1		2	240	480
		HP					3		3	264	792
		DELL			No record						
		HP			No record						
12	CPU	HP	PRO 3400 MT	1					1	146	146
		Lenovo			1				1	616	616
		HP			1				1	300	300
		HP COMPAQ	NA			2			2	690	1380
		HP			2				2	No Rec	
		DELL	M7835		1				1	305	305
		DELL	OPTIPLEX 7010				1		1	528	528
		HP COMPAQ	500B-MT			3		1	4	552	2208
		HP COMPAQ	DX2200			1		5	6	480	2880
		HP					3		3	528	1584
		DELL	EH8					1	1	305	305
	CPU+LCD	DELL	NO RECORD				5			NO REC	
											15388
	SCANNER	HP	Scanjet G2710				1		1	176	176
			Scanjet 5590						1	35	35
17	Printer	HP DESKJET	3525			1			1	13.38	13.38
		HP LASERJET Pro	400 M401A			1			1	570	570
		HP LASER JET	P2035	1			1		2	550	1100
		HP LASER JET	P2035n				1		1	528	528
		HP LASERJET	MFP M1132	1					1	375	375
		HP OFFICEJET	7500A					1	1	26	26
		HP LASERJET	P2015	2		1	1		4	350	1400
		HP LASERJET	MFP M175a			1	1		2	310	620
		HP PHOTOSMART	B110 SERIES			1			1	27	27
		HP	P2055					1	1	800	800

		HP	P2055d					1	1	570	570
		HP DESKJET	F2280			1			1	20	20
		HP						1	1	60	60
											6320.38
18	Photocopier	Sharp	AR5620			1			1	1200	1200
		Xerox Workcenter	4118	1					1	340	340
											1540
19	Radio	Panasonic	RX-ES29	1		1	1	1	4	33	132
		Sony	CFD-SO7CP				1		1	13	13
											145
20	Paper Shredder	GBC Shredmaster	SC070			1			1	26	26
21	Laptop	HP	Intel Pentium	1					1	13.38	13.38
		Toshiba					1		1	65	65
		HP			1		1		2	65	130
		HP COMPAQ					4		4	65	260
		HP PAVILLION	DV6000	1		1			2	90	180
		HP PAVILLION	96	1			1		2	65	130
		HP ProBook	4520x			1			1	65	65
		HP	650			1			1	65	65
											934.38
23	Heater (Kettle)	SAVAL				1			1	2200	2200
		MASTERCHEF					1		1	1000	1000
25	Distiller	Surgeinield			1				1	3000	3000
26	Furnace	Carbonite Eurotherm			1				1	1000	1000
	Analytical Balance	Ohaus			1				1	13	13
	Microscope	UNICO			1				1	330	330
	WaterBath	B. Bran			No record						
	AutoClean		LDZX-50FB		No record						
	Incubaor	Prestige			No record						
											7543
27	Water Dispenser	CWay			1	1			2	100	200
		RADOF	VLR2-5-V53B				1		1	500	500
	INCUBATOR	COLE			1				1	150	150
	OVEN	COLE			1				1	800	800
28	Spectro LED		SP-E-360D		1				1	10	10
	Stereo/USB Mixer	Yamaha	MX-12USB		1				1	no rec	
	Digital Video Switcher	Data Video	SE-500		1				1	11	11
	Digital Video Recorder	Sony	DSR-20P		1				1	62	62
	studio camera	Sony HDV	1080i/Mini DV		2				2	22	44
37	Switch/router	HUAWEI	HW-LI2.6AH-C			1			1	19.2	19.2
		D-link	DES1016D				3		3	1000	3000
											4796.2

42	Stabilizer	century	CVR-TUP			3			3	2000	6000
		AFRICAN MAKER	AMX-1060			1		1	2	1000	2000
		AFRICAN MASTER	SMS 55077A					1	1	2000	2000
											10000

Appendix 12: Walk-Through Energy Audit Data, REA (A)

Rural Electrification Agency Annex A												
Walk-Through Energy Audit Data Collation Sheet												
S/N	EQUIPMENT	BRAND NAME	MODEL	FLAT 1	FLAT 2	FLAT 3	FLAT 4	FLAT 5	FLAT 6	TOTAL QTY	POWER RATING (W)	TOTAL POWER RATING (W)
1	Lighting bulb	CFL		3	13	16	6	25	8	71	18	1278
		CFL					2	3	23	28	5	140
		CFL						3		3	26	78
		CFL*								10	18	180
		CFL**								17	25	425
2	Standing fan	OX										
		National	F400W	1		1				2	61.5	123
		National			1					1	64	64
		Binatone	A-1691		1		1			2	50	100
		Panasonic			1					1	54.5	54.5
		Century				2		1		3		
		Meco						1		1	40	40
3	Fridge	Ariston	515	1						1		
		Haier Thermocool	HR-NO79	1						1	85	85
		LG Table fridge	LG GR-131SF		1					1	70	70
			GHT		1					1	100	100
		Thermocool				2				2		
		Haier Thermocool					1			1		
		Thermocool	200					1		1		
4	Television	LG	22MN42	1						1		
		Sharp	SV-1435		1					1		
		Sharp			1					1		
		Sharp				3				3		
		Sharp	21R2MK5G			1				1	83	83
		Sharp	21S-FX10N			1				1	98	98
		Samsung					1			1	110	110

		Sharp					1			1		
		LG	14CC4RB-T2				1			1	65	65
		Sharp	21AGI-S					1		1	85	85
		Sharp						1		1		
		LG						1		1		
		Sharp							1	1		
5	Printer	HP LaserJet	M125a	1						1	572	572
		HP LaserJet Pro M402dn		1						1		
		HP LaserJet Pro 400		1						1	770	770
		HP Office Jet		1						1		
		HP LaserJet P2015			2		1			3		
		HP LaserJet CP1025			1					1		
		HP LaserJet 1320	B0ISB-0402-00			1				1	572	572
		HP LaserJet 1320				1				1		
		HP LaserJet Pro MFP M125a				1				1	440	440
		HP Pro 400					1			1		
6	Photocopier	Sharp	AR-5127	1				1		2		
		Sharp	AR 6020			1				1		
7	Air conditioner	LG		2						2	1900	3800
		LG		3	3	3	2	4	4	19	950	18050
		Panasonic			2					2	1980	3960
		Panasonic	CS-PC18EKF			1		1		2	1980	3960
		Panasonic	CS-C45FFH						1	1	12500	12500
		LG					1			1		
		LG	HS-CO964SA9				1			1	950	950
8	Electric kettle	Binatone	CEJ-2030	1						1	2200	2200
		Philips			1					1	2000	2000
		Pyramid			1					1	2000	2000
						1				1	2200	2200
		Saisho	S-403				1			1	2200	2200
		Philips	8022					1		1	2200	2200
9	Laptop computer	HP 250		1						1	65	65
		HP Envy Beats Audio		1	1					2	90	180
		Omatek			1					1	75	75
		Toshiba	C660-20Q				1			1		
		Samsung N145 plus					1			1	40	40
10	Radio	Sonystar	DVFD-S600	1						1	20	20
		**			1					1	3	3
		Sanyo						1		1		
11	Water heater	Ariston		1	1			1		3	1200	3600

12	Water dispenser	C-Way				1				1		
13	Inverter	Su-Kan		1						1	2800	2800
14	Decoder	DStv 45		1						1		
		Startimes						1		1	10	10
15	Wireless Mic PA Cassette Recorder	Coomber 2060-2/RW							1	1	34	34
16	Projector	DELL 1200MP							1	1		
17	Desktop monitor	HP			1	1				2		
		HP	L1906			1				1		
		Dell				1				1		
		HP LCD	W1572a			1				1		
		DELL	E177FPC				1			1		
		HP						1		1		
		HP						1		1		
18	Desktop CPU	HP			1	1				2		
		HP	DX 2300 Microtower			1				1		
		Dell	Optiplex 2010			1				1		
		HP				1				1		
		DELL	Optiplex 201L				1			1		
		HP						1		1		
		HP						1		1		
19	Scanner	HP ScanJet 3770			1					1		

Appendix 13: Walk-Through Energy Audit Data, REA (B)

Rural Electrification Agency, Annex B												
Walk-Through Energy Audit Data Collation Sheet												
S/N	EQUIPMENT	BRAND NAME	MODEL	FLAT 1	FLAT 2	FLAT 3	FLAT 4	FLAT 5	FLAT 6	TOTAL QTY	POWER RATING (W)	TOTAL POWER RATING (W)
1	Lighting bulb	CFL							49	49	5	245
		CFL**		11	59					70		
		Panasonic	F-Y70		1					1	47.5	47.5
		Panasonic	F-402Y		1					1	54.5	54.5
		Lucky	52431		1					1		
		LG Table fridge			1					1		

		IKSONIC		1						1		
		LG Table fridge	CR131SF		1					1	70	70
		Westpoint	PR 134 GX						1	1		
		LG			1					1	15	15
		**	PR 141-GC		1					1		
2	Television	Sharp		1						1	98	98
		Sharp	215-FX10A		1					1	98	98
		Sharp	29E-S1A		1					1	147	147
		Sharp	21R2MK5G		1					1	83	83
		Sharp	29E-51A		1					1	147	147
		Sharp	215-FX10A		1					1	96	96
		LG LN41 Series			1					1		
3	Printer	HP LaserJet P2035dn		2						2		
		HP LaserJet 5200			1					1		
		HP LaserJet Pro 400							1	1		
		HP CP1025			1					1		
		HP LaserJet P2015			1				2	3		
		HP			1					1		
		HP Deskjet 1280	SNPRC-0305						1	1		
		Brother	DCP-135C						1	1		
		HP P2055dn			1					1		
4	Photocopier	Sharp	5127	1	1					2	1200	2400
		Sharp	AR-6020	1						1	1200	1200
5	Air conditioner	LG	HS-C0964SA9	2	1					3	950	2850
		LG	HSC-09CASA9		1					1	950	950
		LG			2					2	950	1900
		Panasonic			1					1		
		LG	HS-CO964SA9						4	4	1600	6400
		Panasonic							1	1	1492	1492
		LG	HS CO6645A9		1					1	950	950
		LG	HS-C0964SA9		5					5	1060	5300
		**		1						1	950	950
6	Electric kettle	Binatone	CEJ-1730	1	1					2	2000	4000
		Kenwood	JKP280						1	1	3000	3000
7	Laptop computer	HP 615			1					1	65	65
		Lenovo 950			1					1	65	65
		HP Protectsmart		1						1	65	65
8	Radio	Sonystar	DVFD-5600		1					1	20	20
9	Water heater	Ariston Pro 15 R/S							2	2	1200	2400
10	Water dispenser	C-Way	LM-YLI-58BY0	1						1	500	500
		Ariston	HSM-35LBA		1					1	550	550
11	Desktop monitor	HP	W1972a	1	2					3		

		HP	L1706		1					1		
		Dell		1						1		
		HP LCD	L1906						2	2		
		HP	CNC715PPK7		1					1		
12	Desktop CPU	HP	Compaq dc2000	2	1					3		
		HP	Compaq dx2300	1	2				1	4		
		DELL optiplex 210L							1	1		
13	Rechargeable lamp	Lontor			1					1	3.2	3.2
14	UPS	Bluegate BG1230 Elite Pro							3	3		
15	Stabilizer African Master	SMS-1577							1	1		

Appendix 14: Data Captured from Plug Loads Monitoring Using Serial Wattmeter, ECN

Energy Commission of Nigeria											
Appliance	SW Number	Brand/Model	Consumption per day (Wh)							Average Consumption/day (W)	Plate Rating (W)
			Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7		
CPU	7146	HP Compaq	57.45	62.96	64.29	61.88				61.65	280
	7404	HP Compaq /dx 2390	2.25	43.1	25.53	31.8				25.67	480
	7609		19.4	45.39	47.31	47.31	40.57			40	480
	7680		24.06	53.9						38.98	480
	7837		26.25	5.65	7.44	5.33	2.4	30.65		12.95	480
	7687	HP Compaq /dx 3700	41.85	46.8	47.81	44.85				45.33	480
	7613	Blue Gate 1200 BA	78.08	143.16	116.65	101.56	60.37	53.5	53.9	86.75	480
	10294	HP CZC 8281 SBR	14.38							14.38	480
	10465	HP 5008 MT	7.11							7.11	480
	10477	HP 5008 MT	45.65							45.65	480
Electric Calculator	7492	Casio	2.16	2.32	2.07					2.18	65
Decoder	7003	DSTV	19.2	17.2	16.88	16.5				17.45	18
	7044	Startimes	4.7	4.72	4.78	4.69	4.7	4.65		4.71	
Deep Freezer	7078	Haier Thermocool	83.8	58.36	48.47	86.32	85.19	63.23	64.13	69.93	500
	8017	GHT	268.17	278.36	269.34	218.47	277.63			262.39	500
Digital Video Recoder	7642	Chloride	37.38	34.58	33.61	31.5				34.27	300
DVD Change System	7489		12.8	12.39	12.66	13.4	13.26	12.9		12.9	70
Laptop	7281	HP 620	57.86	38.3	35.75	62.08	33.03			45.4	65
	7499	HP 530	7.2	35.38	32.81	6.55	19.23			20.23	65
	8018	HP Pavilion dv6	43.2	56.8	67.97	28.9	85.2			54.41	65
	7216	HP Pavilion dv6000	17.45							17.45	65
	7222	HP Compaq	18.25	20.07	13.45	22.16				18.48	44

	7240	HP Pavilion gseries	18.91	20.12	10.28					16.44	65
	7355	HP Compaq	21.95	14.2	4.58	14.35				13.77	44
	10482	Presario CQ61	52.74	41.96	78.26					57.65	65
	7606	Acer	21.63	11.57	25.4					19.53	
	10277	HP Pavilion small	44.77	14.4	22.31	19.27	19.9			24.13	40
	7157	HP 630	87.6	33.07	42.43					54.37	65
	7079	DELL	28.1	27.05	16.96					24.04	26
	7164	Dell Vostra D586B									26
Touch Smart PC	7004	HP610	127.32	94.01	137.62					119.65	480
	7334	HP ENVY23	18.2	13.28						15.74	480
	7608	310PC	76.2							76.2	480
Paper Shredder	7444	SBS 650	2.285	2.378	2.261					2.31	10
	7820	SBS 650	0.233	0.194						0.21	10
Internet Switch	7029	D-link DES1024D	0.392	0.415	0.414	0.412				0.41	3
Printer	7153	HP DeskJet F482	19.5	17.34	18.46	16.86				18.04	
	7124	Epson FX 219	11.33							11.33	
	7013	HP LaserJet 4350n	16.12	14.91	22.52	14.72	17.3			17.11	480
	7139	HP Pro MFP M125a	7.5	7.55	7.51	7.28	6.4			7.25	400
	7116	HP LaserJet CP1515n	4.2	6.15	5.38					5.24	320
	7211	HP D4163	7.8	8.43	7.91	7.68	8.5	8.69	8.29	8.19	480
	7449	HP LaserJet 4350n	11.1	11.28	12.34	14.96				12.42	480
	7462	HP DeskJet 960c	8.63	10.25	8.2					9.03	60
	7368	HP LaserJet 4250	10.2	13.4						11.8	400
	7472	HP LaserJet 2420n	36.53	26.74	13.3					25.52	65
	7587	HP LaserJet P2055dn	10.03	24.49	27.12					20.55	800
	7627	HP LaserJet M476n	26.61	22.53	17.9					22.35	400
	7697	HP LaserJet 2420	47.67	115.8	69.2					77.56	65
	7702	HP laserJet 2420	8.85	15.08	25.54	25.87				18.84	65
	7829	HP LaserJet Pro 200 Colour M251n	5.4	19.3						12.35	400
	7823	HP LaserJet 4250	36.41	42.01	18.5					32.31	400
	7848	HP LaserJet CP1515n	13.16	9.7	7.74					10.2	320
	7873	HP Laserjet 4350	8.39	12.53	9.23	9.69	7.52	7.59	8.76	9.1	480
	8059	HP LaserJet CP1515n	21.4							21.4	320
	8055	HP LaserJet 4350	11.2	27.18						19.19	480
	8027	HP LaserJet 3015	4.03	7.66	29.08	17.8				14.64	800
Scanner	7679	HP ScanJet 5530	14.53	14.25	14.38	14.26	20.33			15.55	2800
LCD+CPU+UPS	7117	HP	18.2	38.46	28.81	20.4	16.12	16.85	19.51	22.62	100
	7182	HP	37.46	36.22	35.82	41.87	52.27			40.73	200
	7698	HP	20	41.08	30.39	59.56				37.76	720
LCD	7088	HP W1972A	9.32							9.32	240

	7106	HP L1908W	31.7	7.6	7.8	23.1				17.55	240
	7127	HP L1908	5.8	7.96	6.35	5.91	6.97			6.6	240
	7150	HP L1908W	15.82	22.46	19.96	17.74				19	240
	7155	HP S2031A	7.94	12.89	40.92					20.58	240
	7190	HP L1710	22.5	25.5	25.46	25.13				24.67	
	7285	HP S2031A	18.8	12.04	16.23					15.69	240
	7588	HP 211710	0.6	25.76	6.05	0.62	0.6	6.95		6.76	
	7706		15.7							15.7	
	7035	SHARP AR55208	14.1	13.38						13.74	800
	7303	SHARP AR5127	55.7							55.7	
PHOTOCOPIER	7408	XEROX	18.45	23.28	31.32	47.94	61			36.4	40
	7532	SHARP AR5520	159.5	66.1						112.8	800
	10355	XEROX	9.9	4.5	4.09	14.48				8.24	40
STANDING FAN	7017	OX	147.4	112.3	73.31	115.93				112.35	250
	7060	PANASONIC F-407X	37.72	35.4	39.77	31.03	39.38	37.5	33.88	36.38	54.5
	7080		77.6	38.59	32.53	86.06	85.19	64.9	60.39	63.61	
	7133	KDK P40U	21.6	19.6	19.4					20.2	54.5
	7475	OX	66.2	69.71	69.93	68.04				68.47	135
	7528	KDK	36.67	38.94	36.78	31.59	35.68	33.57		35.54	53.76
	7847	KDK A40V	105.1	214.43	203.08	155.7				169.58	54.5
	10361	Panasonic F407X	34.53							34.53	54.5
Fridge	7033	LG Express Cool	44.1	110.1	60.1					71.43	600
	7293	Newcastle NC60	49.3	52.1	52.9					51.43	50
	7360	LG 3A54-JS1001B	61.8	60.8	63					61.87	70
	7635	West Point	161.3	162.6	159.1					161	600
	7809	LG Express Cool Double Deck Fridge	77.4	68.2	74.9					73.5	145
	7857	LG Table Top	36.3	30.7						33.5	70
	8034	LG	85.6	103.4	55.6					81.53	83
	10348	LG GF-131SF	164	76.8						120.4	145
	10476	Haier Thermocool	185	150	142					159	150
Radio	7010	Panasonic	14.4	11.9	13.1					13.13	1200
	8067	Sony CFD-503CP	0.6	2.7	2					1.77	1200
Television	7026	LG 21FG5RG	39.3	35.5	10.3					28.37	85
	7315	Panasonic THL50B6L	87.8	29.4	11.1					42.77	136
	7616	Sharp 14BM_2G	43.8	43	38.8					41.87	80
	7854	LG 42PG20R	241.3	225.3	231					232.53	250
	10358	LG 10 Series	332.6	190.1	191.5					238.07	552
CCTV Monitor	10307	Samsung LA32C350D1	74.4	74.7	70.1					73.07	95

Appendix 15: Data Captured from Plug Loads Monitoring Using Serial Wattmeter, CPC

Consumer Protection Council											
Appliance	SW Number	Brand/Model	Consumption per Day (Wh)							Average Consumption /Day (W)	Plate rating (W)
			Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day7		
LCD	7033	DELL E2013HC	9.95	8.63	11.1	11.4				10.27	14
	7044	HP COMPAQ LE1711	4.475	6.925	7.675					6.36	240
	7060	DELL CN01X2HC	7.9	1.1	1.075	9.2				19.28	
	7146	DELL E2013HC	19.15	20.3	16.85	19.2				18.88	14
	7211	HP 2011X	22.9	18.75	25.5	24.2				22.84	22
	7293	DELL	15.125							15.13	
	7809	DELL	9.2	9.5	9.075					9.26	
	8059	HP 2011X	24.025	29.15	23.475					25.55	22
	8067	DELL E173FPI	10.6	12.525	12.6	7.7				10.86	22
LCD+CPU+UPS	7315	HP L1706	78.025	2.75	19.625	3.2				25.9	
	7449	HP S2031a, HP 5008MT	70.675	60.633	81.6	64.475	62.825			68.04	
	7613	DELL CN01X2HC	62.85	60.75	7.575	62.6				48.44	
	10465	XF965EA	67.3	27.325	54.425	56				51.26	
MICROPHONE	7116	SC 600B	12.45	12.133	12.4					12.33	
PHOTOCOPIER	7193	SHARP AR-5620	52.35	35.1	79.375	26				48.21	1200
	7222	BIZ HUB C224E	91.975	128.975	129.25	127.575	147.8			125.12	1400
	7355	XEROX	44.2							44.2	340
	7587	SHARP AR 5620	141.7	104.2	76.275	89.325	145.1	100.9		109.58	1200
	8034	XEROX	92	52.55	19.6	14				44.54	880
STANDING FAN	7157	KDK	5.211	6.472	412.383					141.36	40
	7588	OX	7.1	6.96	6.9					6.99	
	7606	OX	10.617	10.767	10.305					10.56	
	7679	OX	13.244	12.347	13.747					13.11	
	7697	OX	16.29	14.511						15.4	
	7609	Golden breeze	825.6	825.6	825.6					825.6	60
	10477	Golden breeze	11.533	0.86	0.905	8.017				5.33	60
	7642	Binatone A-1693	1.325	1.38	6.394	1.25				2.59	70
	7854	Binatone Vs-1655	6.4	6.5	6.483	6.6				6.5	65
	7837	PFSI-45B-B	8.52	8.439	8.497	7.7				8.29	
	7873	Afrik	11.971	12.4	12.489	12.667				12.38	
LAPTOP	7360	HP 350	5.533							5.53	45
	7702		1.233	2.794	4.263	5.039	2.133			3.09	
	10348		1.833	5.764	3.181	2.425				3.3	
	7532		1.283	2.553	1.705	3.992				2.38	
	7706	Pavillion g series	8.897	8.253	1.85	1.971	1.567			4.51	

	7680	Hp Pavillion dv 6000	2.53	0.967	1.185	12.57				4.31	90
	7128	Hp Pavillion M6	5.35	7.762	7.8					6.97	65
	7003	Hp	12.642	1.169	7.26	1.264	1.489	1.45		4.21	
	7489		1.978	3.194	1.178	1.25				1.9	
	7153	Hp 650	3.222	3.107	3.125	2.817	2.522			2.96	65
	7545	Compaq CND 410120M	3.322	3.983	5.917					4.41	
	10307	Compaq Pressario Ca56	8.167							8.17	
	8017	Lenovo G400	3.217	2.667	2.4					2.76	
LAPTOP	7281	HP 620	57.86	38.3	35.75	62.08	33.03			45.4	
	7499	HP 530	7.2	35.38	32.81	6.55	19.23			20.23	65
	8018	HP Pavilion dv6	43.2	56.8	67.97	28.9	85.2			56.41	65
	7216	HP Pavilion dv6000	17.45							17.45	90
	7222	HP Compaq	18.25	18.25	13.45	22.16				18.02	65
	7240	HP Pavilion gseries	18.91	20.12	10.28					16.44	
	7355	HP Compaq	21.95	14.2	4.58	14.35				13.77	65
	10482	Presario CQ61	52.74	41.96	78.26					57.65	
	7606	Acer	21.63	11.57	25.4					19.53	
	10277	HP Pavilion small	44.77	14.4	22.31	19.27	19.9			24.13	
	7157	HP 630	87.6	33.07	42.43					54.37	
	7079	DELL	28.1	27.05	16.96					23.95	
RADIO	7847	Panasonic	0.422	14.3	13.333					9.35	33
	10476		31.337	1.167	1.2					11.23	13
PAPER SHREDDER	7124	Silicon Ps-800C	1.725	1.229	1.152	1.269	1.096			1.29	26
TOUCHSMART PC	7004	HP 610	127.32	94.01	137.62					119.65	
	7334	HP ENVY23	18.2	13.28						15.74	
	7608	310PC	76.2							76.2	
SMART TOUCH PC	7010	HP Pro One 400	23.4	29	38.68	42.77				33.46	120
	7133	HP Pro One 400	50.66	39.25						44.96	120
	7182	HP Pro1400GI	39.62	39.64	41.78					40.35	
	7285	HP Pro One 400	91.65	73.78	104.21					89.88	120
	7368	HP Pro One 400	20.1	9.11	37.96	11.57				19.69	120
TELEVISION	7499	Panasonic TC-21FX2ORG	98.1	101.88	100.8					100.26	58
	7616	Panasonic TC-21F	37.06	19.41	20.3	20.3				24.27	
	7698	LG Flatron	53.42	55.13	55.2					54.58	
	8027	Panasonic TC-21FX20RG	120.58	76.43	7.34					68.12	58
	8060	Sony	58.47							58.47	108
	10355	LG Flatscreen	90.3	81.82	84	90.04				86.54	
SCANNER	7408	HP ScanJet 5590	15.3	14.1	12.86	13.3				13.89	35
PRINTER	7004	HP LaserJet M1132 MFP	44.06	17	23.82	12.55	12.5	10.5		20.07	375
	7035	HP Laserjet P2035	7.54	6.94						7.24	550
	7088	HP 2015	9.03							9.03	350
	7106	HP LaserJet P2015	13.14	6.87						10.01	350
LITTLE OR NO DATA	7150	HP LaserJet P2015	46.64	22.14	21.53	30.25				30.14	350

	7155	HP LaserJet P2015 PCL6	16.67	15.38	13.21					15.08	350
	7190	3-in-1 LaserJet Pro MFP M127 Fw	7.6	2.27	6.63	8.14	9.86			6.9	480
	7240	HP LaserJet M1132 MFP	12	8.33	12					10.78	375
	7404	HP LaserJet 2055	14.13	32.62	17.03					21.26	800
	7444	HP Laserjet P2035	12.52	13.54						13.03	550
	7472	HP LaserJet P2015	11.7	13	21.66	54.15	54.86			31.07	350
	7608	HP LaserJet 2035	53.97	45.73	20.25					39.98	550
	7687	HP LaserJet P2015	6.97	7.42	8.57	7.98	7.86			7.76	350
	10361	HP Laserjet Pro MFP M127fw	34.53	35.8	6.15	4.26	6.9	5.78		15.57	480
	7139	HP DeskJet 3225									
CPU	6912	DELL 7010	31	27.9	12.4	27.85				24.79	528
	7078	DELL OPTIPLX 710	5.68	38.4	37.25					27.11	528
	7079	HP PRO	30	26	33.5	21.97				27.87	146
	7117	dell	7.93	6.9	7.52					7.45	
	7127	DELL OPTIPLEX 7010	31.2							31.2	528
	7164	HP PRO	24.2	33.16	36.25					31.2	146
	7303	DELL OPTIPLX 710	28.5	27.47	25.44	29.67				27.77	528
	7678	HP COMPAQ	70.6	65.1	60.7	31.6				57	690
DV CAMERA	7281	Sony	16.2	15.94	16.51					16.22	
ELECTRICAL DISPLAY SYSTEM	7829	DIVERSIFIED	81.6	81.4	79.82	81.6				81.11	
FAN	10482	QASA	10.35	15.44	11.47	17.17	11.91	18.7		14.17	60
	10294	OX SMALL	77.82	11.6	58.05	68.65	46.71	76.47		56.55	125
	7835	OX LEXUS	130.55	133.1	133.1	130.93	130.03	113.2	73.1	120.57	
FRIDGE	7848	HAIER THERMOCOOL	128.85	141.2	101.09	129.11	138.11	149.7		131.34	
	7857	HAIER THERMOCOOL	76.4	76.59	75.87	77.33	84.9			78.22	
	7528	HAIER THERMOCOOL	37.8	75.2	65.6	54.24	47.75	74.24	100.9	65.1	
	7462	HAIER THERMOCOOL	115.6							115.6	
	8055	MIDEA HS-65L	59.72	53.19	70.34	40.75	72.5			59.3	150
	7635	HAIER THERMOCOOL	64.95	69.67	86.72	96.75				79.52	
	8018	HAIER THERMOCOOL 250	170.5	187.5	188.03	209.5				188.88	150
	7475	HAIER THERMOCOOL	157.6	148.4	111.2	104.8	130.55	110.3	165	132.55	
	10277	HAIER THERMOCOOL	312.16	80.66	99.2					164.01	
	7823	HAIER THERMOCOOL	8.63							8.63	

Appendix 16: Data Captured from Plug Loads Monitoring Using Serial Wattmeter, REA

Rural Electrification Agency											
Appliance	SW Number	Brand/Model	Consumption per day (Wh)							Average Consumption /day (W)	Plate Rating (W)
			Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7		
LCD + CPU + UPS	7035	DELL, Optiplex, Mercury	21.05	41.08	40.77	74.6				44.375	
	7044	HP 1706	31.28	28.8	31.84	31.83	33.52	25.6	26.95	29.9742857	
Fridge	7079	Haier Thermocool	48.6	50.6	47.8	50.7	46.85			48.91	85
	7627	Haier Thermocool	67.87	82.13	81.84	77.67	81.12	74.95	94.5	80.0114286	85
	10476	Haier Thermocool	189.85	155.23	151.81					165.63	85
	7472	LG	10.7	45.5	67.3	63.2	55.08			48.356	83
	7613	LG	113.95	172.63						143.29	83
	7847	LG	50.4	71.78	53.52	51.23				56.7325	83
	10355	LG GR-1315F	93.38	81.83	37.63	57.77	44.03	32.07	39.23	55.1342857	70
	7489	Akai	63.68	71.79	43.96	54.3	123.77	100.8	61.41	74.2442857	800
	8017	Thermocool 2000	119.3	108.5	122.5	115.85	124.67	117.28	101.63	115.675714	110
	10294	Iksonic	91.17	84.78	89.47	81.12	114.48	93.16	87.35	91.6471429	
Laptop	7444	Lenovo	3.408	3.104	2.797	2.712	3.611	4.833	2.7	3.30928571	65
	7706		4	4.697	3.68	3.469	5.017	4.317		4.19666667	
	7240		2.589							2.589	
	7190	Hp	2.7	2.533						2.6165	65
	7368	Hp G42	0.606	3.233	1.603	1.15	2.478	1.027		1.68283333	65
	7475	Hp Beats Audio	10.483	2.625	2.509	2.575				4.548	90
	7017	Hp 2000	1.375	2.483	2.333	2.494	2.456	2.983		2.354	
	7016	Samsung N145 plus	2.05							2.05	40
	10348	Omatek	9.908	14.3	7.573	4.75	13.967	3.483	16.477	10.0654286	75
CFL LIGHT BULB	7829	27 W	21.26667	19.28333	20.65	21.4	20.95	20.81667	19.26667	20.5190476	
CPU	7146	HP	139.5333	106.5833	72.0375	49.16667	118.7667	66.46667	71.7	89.1791667	300
	7211	OPTIPLEX 3020	37.2	19.3	22.1					26.2	
	7293	HP COMPAQ	1.6	6	27.38333	34.12	52.05	61.2	72.63333	36.4266667	300
	7608	HP 6008 SERIES	20.9	76.43333	59.26667	91.1	57.8	77.7	78.5	65.9571429	
Smart Touch PC	7680	HP PRO	6.733333	24.71667	10.7	32.4				18.6375	
Smart Touch PC	7698	HP PRO	27.05	20.45	2.55	18.4	17.3			17.15	
Smart Touch PC	7848	HP PRO	43.2	35.275	35.06667	30.67692	12.14	37.54		32.3164316	
Decoder	7088	MODEL 45	12.3	10.31	10.87778	11.61818	9.8	12.18	10.90909	11.1421501	
	7150	STAR TIMES STAR 8000T	86.425	72.88571	90.74	72.35				80.6001786	18
	7702	GO TV DTD 3S	5.7	5.733333	6.033333	6.122727	6.046154	5.9	5.618182	5.87910423	
	10358	GO TV DTD U-A	7.75	7.8125	7.825	7.4	7.95	7.733333		7.74513889	
Paper Shredder	8060	Sanyo SBS 650	3.9	1357.4	7.9	1.5				342.675	10
LCD	7010	HP W1972a	17.25							17.25	240
	7116	HP W1972a	11.7	13.4						12.55	240
	7128	HP W1972a	9.6	10.5						10.05	240
	7155	DELL	7.5	7.04	12.54	14.92	17.84	20.2	22.4	14.6342857	
	7616	HP W1972a	10	14.75	14.55	13.9	15.33			13.706	240
	7635	HP L1706	31.8	25.6	18.9	17.35	29.35	17.72		23.4533333	192
	7835	DELL E1914Hef	5.35	5.4						5.375	
	8034	HP W1972a	43.8	31.2	34.03	40.93	54.48	24.05		38.0816667	240

Photocopier	7117	Sharp AR6020	7.2	6.9	7.51	19.3	9.87			10.156	1200
	7157	Sharp AR6020	82.45	51.77	97.4	41.4	74.8	98.05		74.3116667	1200
	7679	Sharp AR5127	42.93	19.9	63.06	12.72	53.12	11.51		33.8733333	1200
Printer	7013	HP LaserJet CP 1025 color					2.45	1.75	1.35	1.85	
	7060	HP LaserJet Pro 400		14.22	11.66	8.42	13.52		19.1	13.384	770
	7124	HP LaserJet P2035	10.86	13	12.06	12.79	11.77		9.9	11.73	
	7281	HP LaserJet P2015		13.27	7.45	10.23	7.4		8.25	9.32	
	7285	HP LaserJet Pro 400m 401d	6.85	4.5	6.52	5.32	5.3			5.698	570
	7315	HP LaserJet 2015		5.4	5.4	5.73			10.34	6.7175	350
	7462	HP LaserJet 5200	59.43	7.53					16.1	27.6866667	
	7528	HP LaserJet P2055d	7.23	9.96	10.84	11.65	8.7		10.65	9.83833333	800
	7645	HP Pro 400				4.25		3.5		3.875	770
	7687	HP LaserJet M1132 MFP					7.66		44	25.83	375
	7809	HP LaserJet 1320		5	4.33	3.07	5.2			4.4	572
	7820	HP LaserJet P2035			8.45		5.65			7.05	
	7858	HP LaserJet P2015	18.33	17.2	18	14.7			15.77	16.8	
	8018	HP LaserJet 1320		12.52	16.45				17.06	15.3433333	572
Standing fan	7078	Lucky WF-7409C	92.13	15.7	13.8	12.13	99.5		105.9	56.5266667	
	7133	Sonik SRF-818R	60.63	27.03	19.4	32.22	24		17.6	30.1466667	
	7153	Panasonic F402Y		74.8	73.3					74.05	
	7164	Panasonic 01215-0224A	45.7	42.1		48.5	46.3		48.9	46.3	
	7296	National F-400W	45		41.8					43.4	
	7404	Panasonic		34	40.8	42			41.1	39.475	
	7606	Century		64.4	66.3			25.4		52.0333333	
	7837	Century		92.3						92.3	
	10477	Century	69.9							69.9	
	10482	Panasonic F402Y	54.6			52.9	53.6		52.5	53.4	
Television	7003	Sharpage	126	115.9	118.9	120.8	123.5		113.1	119.7	
	7004	Sharp	133	124.5	127.1	51.2				108.95	80
	7033	Sharp Multi System							58.4	58.4	
	7127	Sharp			123	121.2	129.6			124.6	80
	7139	Sharp Xflat Slim 29S-FX10A		105.4	119.5	106.7	115		105.8	110.48	
	7182	LG 22MN42	21.2	21.2	20.8	21.2	21.3		21.3	21.1666667	100
	8059	Sharp 21R2 MK 5G	110.5	104	123.5	106.5	105.8		104.9	109.2	
	8067	Sharp 21L-FG1SA	4.5		5	5	5			4.875	
	8055	Sharp Xflat Slim	65.6	70	52.1					62.5666667	116
	7823	Sharp 21S-FX10N	137.5	4.6						71.05	96
	7678	Sharp 21R2	40.3	34.2						37.25	83
	7587	Sharp Xflat Slim	2.9	4.9	4.5					4.1	63
	7532	Sharp Xflat Slim	60.9	57.3	61.3					59.8333333	88
	7360	Sharp 29E-S1A	69.4	72	73.3					71.5666667	147
	7334	Samsung LA26A450C1N	65.9	67.2	66.5					66.5333333	
	7222	Sharp 21R2 MK 5G	56							56	
	7355	Sharp Xflat Slim	74.5	68.5	72.5					71.8333333	116
	7857	METRO BOX									
	7026	HP LaserJet Pro 400									
	7303	HP LaserJet P2015									
	7588	HP Envy5532									
	7449	HP LaserJet P2015									

Standing fan	7854	HP LaserJet Pro MFP M125a									
	6912	OX									135
	7492	Daystar DSF-2318									50
	8027	Panasonic F402Y									54.5
	7499	LG LN41 Series									
	7545	Sharp Xflat Slim 29S-FX10A									
	7697	National F-400W									61.5

Appendix 17: Sample of Serial Wattmeter Reading (CPU)

Serial Watt Meter Reading (CPU)			
Type	60	Con., W	Voltage, V
Serial number	7613		
Start date	21/11/2016		
Start time	15:50:00		
Current date	07/01/2000		
Current time	19:20:36		
Current address	835		
Last read address	0		
Measurement interval	10		
Memory overflow	0		
Total Wh	12026.1		
Total Wh (RAM)	12026.1		
Gain U	49207		
Gain I	3245		
Offset I1	0		
Offset I2	-3		
Calibration Wh	9456291		
Calibration U2	2252024		
Calibration Wh (RAM)	9456291		
Calibration U2 (RAM)	2252024		
Days of battery use	2127		
21/11/2016	15:50	4	74.5
21/11/2016	16:00	0.3	0
21/11/2016	16:10	0	0
21/11/2016	16:20	0	0
21/11/2016	16:30	0	0
21/11/2016	16:40	0	0
21/11/2016	16:50	0	0
21/11/2016	17:00	8.4	128.1
21/11/2016	17:10	22	215.8
21/11/2016	17:20	23.1	217
21/11/2016	17:30	21	217
21/11/2016	17:40	20	217
21/11/2016	17:50	21	215.8
21/11/2016	18:00	14.4	212
21/11/2016	18:10	12.8	212.7
21/11/2016	18:20	12	210.2
21/11/2016	18:30	11.2	208.9
21/11/2016	18:40	11.2	211.4
21/11/2016	18:50	11.2	208.9
21/11/2016	19:00	10.5	207.6
21/11/2016	19:10	10.5	208.3
21/11/2016	19:20	10.5	210.2
21/11/2016	19:30	7.8	178.2
21/11/2016	19:40	0.2	0
21/11/2016	19:50	0	0
21/11/2016	20:00	0	0
21/11/2016	20:10	0	0
21/11/2016	20:20	0	0
21/11/2016	20:30	0	0
21/11/2016	20:40	0	0
21/11/2016	20:50	0	0
21/11/2016	21:00	0	0
21/11/2016	21:10	0	0
21/11/2016	21:20	0	0
21/11/2016	21:30	0	0

Appendix 18: Sample of Serial Wattmeter Reading (Laptop)

Serial Watt Meter Reading (Laptop)			
Type	60	Con., W	Voltage, V
Serial number	7079		
Start date	21/11/2016		
Start time	12:30:00		
Current date	01/01/2000		
Current time	00:26:49		
Current address	344		
Last read address	0		
Measurement interval	10		
Memory overflow	0		
Total Wh	549.7		
Total Wh (RAM)	549.7		
Gain U	49225		
Gain I	3227		
Offset I1	0		
Offset I2	-21		
Calibration Wh	9505560		
Calibration U2	2250377		
Calibration Wh (RAM)	9505560		
Calibration U2 (RAM)	2250377		
Days of battery use	32		
21/11/2016	14:40	0	0
21/11/2016	14:50	0	0
21/11/2016	15:00	0	0
21/11/2016	15:10	0	0
21/11/2016	15:20	0	0
21/11/2016	15:30	5.5	186.9
21/11/2016	15:40	8.4	217.6
21/11/2016	15:50	8.4	217.6
21/11/2016	16:00	7.2	217.6
21/11/2016	16:10	5.5	217
21/11/2016	16:20	4	215.8
21/11/2016	16:30	4.5	217.6
21/11/2016	16:40	4.5	215.1
21/11/2016	16:50	4	215.8
21/11/2016	17:00	4	215.8
21/11/2016	17:10	4	216.4
21/11/2016	17:20	4.5	218.8
21/11/2016	17:30	4	220.6
21/11/2016	17:40	3.6	215.1

Appendix 19: Design of Solar PV System, ECN Option A (Total Loads)

Energy Commission of Nigeria

DESIGN OF SOLAR PV INTEGRATED POWER SYSTEM

Design specification/parameters

1. 300W_p, 24V Polycrystalline Module dimension; 1.95m × 0.99m
2. System Voltage is 48V
3. Sunshine Hour is 6hr/day
4. Average radiation intensity is 500W/m^2 (Out of 1000W/m^2)
5. 1000Ah, 2V Batteries @ 80% Depth of Discharge (DoD) used
6. Days of Autonomy (DoA) are 3 days
7. 20% Energy for losses; and
8. 60A, 24V rated Charge Controllers used.
9. Inclination: Lat 9˚ 3' 39.51'' N Long 7˚ 29' 30.05''E

Component Sizing

- Load = 156.25kW
- Energy (Wh/day) = 625,033.2Wh/day at 4 hours
- Irradiation is minimum @ 500W/m^2
- Sunshine hour = 6
- Energy generated by a 300W module in @ 500W/m^2 = 300 × 6 × 0.5 = 900Wh/day

Module Sizing

- Numbers of module = Energy (Wh/day)/Energy Generated by a 300W module = 625033.2/900 = 695Nos. of 300W, 24V Module

Battery Sizing

- System voltage = 48V
- Energy to be stored in the Batteries = (Available Energy × DoA)/ System Voltage = (625033.2 × 3)/48 = 39064.575Ah
- Total Number of Batteries required to meet 3 days energy storage @ 80% DoD = 39064.575 Ah/ (1000Ah × 0.8) = 48.83 = 49 (approx.) = 49 Nos. of 1000Ah, 2V Batteries

Charge Controller Sizing / Numbers of Charge Controllers

- Total current from modules: Available Energy/ (System Voltage × Sunshine hour)= 625033.2/(48×6) = 2170.25 Ampere
- Charge Controller selection: 60Amp
- Nos. of Controllers = Total Current from the Modules/ Charge Controller Ampere rating = 2170.25/60 = 36.2 ≈ 37Nos of Charge Controllers of 60A, 24V

Current Contributions

- A 300W panel short circuit current: 8.72Amp (From Manufacturer name plate)
- 2Nos 300W Panel serially connected gives 48V

- 348 Parallel circuit current contribution = 8.75 × 348 = 3045A
- A stack of 3 KAmp Circuit Breaker is suitable
- 4 separate circuits each will have current contribution: I = 3045/4 = 761.25A

Inverter Sizing

- Available Power = 156.25kW
- Inverter = 156.25 × 120/100= 187.5 = 190kVA
- 190kVA = 4Nos. @ 50kVA each; 48Vd.c, 230Va.c Inverter is recommended

Space for Modules Installation

- Area of a 300W module = (1.95 × 0.99) m^2 = 1.9305m^2
- Space for 695 Modules: 1.9305 × 695 = 1,341.70 m^2
- 20% PV array space allowance = 268.34m^2
- Total space for module installation = 1,610.04 m^2
- Space for battery bank, inverters and other accessories = 12.96m^2

Bill of Engineering Measurement and Evaluation (Cost of PV Integration)

S/N	Component Description	Quantity	Unit Price (₦)	Amount (₦)	Remarks
1	300W_{p}, 24V Polycrystalline Solar Module	695	110,000	76,450,000	Solar World, Sun Tech, Simba products.
2	1000Ah, 2V Deep Cycle Battery	49	229250	11,233,250	Hoppecke, Trojan, Simba Products.
3	60A, 24V Charge Controller.	37	45,000	1,665,000	Stecca, Morning Star, Simba Products.
4	48$V_{d.c}$, 230$_{a.c}$190kW pure sine wave inverter. (50kW Each)	4	5,640,000	22,560,000	Sumcam
5	Stack of 3 Kamp Circuit Breaker (750 Amp Each)	4	40,000	160,000	
6	16mm^2 Single core Copper Cable (Solar)	25 Coils	15,000	375,000	Nigerian Wire and Cable.
7	Connectors/ Cable logs	Many	40,000	40,000	
8	Change Over Switch	4	5,000	20,000	
9	Steel Rack for Installation Frames	LOT	1,500,000	1,500,000	
10	Lighting Protection System	4 Sets	10,000	40,000	
11	150A Circuit Breaker	4	3,000	12,000	
12	100A Circuit Breaker	4	5,000	20,000	
13	Transportation	LOT	300,000	300,000	
	Sub-total 1			**114,375,250**	
14	10% Contingency			11,437,525	
15	5% Workmanship			5,642,263	
	Sub-total 2			131,455,038	
16	5% VAT			6,572,752	
17	35% Profit			46,009,263	
	Grand Total			**184,037,053**	

Appendix 20: Design of Solar PV System, ECN Option B (Without cooling loads)

Energy Commission of Nigeria

DESIGN OF SOLAR PV INTEGRATED POWER SYSTEMS

Design specification/parameters

1. $300W_p$, 24V Polycrystalline Module dimension; 1.95m × 0.99m
2. System Voltage is 48V
3. Sunshine Hour is 6hr/day
4. Average radiation intensity is $500W/m^2$ (Out of $1000W/m^2$)
5. 1000Ah, 2V Batteries @ 80% Depth of Discharge (DoD) used
6. Days of Autonomy (DoA) are 3 days
7. 20 % Energy for losses; and
8. 60A, 24V rated Charge Controllers used.
9. Inclination: Lat 9˚ 3’ 39.51’’ N Long 7˚ 29’ 30.05’’E

Component Sizing

- Load = 28.906kW
- Energy (Kwh/day) = 115,625.248 Wh/day at 4 hours
- Irradiation is minimum @ $500W/m^2$,
- Sunshine hour = 6
- Energy generated by a 300W module in @ $500W/m^2$ = 300 × 6 × 0.5 = 900Wh/day

Module Sizing

- Numbers of module: 115,625.248/900 = 128.472 = 129Nos of 300W, 24V Module

Battery Sizing

- System voltage = 48V
- Energy to be stored in the Batteries: (Available Energy × DoA)/ System Voltage = (115,625.248× 3)/48
- Numbers of Batteries required to meet 3-days energy storage @ 80% DoD: =6,976.578 Ah/ (1000Ah × 0.8) = 8.72 = 9Nos of 1000Ah, 6V Batteries
- Total number of Deep Cycle Batteries of 80% DoD : 9Nos of 1000Ah, 2V Batteries are required

Charge Controller Sizing

- Total current from modules: Available Energy/ (System Voltage × Sunshine hour) =115,625.248/(48 × 6) = 401.48 Ampere;
- Charge Controller selection: 60Amp
- Nos. of Controllers: Total Current from the Modules/ Charge Controller Ampere rating = 401.48/60 = 6.69 = 7Nos. of Charge Controllers of 60A, 24V;

Current Contributions

- A 300W panel short circuit current: 8.72Amp (From Manufacturer name plate)
- 2 Nos. 300W Panel serially connected gives 48V
- 65 Parallel circuit current contribution = 8.75 × 65 = 568.75 A
- A stack of 0.6 KAmp Circuit Breaker is suitable
- 4 separate circuits each will have current contribution: I =568.75/4 = 142.19A

Inverter Sizing

- Available Power: 28,906.312W = 28.9kW
- Inverter 28.9 × 125/100 = 36.125kW
- 36.125kW, 48Vd.c, 230Va.c Inverter is recommended

Space for Modules Installation

- Area of a 300W module = (1.95 × 0.99) m^2 = 1.9305m^2
- Space for 129 Modules: 1.9305 × 129 = 249.035 m^2
- 20% PV array space allowance = 49.81m^2
- Total space for module installation = 298.84 m^2
- Space for battery bank, inverters and other accessories = 12.96m^2

Bill of Engineering Measurement and Evaluation (Cost of PV Integration)

S/N	Component Description	Quantity	Unit Price (₦)	Amount (₦)	Remarks
1	300$W_{p,}$ 24V Polycrystalline Solar Module	129	110,000	14,190,000	Solar World, Sun Tech, Simba products.
2	1000Ah, 2V Deep Cycle Battery	9	229,250	2,063,250	Hoppecke, Trojan, Simba Products.
3	60A, 24V Charge Controller.	7	45,000	315,000	Stecca, Morning Star, Simba Products.
4	24$V_{d.c}$, 230$_{a.c}$40kW pure sine wave inverter.	1	4,720,000	4,720,000	
5	Stack of 0.6Kamp Circuit Breaker (150Amp Each)	4	50,000	200,000	
6	16mm^2 Single core Copper Cable (Solar)	25 Coils	15,000	375,000	Nigerian Wire and Cable.
7	Connectors/ Cable logs	Many	40,000	40,000	
8	Change Over Switch	4	5,000	20,000	
9	Steel Rack for Instal Frames	LOT	1,500,000	1,500,000	
10	Lighting Protection System	4 Sets	10,000	40,000	
11	100A Circuit Breaker	4	3,000	12,000	
12	150A Circuit Breaker	4	5,000	20,000	
13	Transportation	LOT	300,000	300,000	
	Sub-Total 1			**23,795,250**	
14	10% Contingency			2,379,525	
15	5% Workmanship			5,642,263	
	Sub-total 2			31,817,038	
16	5% VAT			1,590,852	
17	35% Profit			11,135,963	
	Grand Total			**44,543,853**	

Appendix 21: Design of Solar PV System, CPC (Option A – Total Loads)

Consumer Protection Council

DESIGN OF SOLAR PV INTEGRATED POWER SYSTEMS

Design specification/parameters

1. $300W_p$, 24V Polycrystalline Module dimension; 1.95m × 0.99m
2. System Voltage is 48V
3. Sunshine Hour is 6hr/day
4. Average radiation intensity is $500W/m^2$ (Out of $1000W/m^2$)
5. 1000Ah, 2V Batteries @ 80% Depth of Discharge (DoD) used
6. Days of Autonomy (DoA) are 3 days
7. 20 % Energy for losses; and
8. 60A, 24V rated Charge Controllers used.
9. Site coordinates: Lat $9^{O}4^{1}33.01^{11}$N Long $7^{O}28^{1}11.93^{11}$E

Component Sizing

- Load = 91.7541kW
- Energy (Wh/day) = 367,016.4Wh/day
- Irradiation is minimum @ $500W/m^2$
- Sunshine hour = 6
- Energy generated by a 300W module in @ $500W/m^2$ = 300 × 6 × 0.5 = 900Wh/day

Module Sizing

- Numbers of module: Energy (Wh/day)/Energy Generated by a 300W module = 367,016.4/900 = 408Nos of 300W, 24V Module

Battery Sizing

- System voltage = 48V
- Energy to be stored in the Batteries = (Available Energy × DoA)/ System Voltage = (367,016.4× 3)/48 = 22,938.525Ah
- Total Number of Batteries required to meet 3 days energy storage @ 80% DoD = 22,938.525Ah/ (1000Ah × 0.8) = 29Nos of 1000Ah, 2V Batteries
- Total number of Deep Cycle Batteries of 80% DoD = 29Nos of 1000Ah, 2V Batteries are required

Charge Controller Sizing / Numbers of Charge Controllers

- Total current from modules: Available Energy/ (System Voltage × Sunshine hour) = 367,016.4/(48×6) = 1,274.36 Ampere;
- Charge Controller selection: 60Amp
  Nos. of Controllers: Total Current from the Modules/ Charge Controller Ampere rating = 1,274.36/60 = 22Nos of Charge Controllers of 60A, 24V;

Current contributions

- A 300W panel short circuit current: 8.72Amp (From Manufacturer name plate)
- 2Nos 300W Panel serially connected gives 48V
- 204 Parallel circuit current contribution = 8.75 × 204 = 1,785 A

- A stack of (1.7 – 2.0) KAmp Circuit Breaker is suitable
- 4 separate circuits each will have current contribution: I =1785 /4 = 446.25A

Inverter Sizing

- Available Power: 91,754.1W = 91.75kW
- Inverter 91.75 × 125/100 = 114.69kW
- 115kW, 48Vd.c, 230Va.c Inverter is recommended

Space for Modules Installation

- Area of a 300W module = (1.95 × 0.99) m^2 = 1.9305m^2
- Space for 408 Modules: 1.9305 × 408 = 787.644 m^2
- 20% PV array space allowance = 157.53m^2
- Total space for module installation = 945.17 m^2
- Space for battery bank, inverters and other accessories = 9.26m^2

Bill of Engineering Measurement and Evaluation (Cost of PV Integration)

S/N	Component Description	Quantity	Unit Price (₦)	Amount (₦)	Remarks
1	300W_p, 24V Polycrystalline Solar Module	408	110,000	44,880,000	Solar World, Sun Tech, Simba products.
2	1000Ah, 2V Deep Cycle Battery	29	229,250	6,648,250	Hoppecke, Trojan, Simba Products.
3	60A, 24V Charge Controller.	22	45,000	990,000	Stecca, Morning Star, Simba Products.
4	24$V_{d.c}$, 230$_{a.c}$ 115kW pure sine wave inverter. (40kVA Each)	3	4,720,000	14,160,000	
5	Stack of (1.7 - 2.0)Kamp Circuit Breaker (500Amp Each)	4	40,000	160,000	
6	16mm^2 Single core Copper Cable (Solar)	25 Coils	15,000	30,000	Nigerian Wire and Cable.
7	Connectors/ Cable logs	Many	40,000	40,000	
8	Change Over Switch	4	5,000	20,000	
9	Steel Rack for Installation Frames	LOT	1,500,000	1,500,000	
10	Lighting Protection System	4 Sets	10,000	40,000	
11	100A Circuit Breaker	4	3,000	12,000	
12	150A Circuit Breaker	4	5,000	20,000	
13	Transportation	LOT	300,000	300,000	
	Sub-Total 1			**68,800,250**	
14	10% Contingency			6,880,025	
15	5% Workmanship			3,440,013	
	Sub-Total 2			79,120,288	
16	5% VAT			3,956,014	
17	35% Profit			27,692,101	
	Grand Total			**110,768,403**	

Appendix 22: Design of Solar PV System, CPC (Option B – Without Cooling Loads)

Consumer Protection Council

DESIGN OF SOLAR PV INTEGRATED POWER SYSTEMS

Design specification/parameters

1. $300W_p$, 24V Polycrystalline Module dimension; 1.95m × 0.99m
2. System Voltage is 48V
3. Sunshine Hour is 6hr/day
4. Average radiation intensity is $500W/m^2$ (Out of $1000W/m^2$)
5. 1000Ah, 2V Batteries @ 80% Depth of Discharge (DoD) used
6. Days of Autonomy (DoA) are 3 days
7. 20 % Energy for losses; and
8. 60A, 24V rated Charge Controllers used.
9. Site coordinates: Lat $9^{O}4^{1}33.01^{11}$N Long $7^{O}28^{1}11.93^{11}$E

Component Sizing

- Load = 34.312kW
- Energy (Wh/day)= 137,251.152Wh/day at 4 hours
- Irradiation is minimum @ $500W/m^2$
- Sunshine hour = 6
- Energy generated by a 300W module in @ $500W/m^2$ = 300 × 6 × 0.5 = 900Wh/day

Module Sizing

- Numbers of module: Energy Wh/day)/Energy Generated by a 300W module = 137,251.152/900 = 153Nos of 300W, 24V Module

Battery Sizing

- System voltage = 48V
- Energy to be stored in the Batteries = (Available Energy × DoA)/ System Voltage = (137,251.152× 3)/48 = 8,578.197Ah
- Total Number of Batteries required to meet 3 days energy storage @ 80% DoD = 8578.197Ah /(1000Ah × 0.8) = 11Nos of 1000Ah, 2V Batteries
- Total number of Deep Cycle Batteries of 80% DoD = 11Nos of 1000Ah, 2V Batteries are required

Charge Controller Sizing / Numbers of Charge Controllers

- Total current from modules: Available Energy/ (System Voltage × Sunshine hour) = 137,251.152 / (48×6) = 476.57 Ampere;
- Charge Controller selection: 60Amp
- Number of Controllers: Total Current from the Modules/ Charge Controller Ampere rating = 476.57 /60 = 8Nos of Charge Controllers of 60A, 24V

Current contributions

- A 300W panel short circuit current: 8.72Amp (From Manufacturer name plate)
- 2Nos 300W Panel serially connected gives 48V
- 153 Parallel circuit current contribution = 8.75 × 153 = 1,338.75 A
- A stack of 1.5 KAmp Circuit Breaker is suitable
- 4 separate circuits each will have current contribution: I =1338.75 /4 = 334.69A

Inverter Sizing

- Available Power: 34,312.79W = 34.312kW

- Inverter 34.312 × 125/100 = 42.89kW
- 43kW, 48Vd.c, 230Va.c Inverter is recommended

Space for Modules Installation

- Area of a 300W module = (1.95 × 0.99) m^2 = 1.9305m^2
- Space for 408 Modules: 1.9305 × 153 = 295.37 m^2
- 20% PV array space allowance = 59.07m^2
- Total space for module installation = 354.44s m^2
- Space for battery bank, inverters and other accessories = 9.26m^2

Bill of Engineering Measurement and Evaluation (Cost of PV Integration)

S/N	Component Description	Quantity	Unit Price (₦)	Amount (₦)	Remarks
1	300W_p, 24V Polycrystalline Solar Module	153	110,000	16,830,000	Solar World, Sun Tech, Simba products.
2	1000Ah, 2V Deep Cycle Battery	11	229,250	2,521,750	Hoppecke, Trojan, Simba Products.
3	60A, 24V Charge Controller.	8	45,000	360,000	Stecca, Morning Star, Simba Products.
4	24$V_{d.c}$, $230_{a.c}$ 45kW pure sine wave inverter.	1	5,200,000	5,200,000	
5	Stack of 1.5Kamp Circuit Breaker (375Amp Each)	4	10,000	40,000	
6	16mm^2 Single core Copper Cable (Solar)	25 Coils	15,000	375,000	Nigerian Wire and Cable.
7	Connectors/ Cable logs	Many	40,000	40,000	
8	Change Over Switch	4	5,000	20,000	
9	Steel Rack for Instal Frames	LOT	1,500,000	1,500,000	
10	Lighting Protection System	4 Sets	10,000	40,000	
11	100A Circuit Breaker	4	3,000	12,000	
12	150A Circuit Breaker	4	5,000	20,000	
13	Transportation	LOT	300,000	300,000	
	Sub-Total 1			**27,258,750**	
14	10% Contingency			2,725,875	
15	5% Workmanship			1,362,938	
	Sub-Total 2			31,347,563	
16	5% VAT			1,567,378	
17	35% Profit			10,971,647	
	Grand Total			**43,886,588**	

Appendix 23: Design of Solar PV System, REA (Option A – Total Loads)

Rural Electrification Building

DESIGN OF SOLAR PV INTEGRATED POWER SYSTEMS

Design specification/parameters

1. $300W_p$, 24V Polycrystalline Module dimension; 1.95m × 0.99m
2. System Voltage is 48V
3. Sunshine Hour is 6hr/day
4. Average radiation intensity is $500W/m^2$ (Out of $1000W/m^2$)
5. 1000Ah, 2V Batteries @ 80% Depth of Discharge (DoD) used
6. Days of Autonomy (DoA) are 3 days
7. 20 % Energy for losses; and
8. 60A, 24V rated Charge Controllers used.
9. Site coordinates = Lat $9^{O}4^{1}23.01^{11}$N Long $7^{O}29^{1}18.74^{11}$E

Component Sizing

- Load = 59.162kW
- Energy (Wh/day) = 236,651.04 Wh/day at 4 hours
- Irradiation is minimum @ $500W/m^2$
- Sunshine hour = 6
- Energy generated by a 300W module in @ $500W/m^2$ = 300 × 6 × 0.5 = 900Wh/day

Module Sizing

- Numbers of module = Energy (Wh/day)/Energy generated by a 300W module = 236651.04/900 = 262.95 ≈ 263Nos. of 300W, 24V Module

Battery Sizing

- System voltage = 48V
- Energy to be stored in the Batteries: (Available Energy × DoA)/ System Voltage = (236651.04× 3)/48 = 14,790.69Ah
- Numbers of Batteries required to meet 3-days energy storage @ 80% DoD = 14,790.69Ah / (1000Ah × 0.8) = 18.488 ≈ 19Nos of 1000Ah, 2V Batteries
- Total number of Deep Cycle Batteries of 80% DoD = 19Nos of 1000Ah, 2V Batteries are required

Charge Controller Sizing / **Numbers of Charge Controllers**

- Total current from modules: Available Energy/ (System Voltage × Sunshine hour) =236,651.04 / (48×6) = 821.71Ampere
- Charge Controller selection: 60Amp
- Nos. of Controllers: Total Current from the Modules/ Charge Controller Ampere rating = 821.71 /60 = 13.695 =14 ≈ 14Nos of Charge Controllers of 60A, 24V

Current contributions

- A 300W panel short circuit current: 8.72Amp (From Manufacturer name plate)
- 2 Nos 300W Panel serially connected gives 48V
- 132 Parallel circuit current contribution = 8.75 × 132 = 1,155 A
- A stack of 1.2 KAmp Circuit Breaker is suitable
- 4 separate circuits each will have current contribution: I =1155 /4 = 288.75 A

Inverter Sizing

- Available Power: **=** 59.162kW
- Inverter 59.162 × 125/100 = 73.95 kW
- 75kW, 48Vd.c, 230Va.c Inverter is recommended

Space for Modules Installation

- Area of a 300W module = (1.95 × 0.99) m^2 = 1.9305m^2
- Space for 263 Modules: 1.9305 × 263 = 507.72 m^2
- 20% PV array space allowance = 101.54m^2
- Total space for module installation = 609.26 m^2
- Space for battery bank, inverters and other accessories = 12.056m^2

Bill of Engineering Measurement and Evaluation (Cost of PV Integration)

S/N	Component Description	Quantity	Unit Price (₦)	Amount (₦)	Remarks
1	300W_p, 24V Polycrystalline Solar Module	263	110,000	28,930,000	Solar World, Sun Tech, Simba products.
2	1000Ah, 2V Deep Cycle Battery	19	229,250	4,355,750	Hoppecke, Trojan, Simba Products.
3	60A, 24V Charge Controller.	14	45,000	630,000	Stecca, Morning Star, Simba Products.
4	24$V_{d.c}$, 230$_{a.c}$ 75kW pure sine wave inverter.	1	4,450,000	4,450,000	China product (CBC)
5	Stack of 1.2KAmp Circuit Breaker (300Amp Each)	4	25,000	100,000	
6	16mm^2 Single core Copper Cable (Solar)	25 Coils	15,000	375,000	Nigerian Wire and Cable.
7	Connectors/ Cable logs	Many	40,000	40,000	
8	Change Over Switch	4	5,000	20,000	
9	Steel Rack for Installation Frames	LOT	1,500,000	1,500,000	
10	Lighting Protection System	4 Sets	10,000	40,000	
11	100A Circuit Breaker	4	3,000	12,000	
12	150A Circuit Breaker	4	5,000	20,000	
13	Transportation	LOT	300,000	300,000	
	Sub-Total 1			**40,772,750**	
14	10% Contingency			4,077,275	
15	5% Workmanship			2,038,637.5	
	Sub-Total 2			**46,889,137.5**	
16	5% VAT			2,344,456.88	
17	35% Profit			16,411,198.13	
	Grand Total			**65,644,792.51**	

Appendix 24: Design of Solar PV System, REA (Option B)(Without cooling loads)

Rural Electrification Building

DESIGN OF SOLAR PV INTEGRATED POWER SYSTEMS

Design specification/parameters

1.` $300W_p$, 24V Polycrystalline Module dimension; 1.95m × 0.99m
2. System Voltage is 48V
3. Sunshine Hour is 6hr/day
4. Average radiation intensity is $500W/m^2$ (Out of $1000W/m^2$)
5. 1000Ah, 2V Batteries @ 80% Depth of Discharge (DoD) used
6. Days of Autonomy (DoA) are 3 days
7. 20 % Energy for losses; and
8. 60A, 24V rated Charge Controllers used.
9. Site coordinates = Lat $9^O4^123.01^{11}N$ Long $7^O29^118.74^{11}E$

Component Sizing

- Load = 26.78kW
- Energy (Wh/day) = 107,103.168 Wh/day at 4 hours
- Irradiation is minimum @ $500W/m^2$
- Sunshine hour = 6
- Energy generated by a 300W module in @ $500W/m^2$ = 300 × 6 × 0.5 = 900Wh/day

Module Sizing

- Numbers of module = Load/Energy generated by a 300W module = 107,103.168/900 = 119.004 ≈ 120Nos of 300W, 24V Module

Battery Sizing

- System voltage = 48V
- Energy to be stored in the Batteries: (Available Energy × DoA)/ System Voltage = (107,103.168× 3)/48 = 6,693.95Ah Ah
- Numbers of Batteries required to meet 3-days energy storage @ 80% DoD = 6693.95Ah / (1000Ah × 0.8) = 8.37 ≈ **9**Nos of 1000Ah, 2V Batteries
- Total number of Deep Cycle Batteries of 80% DoD = 9Nos of 1000Ah, 2V Batteries are required

Charge Controller Sizing / Numbers of Charge Controllers

- Total current from modules: Available Energy/ (System Voltage × Sunshine hour) =107103.168 / (48×6) = 371.89 Ampere
- Charge Controller selection: 60Amp
- Nos of Controllers: Total Current from the Modules/ Charge Controller Ampere rating =371.89 /60 = ≈ 6.20 = 7Nos of Charge Controllers of 60A, 24V

Current contributions

- A 300W panel short circuit current: 8.72Amp (From Manufacturer name plate)
- 2Nos 300W Panel serially connected gives 48V
- 60 Parallel circuit current contribution = 8.75 × 60 = 525 A
- A stack of 0.6 KAmp Circuit Breaker is suitable
- 4 separate circuits each will have current contribution: I = 525 /4 = 131.25 A

Inverter Sizing

- Available Power: **=** 26.78kW
- Inverter 26.78 × 125/100 = 33.48 kW
- 34kW, 48Vd.c, 230Va.c Inverter is recommended

Space for Modules Installation

- Area of a 300W module = (1.95 × 0.99) m^2 = 1.9305m^2
- Space for 263 Modules: 1.9305 × 120 **=** 231.66 m^2
- 20% PV array space allowance = 46.332m^2
- Total space for module installation = 277.992 m^2
- Space for battery bank, inverters and other accessories = 12.056m^2

Bill of Engineering Measurement and Evaluation (Cost of PV Integration)

S/N	Component Description	Quantity	Unit Price (₦)	Amount (₦)	Remarks
1	300W_{p}, 24V Polycrystalline Solar Module	120	110,000	13,200,000	Solar World, Sun Tech, Simba products.
2	1000Ah, 2V Deep Cycle Battery	9	229,250	2,063,250	Hoppecke, Trojan, Simba Products.
3	60A, 24V Charge Controller.	7	45,000	315,000	Stecca, Morning Star, Simba Products.
4	24$V_{d.c}$, 230$_{a.c}$ 35kW pure sine wave inverter.	1	1,960,000	1,960,000	**China product (**Yongda)
5	Stack of 0.6 Kamp Circuit Breaker (150Amp Each)	4	5,000	20,000	
6	16mm^2 Single core Copper Cable (Solar)	25 Coils	15,000	375,000	Nigerian Wire and Cable.
7	Connectors/ Cable logs	Many	40,000	40,000	
8	Change Over Switch	4	5,000	20,000	
9	Steel Rack for Installation Frames	LOT	1,500,000	1,500,000	
10	Lighting Protection System	4 Sets	10,000	40,000	
11	100A Circuit Breaker	4	3,000	12,000	
12	150A Circuit Breaker	4	5,000	20,000	
13	Transportation	LOT	300,000	300,000	
	Sub-Total 1			**19,865,250**	
14	10% Contingency			1,986,525	
15	5% Workmanship			993,263	
	Sub-Total 2			**22,845,038**	
16	5% VAT			1,142,252	
17	35% Profit			7,995,763	
	Grand Total			**31,983,053**	

Appendix 25: Calculation of Cost of Energy Consumption of Lighting and Plug Loads

Formulae

$n = Number\ of\ public\ hoildays, days$

$E = Energy\ consumption, KWh$

$W = Planned\ working\ hours\ to\ be\ transfered\ to\ Solar\ PV\ Back-up, h/day$

$T = Electircity\ tariff, ₦/Kwh$

$N = Number\ of\ working\ days\ in\ a\ year$

Inputs

$N = 52 * 5 - n$

$n = 13\ days$

$N = 260 - 13 = 247\ days$

$W = 4\ h/day$

$C = Cost, Naira$

Energy Commission of Nigeria

$E_{ecn} = 24.089\ kWh$

$C_{ecn} = E_{ecn} * W * N * T$

$C_{ecn} = 24.089 * 4 * 247 * 47.09 =$ **₦1,120,739**

Consumer Protection Council

$E_{cpc} = 28.594\ KWh$

$C_{cpc} = E_{cpc} * W * N * T$

$C_{cpc} = 28.594 * 4 * 247 * 47.09 =$ **₦1,330,334**

Rural Electrification of Nigeria

$E_{rea} = 22.313\ KWh$

$C_{rea} = E_{rea} * W * N * T$

$C_{rea} = 22.313 * 4 * 247 * 47.09 =$ **₦1,038,111**

Appendix 26: Energy and Monetary Savings from Lighting Retrofit

The steps taken to arrive at the savings are as follows[5]:

i. $Fixture\ Quantity\ \times Fixture\ Wattage = Total\ Watts$
ii. $Total\ Watts \div 1000 = kiloWatts\ (kW)$
iii. $kiloWatts\ \times (hours\ of\ use) = kWh$
iv. $(kWh\ \times (Cost\ of\ energy\ or\ current\ electricity\ tariff) = Cost\ per\ hour)$

ENERGY COMMISSION OF NIGERIA

1. Replacing 60W ICL with either 10W LED or 12W CFL

Given the following values:

i. $Fixture\ Quantity = 12$
ii. $Fixture\ Wattage = 60W$
iii. $Hours\ of\ use = 1h$
iv. $Cost\ of\ Energy\ (current\ electricity\ tariff) = N47.09k/kWh$

1.1 60W ICL

$12 \times 60 = 720W$
$720W\ \div 1000 = 0.72kW$
$0.72kW\ \times\ 1h = 0.72kWh$
$0.72kWh\ \times ₦47.09kWh = ₦33.9048 \approx ₦\mathbf{33.90k/kWh}$

1.2 10W LED

$12 \times 10 = 120W$
$120W \div 1000 = 0.12kW$
$0.12kW \times 1h = 0.12kWh$
$0.12kWh\ \times ₦47.09kWh = N5.6508\ \approx ₦5.65/kWh$
Savings in kWh: $0.72kWh - 0.12kWh = 0.6kWh$
Savings in Naira for utility bill: $0.6kWh * ₦47.09 = ₦28.25k/kWh$

1.3 12W CFL

$12\ \times 12W = 144W$
$144W\ \div 1000 = 0.144kW$
$0.144kW\ \times 1h = 0.144kWh$
$0.144kWh \times ₦47.09kWh = ₦6.78096 \approx ₦6.78k/kWh$
Savings in kWh: $0.72kWh\ - 0.144kWh = 0.576kWh = 576Wh$
Savings in Naira for utility bill: $N33.90\ - ₦6.78 = ₦27.12k/kWh$

2. Replacing 18W LFL with either 5W LED or 9W CFL

Given the following values:

i. $Fixture\ Quantity = 32$
ii. $Fixture\ Wattage = 18W$
iii. $Hours\ of\ use = 1h$
iv. $Cost\ of\ Energy\ (current\ electricity\ tariff) = ₦47.09/kWh$
v. 18W LFL is equivalent to 5W LED or 9W CFL

2.1 18W LFL

$32\ \times 18 = 576W$
$576W\ \div 1000 = 0.576kW$
$0.576kW\ \times\ 1h = 0.576kWh$
$0.576kWh\ \times ₦47.09kWh = ₦27.107 \approx ₦27.11/kWh$

[5] (Source: http://www.hoveyelectric.com/hovey-electric-power-blog/bid/55242/How-To-Calculate-Watts-For-Analyzing-Energy-Efficiency-Projects)

2.2 5W LED

$32 \times 5 = 160W$
$160W \div 1000 = 0.16kW$
$0.16kW \times 1h = 0.16kWh$
$0.16kWh \times ₦47.09kWh = ₦7.5344 \approx ₦7.53/kWh$
Savings in kWh: $0.576kWh - 0.16kWh = 0.416kWh = 416Wh$
Savings in Naira for utility bill: $₦27.11 - ₦7.53 = ₦19.58/kWh$

2.3 9W CFL

$32 \times 9 = 288W$
$288W \div 1000 = 0.288kW$
$0.288kW \times 1h = 0.288kWh$
Savings in kWh: $0.576kWh - 0.288kWh = 0.288kWh$
Savings in Naira for utility bill: $0.288kWh * ₦47.09/kWh = ₦13.56(per\ kWh)$

3. Replacing 36W LFL with either 20W LED or 23W CFL

Given the following values:
$Fixture\ Quantity = 61$
$Fixture\ Wattage = 36W$
$Hours\ of\ use = 1h$
$Cost\ of\ Energy\ (current\ electricity\ tariff) = ₦47.09/kWh$
LED equivalent of 36W LFL is 20W[6]

3.1 36W LFL

$61 \times 36 = 2{,}196W$
$2196W \div 1000 = 2.196kW$
$2.196kW \times 1h = 2.196kWh$
$2.196kWh \times ₦47.09kWh = ₦103.40964 \approx ₦103.41/kWh$

3.2 20W LED

$61 \times 20 = 1220W$
$1220W \div 1000 = 1.22kW$
$1.22kW \times 1h = 1.22kWh$
$1.22kWh \times ₦47.09kWh = ₦57.4498 \approx ₦57.45/kWh$
Savings in kWh: $2.196kWh - 1.22kWh = 0.976kWh$
Savings in Naira for utility bill: $₦103.41 - ₦57.45 = ₦45.96/kWh$

3.3 23W CFL

$61 \times 23 = 1403W$
$1403W \div 1000 = 1.403kW$
$1.403kW \times 1h = 1.403kWh$
$1.403kWh \times ₦47.09kWh = ₦66.06727 \approx ₦66.08/kWh$
Savings in kWh: $2.196kWh - 1.403kWh = 0.793kWh$
Savings in Naira for utility bill: $₦103.41 - ₦66.08 = ₦36.33/kWh$

[6] (source: http://www.newenergyco-op.co.uk/blog/blog-36.html)

CONSUMER PROTECTION COUNCIL

The steps taken to arrive at the savings are as follows[7]

i. $Fixture\ Quantity\ \times Fixture\ Wattage = Total\ Watts$
ii. $Total\ Watts \div 1000 = kiloWatts\ (kW)$
iii. $kiloWatts\ \times (hours\ of\ use) = kWh$
iv. $kWh\ \times (Cost\ of\ energy\ or\ current\ electricity\ tariff) = Cost\ per\ hour$

1. Replacing 18W LFL with 5W LED or 9W CFL

Given the following values

$Fixture\ Quantity = 544$
$Fixture\ Wattage = 18W$
$Hours\ of\ use = 1h$
$Cost\ of\ Energy\ (current\ electricity\ tariff) = ₦47.09/kWh$

1.1 18W LFL

$544\ \times 18 = 9792W$
$9792W\ \div 1000 = 9.792kW$
$9.792kW\ \times\ 1hr = 9.792kWh$
$9.792kWh\ \times ₦47.09kWh = ₦461.10528\ \approx ₦461.11/kWh$

1.2 5W LED

$544\ \times 5 = 2720W$
$2720W\ \div 1000 = 2.72kW$
$2.72kW\ \times\ 1hr = 2.72kWh$
$2.72kWh\ \times ₦47.09kWh = ₦128.0848\ \approx ₦128.08/kWh$
Savings in kWh: $9.792kWh\ - 2.72kWh = 7.072kWh$
Savings in Naira for utility bill: $₦461.11\ - ₦128.08 = ₦333.03/kWh$

1.3 9W CFL

$544\ \times 9 = 4896W$
$4896W\ \div 1000 = 4.896kW$
$4.896kW\ \times\ 1hr = 4.896kWh$
$4.896kWh\ \times ₦47.09kWh = ₦230.55264\ \approx ₦230.55/kWh$
Savings in kWh: $9.792kWh - 4.896kWh = 4.896kWh = 4896Wh$
Savings in Naira for utility bill: $₦461.11\ - ₦230.55 = ₦230.56/kWh$
LED light for indoor use – CE[8]; LED light for outdoor use – UL

Appendix 27: Comparison of Different Lighting Equipment

Light Output	LEDs	ICLs	CFLs	LFLs*
Lumens	Watts	Watts	Watts	Watts
450	4 – 5	40	9 – 13	18
800	6 – 8	60	13 – 15	-
1,100	9 – 13	75	18 – 25	-
1,600	16 – 20	100	23 – 30	36
2,600	25 – 28	150	30 – 55	-

Source: http://www.usailighting.com/stuff/contentmgr/files/1/92ffeb328de0f4878257999e7d46d6e4/misc/lighting_comparison_chart.pdf)
*Added based on an earlier lighting retrofit at the ECN building.

[7] (Source: http://www.hoveyelectric.com/hovey-electric-power-blog/bid/55242/How-To-Calculate-Watts-For-Analyzing-Energy-Efficiency-Projects)
[8] Source: https://www.ledlight.com/LED-Information.aspx

Appendix 28: Data of Temperature Measurement of Some Offices in ECN Captured using Temperature Meter, from 23rd Dec., 2016 and 10th Jan., 2017.

S/No	Office	Temperature, °C				
		Max	Min	Average	Noon	Night
1	Director General	30	23	27	28	27.5
2	Director EIS	28.5	20.5	24.9	25	25
3	Director EPA	30	24	28.8	29	29
4	Director EMTMD	30	18.5	26.9	27	27
5	Director NST	29	20.5	27.7	27.5	27.5
6	Director RENEWABLE	29	22	26.8	27	27
7	Deputy Director EMTMD	32	25.5	27.8	27	27
8	Deputy Director EIS	33.5	22.5	26.1	26.5	26.5
9	Deputy Director BUDGET	29	20	26.8	27.5	27.5
10	UNDP OFFICE	28.5	22.5	26.3	26.5	26.5
11	Server ROOM	29	19	24.5	27.5	26
12	Library	31	22	25.3	25.5	25.5

Appendix 29: Management Responsiveness

1.	Case of Faulty Switch in ECN	
2.	**Inputs and Assumptions**	
3.	No of Lighting Points Controlled a the Switch	3
4.	Wattage of Each Lighting Point, W	20
5.	Hour of Usage during of Official Days	8
6.	No. of Official Days	247
7.	Hours of Use during Work Free Days	24
8.	No of Days per annum	365
9.	Electricity Tariff, Naira	47.09
10.	**Calculations**	
11.	Wastage during Official Days, kWh	237.12
12.	Wastage during work free days, kW	169.92
13.	Total Wastage, kWh	**407.04**
14.	Total Wastage, Naira	**19,167.51**

Appendix 30: Users'/Occupants' Awareness and Compliance

1.	Air conditioners not turn off when the office room is un-occupied during office hours	
2.	From the results of Behavioural Energy Audit, percentage of the office occupants that has this habit is given below:	
3.	**Inputs and Assumptions**	
4.	ECN, % (Chart 3.1.18)	43.14
5.	CPC, % (Chart 3.2.13)	43.5
6.	REA, % (Chart 3.3.15)	34.37
7.	Total Hourly Electricity Consumption by ACs in ECN, kWh (Chart 3.1.2)	104.355
8.	Total Hourly Electricity Consumption by ACs in CPC, kWh (Chart 3.2.2)	47.87
9.	Total Hourly Electricity Consumption by ACs in REA, kWh (Chart 3.3.2)	26.99
10.	No of hours Each ACs was not Shut Off when the office was un-occupied in a week, hr	0.5
11.	Electricity Tariff per kWh, Naira	47.09
12.	No of Weeks per Annum	52
13.	**Calculations**	
14.	Wastage, kWh	**195,309.02**
15.	Wastage, Naira	**9,197,078.00**

Appendix 31: Number of Hours Electricity Supply from the Grid is Available Daily

1.	**Inputs**	
2.	Official Days	247
3.	ECN, Electricity Supply from the Grid, kWh (2015)	244,419.00
4.	ECN, Electricity Supply from the Grid, kWh (2016)	165,217.00
5.	CPC, Electricity Supply from the Grid, kWh (2015)	64,734.00
6.	CPC, Electricity Supply from the Grid, kWh (2016)	56,950.40
7.	REA, Electricity Supply from the Grid, kWh (2015)	35,857.00
8.	REA, Electricity Supply from the Grid, kWh (2016)	36,491.00
9.	ECN, Measured Average Total Hourly Consumption, kWh (Table 3.1.2)	128.44
10.	CPC, Measured Average Total Hourly Consumption, kWh (Table 3.2.2)	76.46
11.	REA, Measured Average Total Hourly Consumption, kWh (Table 3.3.2)	49.30
12.	**Calculations**	
13.	ECN: Availability of Electricity Supply from the Grid, Hour	**6.46**
14.	CPC: Availability of Electricity Supply from the Grid, Hour	**3.22**
15.	REA: Availability of Electricity Supply from the Grid, Hour	**2.97**

Appendix 32: Replacement 544 LFLs with LEDs at CPC

1	**Inputs and Assumptions**	
2	No of 18W LFLs to be Replaced with 5W LEDs	544
3	Wattage of LFLs, W	18
4	Wattage of LEDs, W	5
5	No of Hours of Usage, Hour	8
6	No of Official Working Days in a year	247
7	Measured Average Hourly Total Electricity Consumption, kWh	76.46
8	Estimated Average Total Annual Electricity Consumption, kWh	151,088.42
9	Measured Average Hourly Electricity Consumption (PLs and Lighting), kWh	28.59
10	Estimated Total Annual Electricity Consumption (PLs and Lighting), kWh	56,501.72
11	Estimated Total Annual Electricity Consumption, Naira	**7,114,754**
12	**Calculation**	
13	Saving due to Replacement, kWh	13,974
14	Saving due to Replacement, Naira	658,048
15	Percentage Saving per annum relative to Estimated Average Annual Consumption of Plug Loads and Lighting, kWh	**24.73**
16	Percentage Saving per annum relative to Average Total Annual Consumption, kWh	9.25

Appendix 33: Generator Sizing, Consumer Protection Council

1.	**Background Information**	
2.	There are two (2) diesel generators in CPC: 150kVA (GMJ) and 250kVA (FG Wilson)	
3.	From additional information obtained from the Maintenance Unit of CPC, the 150kVA generator set is operated 2 to 3 hours daily while 250kVA, 6 -7 hours.	
4.	The measured average total hourly power consumption = 76,461.75Wh	
5.	Going by Appendix 7: Diesel Generator Fuel Consumption in Litres, generator set 250kVA is oversized and consume excess of about 4.5litres of diesel every one hour.	
6.	If 250kVA is replaced by a 120/150kVA a saving of 4.5litres of diesel could have been made.	
7.	**Inputs and Assumption**	
8.	Measured Average Total Hourly Consumption, kWh	76.46
9.	Total Annual Electricity Consumption (Gr id; 2015), kWh	64,734
10.	Total Annual Electricity Consumption (Gr id; 2016), kWh	56,950
11.	No of Official working days	247
12.	Diesel Consumption per annum (2015), Litres	41,500
13.	Diesel Consumption per annum (2016), Litres	20,000
14.	Average Diesel Consumption, Litres	30,750
15.	Diesel Consumption per annum (2015), Naira	7,470,000
16.	Diesel Consumption per annum (2016), Naira	3,600,000
17.	Average Diesel Consumption, Naira	5,535,000

18.	Cost and Delivery of 120kW/250kWA, Naira	11,000,000
19.	Hourly Diesel Saving from replacing 250kVA with a 150kVA, hrs	4.5
20.	Unit Price of Litre of Diesel, Naira	180
21.	**Calculation**	
22.	Estimated Daily Electricity Consumption from the Grid, Hrs	3.2
23.	Estimated Daily Electricity Consumption from the Generator Set, Hrs	6.2
24.	Diesel Saving per annum, Litres	6918.75
25.	Diesel Saving per annum, Naira	1,245,375
26.	Percentage Saving of Diesel per annum (Litres)	22.50
27.	Percentage Saving of Diesel per annum (Cost)	22.5
28.	**Pay Back Period**	
29.	Cost of 150kVA Generator Set and Delivery, Naira	11,000,000
30.	10% Contingency	1,100,000.0
31.	5% Installation	550,000.00
32.	Sub Total	12,650,000
33.	5% VAT	632,500.00
34.	30% Profit	3,795,000.0
35.	Grand Total	**17,077,500**
36.	Pay Back Period, years	**13.7**

Appendix 34: Energy Savings in Air Conditioners, Energy Commission of Nigeria

1.	**Inputs and Assumptions**	
2.	Total No of ACs	71
3.	No of Measured ACs	63
4.	Measured Average Total Hourly Power Consumption , kWh	128.44
5.	Measured Power Consumption by the 63 ACs in 1 hour, kWh	104.36
6.	Electricity Tariff (2016), kWh	47.09
7.	Each AC to be retrofitted by 1.5Hp	1.119
8.	No of Usage Daily in hours	6
9.	No of Official Working Days per annum, day	247
10.	Total Cost of Electricity in 2015, Naira	5,790,291.00
11.	Total Cost of Electricity in 2016, Naira	7,613,071.00
12.	Total Cost of Diesel in 2015, Naira	10,140,000.00
13.	Total Cost of Diesel in 2016, Naira	14,710,500.00
14.	**Calculations**	
15.	Expected Power Consumption in 1 hour, if all the 63 were retrofitted to 1.5Hp Slit AC, kWh	70.497
16.	Expected Savings in One Hour, kWh	33.86
17.	Expected Savings per annum if 63 ACs are retrofitted, kWh	50,177.81
18.	Expected Savings per annum if 63 ACs are retrofitted, Naira	**2,362,872.98**
19.	Average Total Expenditure on Electricity (Grid and Generator) - 2015-2016; Naira	19,126,931.00
20.	Percentage Saving to Total Cost of Power Supply (Grid and Gen.), %	**12.35**
21.	Percentage Saving to Measured Average Total Hourly Power Consumption, %	**26.36**
22.	Percentage Saving Relative to Power Consumption by ACs, %	**32.45**
23.	**Pay Back Period**	
24.	Unit Cost of 1.5Hp Split AC plus Delivery, Naira	150,000.00
25.	Cost of 71 ACs and Delivery, Naira	10,650,000.00
26.	10% Contingency	1,065,000.00
27.	5% Workmanship	532,500.00
28.	Sub Total	12,247,500.00
29.	5% VAT	612,375.00
30.	30% Profit	3,674,250.00
31.	Grand Total	**16,534,125.00**
32.	**Pay Back Period, years**	**7**

Appendix 35: Energy Savings in ACs, Consumer Protection Council

1	**Inputs and Assumptions**	
2	Total No of ACs*	60
3	No of Measured ACs	26
4	Measured Average Total Hourly Power Consumption , kWh	76.46
5	Measured Power Consumption by the 26 ACs in 1 hour, kWh	41.67
6	Electricity Tariff (2016), kWh	47.09
7	Each AC to be retrofitted by 1.5Hp	1.119
8	No of Usage Daily in hours	6
9	No of Official Working Days per annum, day	247
10	Total Cost of Electricity in 2015, Naira	3,320,453.78
11	Total Cost of Electricity in 2016, Naira	3,184,018.79
12	Total Cost of Diesel in 2015, Naira	7,470,000.00
13	Total Cost of Diesel in 2016, Naira	3,600,000.00
14	**Calculations**	
15	Expected Power Consumption in 1 hour, if all the 26 were retrofitted to 1.5Hp Slit AC, kWh	29.094
16	Expected Savings in One Hour, kWh	12.57
17	Expected Savings per annum if 26 ACs are retrofitted, kWh	18,634.31
18	Expected Savings per annum if the 26 ACs are retrofitted, Naira	**877,489.77**
19	Average Total Expenditure on Electricity (Grid and Generator) - 2015-2016; Naira	8,787,236.29
20	Percentage Saving to Total Cost of Power Supply (Grid and Gen.), %	**9.99**
21	Percentage Saving to Measured Average Total Hourly Power Consumption, %	**16.44**
22	Percentage Saving Relative to Power Consumption by ACs	**30.18**
23	**Pay Back Period**	
24	Unit Cost of 1.5Hp Split AC plus Delivery, Naira	150,000.00
25	Cost of 30 (half of the total) ACs and Delivery, Naira	4,500,000.00
26	10% Contingency	450,000.00
27	5% Workmanship	225,000.00
28	Sub Total	5,175,000.00
29	5% VAT	258,750.00
30	30% Profit	1,552,500.00
31	Grand Total	**6,986,250.00**
32	Pay Back Period, years	8

* From the measurement taken, about 50% of the ACs consumes above their template value; therefore only half of the 60ACs will be retrofitted to 1.5Hp.

Appendix 36: Savings Computed using LCCA[9]

Table 1: Computed annual energy consumption and cost for the baseline and improved scenario at ECN

Appliances	Unit Cost of Electricity (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)
		Baseline		**Improved**		**Savings**	
LIGHTING	35.79	34,058.30	1,218,946	15,545	556,369	18,512	662,577
OFFICE EQUIPMENT (TV, Radio, Computers, Printers, copiers, scanners etc.)	35.79	343,363.27	12,288,971	98,763	3,534,757.83	244,599	8,754,213
COOLING: Refrigeration, Fan & Air Conditioning	35.79	30,659,928.00	1,097,318,823	16,705,584	597,892,851	13,954,344	499,425,971
HEATING: Cooking, Water Boilers	35.79	-	-	-	-	-	-
Cleaning Equipment	35.79	-	-	-	-	-	-
Electric Motors (E.G.	35.79	-	-	-	-	-	-

[9] Tables 1 to 17 were provided by the Consultants

Lifts)							
OTHERS	35.79	-	-	-	-	-	-
TOTAL		**31,037,349**	**1,110,826,741**	**16,819,893**	**601,983,978**	**14,217,456**	**508,842,762**

Table2: Computed annual energy consumption and cost for the baseline and improved scenario at CPC (Phase A)

Appliances	Unit Cost of Electricity (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)
		Baseline		**Improved**		**Savings**	
LIGHTING	35.79	3,344.95	119,715	1,973.66	70,637	1,371.28	49,078
OFFICE EQUIPMENT (TV, Radio, Computers, Printers, copiers, scanners etc.)	35.79	35,565.55	1,272,890	29,163.46	1,043,760	6,402.09	229,130
COOLING: Refrigeration, Fan & Air Conditioning	35.79	5,174,316.00	185,188,769	3,626,784.00	129,802,599	1,547,532.00	55,386,170
HEATING: Cooking, Water Boilers	35.79	739.20	26,455	739.20	26,455	-	-
Cleaning Equipment	35.79	-	-	-	-	-	-
Electric Motors (E.G. Lifts)	35.79	-	-	-	-	-	-
OTHERS	35.79	-	-	-	-	-	-
TOTAL		**5,213,965.69**	**186,607,832**	**3,658,660.32**	**130,943,452**	**1,555,305**	**55,664,379**

Table 3: Computed annual energy consumption and cost for the baseline and improved scenario at CPC (Phase B)

Appliances	Unit Cost of Electricity (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)
		Baseline		**Improved**		**Savings**	
LIGHTING	35.79	2,967.55	106,208	1,596.67	57,144	1,370.88	49,063
OFFICE EQUIPMENT (TV, Radio, Computers, Printers, copiers, scanners etc.)	35.79	30,686.30	1,098,262	19,588.85	701,084	11,097.46	397,177
COOLING: Refrigeration, Fan & Air Conditioning	35.79	7,669,872.00	274,504,718	5,369,112.00	192,160,518	2,300,760.00	82,344,200
HEATING: Cooking, Water Boilers	35.79	-	-	-	-	-	-
Cleaning Equipment	35.79	-	-	-	-	-	-
Electric Motors (E.G. Lifts)	35.79	-	-	-	-	-	-
OTHERS	35.79	-	-	-	-	-	-
TOTAL		**7,703,525.85**	**275,709,190.32**	**5,390,297.52**	**192,918,748**	**2,313,228.34**	**82,790,442**

Table 4: Computed annual energy consumption and cost for the baseline and improved scenario at REA

Appliances	Unit Cost of Electricity (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)	Annual Utilization (kWh)	Annual Cost (NGN)
		Baseline		**Improved**		**Savings**	
LIGHTING	35.79	15,646.58	559,991	7,838.21	280,529	7,808.37	279,461
OFFICE EQUIPMENT (TV, Radio, Computers, Printers, copiers, scanners etc.)	35.79	28,580.14	1,022,883	15,402.24	551,246	13,177.90	471,637
COOLING: Refrigeration, Fan & Air Conditioning	35.79	11,771,550.00	421,303,774	8,099,784.00	289,891,269	3,671,766.00	131,412,505
HEATING: Cooking, Water Boilers	35.79	5,695,200.00	203,831,208	-	-	5,695,200.00	203,831,208
Cleaning Equipment	35.79	-	-	-	-	-	-
Electric Motors (E.G.	35.79	-	-	-	-	-	-

Lifts)							
OTHERS	35.79	-	-	-	-	-	-
TOTAL		**17,510,976.72**	**626,717,856**	**8,123,024.45**	**290,723,044**	**9,387,952.28**	**335,994,811**

Table 5: Energy Management Alternatives, Escalation and Discount rates

Case	Base Case	Alternative
Type of lighting	Incandescent, 2ft fluorescent tube, 4ft fluorescent tube, CFL	Light Emmittingg Diodes (LED), High quality Compact Fluorescent Lamps (CFL)
Computers	Separate desktop computers	All-in-one desktop computers (smart computer)
Scanners, photocopiers and printers	Separate scanners, photocopiers and printers	All-in-one scanners, photocopiers and printers
Discount rate*	12%	12%
Escalation rate**	5%	5%
Year	2017-2031	
Amounts	Cost and Benefits stated in base year Naira	
Energy Prices	Local electricity prices at commercial rate	
Discounting Convention	End of year	

* CBN 2016 ; ** NERC 2012

Table 6: Life Cycle Cost on Lighting Appliances, ECN

Lighting	Baseline		Improved		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	1,542,200.00	1,542,200.00	Naira
Capital replacement cost	37,457.33	59,404.48	0	-	Naira
Residual cost	0	125.28	434,979.49	346,762.98	Naira
Annual electricity consumption	34,058.30		15,545.38		kWh
Current price of electricity	35		35		N/kWh
Annual electricity cost	1,192,040.64	11,089,332.25	544,088.16	5,061,550.90	Naira
Annual Maintenance and Repair cost	77,380.00	1,200,167.24	0	0	Naira
Total Life Cycle Cost		**12,348,778.69**		**6,256,987.92**	**Naira**
Net Savings				**6,091,790.77**	**Naira**

Table 7: Life Cycle Cost on Desktop Computer, ECN

Computer	Baseline		Improved		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	15,930,000.00	15,930,000.00	Naira
Capital replacement cost	-	12,598,510.39	0	-	Naira
Residual cost	1770000	1,004,345.53	7,080,000.00	4,017,382.14	Naira
Annual electricity consumption	645.12		25,025.11		kWh
Current price of electricity	35		35		N/kWh
Annual electricity cost	22,579.20	34,821,419.04	875,878.92	6,200,178.90	Naira
Annual Maintenance and Repair cost	5,310,000.00	15,065,183.02	885000	3,950,892.86	Naira
Total Life Cycle Cost		**61,480,766.91**		**22,063,689.62**	**Naira**
Net Savings				**39,417,077.29**	**Naira**

Table 8: Life cycle cost on office equipment (Printer, Photocopier and Scanner), ECN

Office Equipment	Baseline		Improved		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	1,845,000.00	1,845,000.00	Naira
Capital replacement cost	2,280,000.00	1,622,858.97	0	-	Naira
Residual cost	570000	323,433.31	600,000.00	340,456.11	Naira

Annual electricity consumption	2,298.24		46,620.00		kWh
Current price of electricity	35		35		N/kWh
Annual electricity cost	80,438.40	14,896,507.78	1,631,700.00	8,100,516.21	Naira
Annual Maintenance and Repair cost	1,710,000.00	4,851,499.62	75000	334,821.43	Naira
Total Life Cycle Cost		**21,047,433.06**		**9,939,881.53**	**Naira**
Net Savings				**11,107,551.53**	**Naira**

Table 9: Life Cycle Cost on Lighting Appliances, CPC

Lighting	**Baseline**		**Improved**		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	195,800.00	195,800.00	Naira
Capital replacement cost	9,221.33	32,633.79	0	-	Naira
Residual cost	0	-	55,225.64	44,025.54	Naira
Annual electricity consumption	3,344.95		1,973.66		kWh
Current price of electricity	35.79		35.79		N/kWh
Annual electricity cost	119,715.66	1,113,692.51	70,637.43	657,126.91	Naira
Annual Maintenance and Repair cost	-	-	0	0	Naira
Total Life Cycle Cost		**1,146,326.30**		**808,901.37**	**Naira**
Net Savings				**337,424.93**	**Naira**

Table 10: Life Cycle Cost on Desktop Computer, CPC

Computer	**Baseline**		**Improved**		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	540,000.00	540,000.00	Naira
Capital replacement cost	-	427,068.15	0	-	Naira
Residual cost	-60000	34,045.61	1,100,000.00	624,169.54	Naira
Annual electricity consumption	2,822.40		29,163.46		kWh
Current price of electricity	35.79		35.79		N/kWh
Annual electricity cost	101,013.70	1,119,969.49	1,043,760.09	788,038.23	Naira
Annual Maintenance and Repair cost	660,000.00	1,872,508.62	110000	491,071.43	Naira
Total Life Cycle Cost		**3,385,500.65**		**1,194,940.12**	**Naira**
Net Savings				**2,190,560.53**	**Naira**

Table 11: Life Cycle Cost on office equipment (printer, photocopier and scanner), CPC

Office Equipment	**Baseline**		**Improved**		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	492,000.00	492,000.00	Naira
Capital replacement cost	675,000.00	480,451.67	0	-	Naira
Residual cost	160000	- 90,788.30	160,000.00	90,788.30	Naira
Annual electricity consumption	1,840.61		-		kWh
Current price of electricity	35.79		35.79		N/kWh
Annual electricity	65,875.36	2,238,637.52	-	2,208,895.05	Naira

cost					
Annual Maintenance and Repair cost	480,000.00	1,361,824.45	20000	89,285.71	Naira
Total Life Cycle Cost		**3,990,125.35**		**2,699,392.47**	**Naira**
Net Savings				**1,290,732.88**	**Naira**

Table 12: Life Cycle Cost on Lighting Appliances, CPC

Lighting	**Baseline**		**Improved**		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	158,400.00	158,400.00	Naira
Capital replacement cost	3,993.60	11,894.12	0	-	Naira
Residual cost	0	46.43	44,676.92	35,616.17	Naira
Annual electricity consumption	2,967.55		1,596.67		kWh
Current price of electricity	35.79		35.79		N/kWh
Annual electricity cost	106,208.69	988,039.64	57,144.89	531,608.29	Naira
Annual Maintenance and Repair cost	33,320.00	522,486.45	0	0	Naira
Total Life Cycle Cost		**1,522,373.78**		**654,392.12**	**Naira**
Net Savings				**867,981.66**	**Naira**

Table 13: Life Cycle Cost on Desktop Computer, CPC

Computer	**Baseline**		**Improved**		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	1,350,000.00	1,350,000.00	Naira
Capital replacement cost	-	1,067,670.37	0	-	Naira
Residual cost	150000	85,114.03	600,000.00	340,456.11	Naira
Annual electricity consumption	-		-		kWh
Current price of electricity	35.79		35.79		N/kWh
Annual electricity cost	-	2,094,271.31	-	573,118.72	Naira
Annual Maintenance and Repair cost	450,000.00	1,276,710.43	75000	334,821.43	Naira
Total Life Cycle Cost		**4,353,538.08**		**1,917,484.03**	**Naira**
Net Savings				**2,436,054.04**	**Naira**

Table 14: Life Cycle Cost on office equipment (printer, photocopier and scanner), CPC

Office Equipment	**Baseline**		**Improved**		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	492,000.00	492,000.00	Naira
Capital replacement cost	725,000.00	516,040.68	0	-	Naira
Residual cost	180000	102,136.83	160,000.00	90,788.30	Naira
Annual electricity consumption	-		-		kWh
Current price of electricity	35.79		35.79		N/kWh
Annual electricity cost	-	2,212,477.04	-	2,208,895.05	Naira
Annual Maintenance and	540,000.00	1,532,052.51	20000	89,285.71	Naira

Repair cost					
Total Life Cycle Cost		**4,158,433.40**		**2,699,392.47**	**Naira**
Net Savings				**1,459,040.93**	**Naira**

Table 15: Life Cycle Cost on Lighting Appliances, REA

Lighting	**Baseline**		**Improved**		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	950,400.00	950,400.00	Naira
Capital replacement cost	44,876.00	159,540.93	0	-	Naira
Residual cost	0	-	268,061.54	213,697.02	Naira
Annual electricity consumption	15,646.58		7,838.21		kWh
Current price of electricity	35.79		35.79		N/kWh
Annual electricity cost	559,991.07	5,209,492.71	280,529.46	2,609,713.40	Naira
Annual Maintenance and Repair cost	-	-	0	0	Naira
Total Life Cycle Cost		**5,369,033.64**		**3,346,416.39**	**Naira**
Net Savings				**2,022,617.26**	**Naira**

Table 16: Life Cycle Cost on Desktop Computer, REA

Computer	**Baseline**		**Improved**		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	-	-	Naira
Capital replacement cost	-	-	0	-	Naira
Residual cost	0	-	-	-	Naira
Annual electricity consumption	-		-		kWh
Current price of electricity	35.79		35.79		N/kWh
Annual electricity cost	-	226,560.99	-	71,639.84	Naira
Annual Maintenance and Repair cost	-	-	0	-	Naira
Total Life Cycle Cost		**226,560.99**		**71,639.84**	**Naira**
Net Savings				**154,921.15**	**Naira**

Table 17: Life Cycle Cost on office equipment (printer, photocopier and scanner), REA

Office Equipment	**Baseline**		**Improved**		
	Cost/Value	Present Value	Cost/Value	Present Value	Unit
Purchase and Installation Costs	0	-	492,000.00	492,000.00	Naira
Capital replacement cost	-	-	0	-	Naira
Residual cost	0	-	160,000.00	90,788.30	Naira
Annual electricity consumption	-		-		kWh
Current price of electricity	35.79		35.79		N/kWh
Annual electricity cost	-	4,005,162.16	-	2,208,895.05	Naira
Annual Maintenance and Repair cost	-	-	20000	89,285.71	Naira
Total Life Cycle Cost		**4,005,162.16**		**2,699,392.47**	**Naira**
Net Savings				**1,305,769.69**	**Naira**