ISSN-L: 2223-9553, ISSN: 2223-9944
Vol. 4 No. 3 May 2013

FEASIBILITY INVESTIGATION OF A HYBRID RENEWABLE ENERGY SYSTEM AS A BACK UP POWER SUPPLY FOR AN ICT BUILDING IN NIGERIA

O.J.Onojo[1], G.A. Chukwudebe[2], E.N.C. Okafor[3], S.O.E. Ogbogu[4]

Department of Electrical and Electronic Engineering,
Federal Universityof Technology Owerri,
Imo State, NIGERIA.

jamesonojo@yahoo.com

ABSTRACT

Back-up power supply for areas where there is hardly a steady power supply from the grid with the use of renewable energy sources have become more cost-effective and a convenient option when compared to the use of diesel generators. A hybrid combination of Renewable Energy Technologies (RET) is generally considered to be the best suited alternative to the use of the environmentally unfriendly option of diesel generators. This paper focuses on creating a model for electricity generation from a mix of renewable energy resources (hydro, solar and biomass) to serve as a back-up power supply to satisfy the electrical needs of a New ICT building in the Federal University of Technology, Owerri Imo State Nigeria. Applying HOMER software, this study presents an analysis for choosing the best hybrid RET system that can be best suited for this purpose. Firstly, the hourly load demand pattern of the building is studied and suitably modeled. With HOMER simulations, the optimized sizing of Hydro power (HP), solar photovoltaic (SPV) and Biogas (Methane) generator systems are obtained. On the basis of the minimized cost of energy (COE) generation obtained, HOMER results show that the solution is sustainable and techno-economically viable. The hybrid RET system selected by HOMER for this load center scenario from the various other prospective combinations of the sensitivity analysis is a combination of 67.4kW HP, 5kW SPV, 1kW biogas generator and1 Battery having a COE generation of $0.131/KWh which is equal to ₦20.96/KWh.

Keywords: Hybrid, Renewable Energy, HOMER, Cost of Energy, Life Cycle Cost, Operation and maintenance

INTRODUCTION

Electricity is a basic requirement to sustain our industrial, commercial, household and to a certain extent agricultural activities. In the rapidly growing economies of the developing countries the demand for electricity is constantly increasing. Electricity is one of the driving forces in a growing economy and increasing demand puts incredible pressure on the countries' energy infrastructure to match that demand [1].

There is no doubt, therefore, that energy is a fundamental tool in any country's development and a priority in the improvement of the people's quality of life [2]. Having this in mind, individuals and governments are doing everything possible to produce enough electricity to meet this growing demand.

Producing electricity from fossil fuel has in recent years increased its disadvantages exponentially due to cost, depletion of this resources and different types of emissions produced by this source. This is raising dust throughout the world and pointing to the need for a change of type of electricity production or need for rapid reduction in the use of fossil fuel. Additionally, the threat of global warming and climate change as a result of CO_2 emissions has forced many people to become interested in renewable energy.

In Nigeria, as in many developing countries, providing energy to rural and urban areas has proved to be a great challenge. The country has an enormous renewable energy potential of hundreds of Mega Watts, which is mostly untapped. Considerations have been put in place to ensure that these large reserves of energy are put into good use to provide continuous supply of energy to the nation. The adoption of alternative energy sources through efficient stand alone and hybrid renewable energy systems will provide an efficient, cost effective and optimized process of embarking on off grid electrification schemes in rural communities of the world.

Using Ihiagwa village as a case study, some renewable energy sources are considered such as solar, hydro (due to the presence of Otammiri River) and biogas from students suck away pits (as the village is host to the federal University of technology) for the firing of gas turbine.

This paper presents a feasibility analysis of the hybrid renewable energy system (hydro, solar PV, and biomass) as a viable means of maximizing power generation through alternative sources to the ICT building. The power produced by this hybrid renewable energy system will serve as an off-grid system to supply electrical energy to the loads of a new ICT building within the institution. The load demand of the building is presently about 64Kw at peak, which was obtained based on the load survey carried out.

This work is organized in sections, one to five. Section I is an introduction, section II presents the theories of the different components and technologies used to generate the different output power from the sources. Section III explains analysis and inputs of the different data obtained from the renewable energy sources using Hybrid Optimization Model for Electric Renewables (HOMER) software. Section IV is the results on analysis and discussion. Section V finally gives the conclusion and recommendations and section VI references.

THEORIES OF DIFFERENT SOURCE TECHNOLOGIES

Photovoltaic

Photovoltaic comes from photo = light; voltaic = produces voltage or PV systems convert light energy directly into electricity using semi-conductor technology. The most basic power conversion unit of a photovoltaic (PV) system is the solar cell. Sunlight strikes a PV cell and a direct current (D.C.) is generated. An inverter inverts the D.C. to an alternating Current (A.C.) and by connecting the electric load to the output terminals the current can be utilized [4]. To understand the operation of a PV cell, both the nature of the material and the sunlight need to be considered. Solar cells consist of two types of materials, often p-type silicon and n-type silicon [5].

The amount of power available from a PV device is determined by:

I. The intensity of the sunlight
II. The type and area of the PV material
III. The wave length of the sunlight [6]

With factors 2 and 3 constant, the intensity of light energy determines the amount of electricity generated. In other words, the conversion of energy relies on the quantum nature of light, whereby we perceive light as a flux of particles -photons - which carry the energy, E_{ph} as energy given by equation 2.1.

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$$E_{ph}(\lambda) = \frac{hc}{\lambda}$$ …….. Equation 2.1

Where:
h = the Planck's constant.
c = the speed of light (m/s), and
λ = the wavelength of light (m).

On a clear day, approximately 4.4 x 10^{17} photons strike a square centimeter of the earth's surface every second. Those photons with energy in excess of the band gap energy of the semiconductor material being used can be converted into electricity by the solar cell. A rough estimate of the current that can be generated by a solar cell is given by equation 2.2. Ignoring losses in the cell, and assuming each photon produces one electron charge, for an electron charge of 1.6 x 10^{-19} coulomb, and 4.4 x 10^{17} photons striking a square centimeter of cell area, the current density is approximately 70 mA/cm^2. [7]

I_L = qNA…………………….…. Equation 2.2

Where N is the number of photons, A the area exposed to light, and q the charge in coulombs. The maximum voltage, V, that a solar cell can generate is equal to the band gap of the semiconductor in use and is expressed in electronvolts. This means that the separation of electrons and holes at the terminals of the solar cell can only continue until the electrostatic energy of the charges after separation, Eg, equals to the pair energy in the semiconductor. Hence, the maximum voltage is given by equation 2.3.

In other words, the maximum voltage that can be generated by a solar cell is numerically equal to the band gap of the particular semiconductor in use expressed in electronvolts [8].

V = Eg / q ……………………… Equation 2.3

The current generated is extracted via contacts on the front and rear sides of the cell. A thin layer of dielectric material, known as an anti-reflection coating or ARC, covers the cell to minimize light reflection from the uppermost surface.

Components

Photovoltaic Panel

A photovoltaic panel is a flat plate, composed by photovoltaic cells that have the property of converting the energy from the sun into electrical energy. When the temperature of a photovoltaic module is increased, the efficiency drops. This can typically result in an efficiency drop off of 0.5% per ^{o}C increase in the cell operating temperature. The operating temperature is increased because a large part of the solar radiation is not converted to electricity but is absorbed by the panel as heat [9, 10]. The voltage and the power output of PV cells are usually very small. For this reason, many cells are combined together in a PV panel with common electrical output.

One of the main features of the panel is the peak power. The peak power is the power from the photovoltaic when the solar irradiance is 1000 W in every square meter, when the temperature is 25ºC. It is obvious that the power from the panel depends on the area of the panel, the type and its operation temperature. The maximum power is given from the manufacturer [10]. The operating voltage is another important characteristic of the panel. Most photovoltaics today are constructed in a way that they produce power higher than 12V in order to charge the 12 V batteries. Apart from the voltage, the operating current is another parameter. It is the current which is determined from the maximum power from the panel and the voltage created, for bigger PV systems, panels with operating voltages equal to 24 V or even 48 V are used.

Charge Controllers

Charge controllers are used in PV systems to protect the batteries from overcharge and excessive discharge. Most controllers function by sensing battery voltages and then taking action based on voltage levels. Other controllers have temperature compensation circuits to account for the effect of temperature on battery voltage and state-of-charge.

Batteries

The electrical energy is stored to the batteries in order to be provided in intervals with minimum solar irradiance (during nights, cloudy days). Solar energy systems for this research use a lead-acid deep cycle battery. This type of battery is different from a conventional car battery, as it is designed to be more tolerant of the varying nature of the charging current due to continuous weather changes [11,12].Lead-acid deep cycle batteries last longer but it also cost more than a conventional battery. The plate is made of a sponge-like material [10, 12].

Inverters

Inverters are the devices usually solid state, which change the array DC to AC of suitable voltage and frequency.

Biomass

In the first sense, biomass is plant matter used to generate electricity with steam turbines & gasifiers or produce heat, usually by direct combustion. Examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. In the second sense, biomass includes plant or animal matter that can be converted into fibres or other industrial chemicals, including biofuels. Industrial biomass can be grown from numerous types of plants, including miscanthus, switchgrass, hemp, poplar, willow, sorghum, sugarcane, bamboo, and a variety of tree species, ranging from eucalyptus to oil palm (palm oil).

Municipal solid waste landfills are the second largest source of human-related methane emissions accounting for approximately 23 percent of these emissions in 2007 [13]. At the same time, methane emissions from landfills represent a last opportunity to capture and use a significant energy resource.

Anaerobic digestion

Anaerobic digestion is a series of processes in which micro organisms break down biodegradable material in the absence of oxygen. It is used for industrial or domestic purposes to manage waste and/or to release energy.

The digestion process begins with bacterialhydrolysis of the input materials to break down insoluble organic polymers, such as carbohydrates, and make them available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. Acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. The methanogenic archaea populations play an indispensable role in anaerobic wastewater treatments. It is used as part of the process to treat biodegradable waste and sewage sludge.

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As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere. Anaerobic digesters can also be fed with purpose-grown energy crops, such as maize.

Anaerobic digestion is widely used as a source of renewable energy. The process produces a biogas, consisting of methane, carbon dioxide and traces of other 'contaminant' gases. This biogas can be used directly as cooking fuel, in combined heat and power gas engines or upgraded to natural gas-quality biomethane. The use of biogas as fuel helps to replace fossil fuels. The nutrient-rich digestate also produced can be used as fertilizer. Anaerobic digestion facilities have been recognized by the United Nations Development Programme as one of the most useful decentralized sources of energy supply, as they are less capital-intensive than large power plants. With increased focus on climate change mitigation, the re-use of waste as a resource and new technological approaches which have lowered capital costs, anaerobic digestion has in recent years received increased attention among governments in a number of European countries.

HYDROPOWER SYSTEM

Hydropower plants capture the kinetic energy of falling water to generate electricity. A turbine and a generator converts the energy from the water to mechanical and then electrical energy. The turbine converts the water pressure to mechanical energy, and the generator converts the mechanical energy from the turbine to electrical energy. The turbines and generators are installed either in or adjacent to dams or with the use of pipelines called penstocks to carry the pressurized water below the dam or diversion structure to the power house. Turbines are of two kinds: impulse and reaction. In impulse turbines (*e.g.,* Pelton), a jet of water impinges on the runner that is designed to reverse the direction of the jet and thereby extract momentum from the water. Reaction turbines (*e.g*., Francis and Kaplan), run full of water and in effect generate hydrodynamic "lift" forces to propel the runner blades. Hydropower projects are generally operated in a run-off river, peaking or storage mode. The power capacity of a hydroelectric power plant is primarily the function of two variables:

1. Flow rate expressed in cubic feet per sec (ft^3/s).
2. The hydraulic head which is the elevation difference in water fall or water head in passing through the plant.

Hydropower System

The basic principle of hydropower systems is that if water can be piped from a certain level to a lower level, then the resulting water pressure can be used to perform work. If the water pressure is allowed to move a mechanical component, then that movement involves the conversion of water energy into mechanical energy. Hydro turbines convert water pressure into mechanical shaft power, which can be used to drive an electrical generator, a grain mill or some other useful device. The system requires a sizeable flow of water and a proper change in elevation, called the effective head, which should be obtained without having to build elaborate and expensive structures.

The source of water is a stream or sometimes an irrigation canal. Small amounts of water can also be diverted from larger flows such as rivers. The most important considerations are that the source of water is reliable and not needed by someone else. For example, any micro hydropower station located in any rural area must be such that the water intake for the village is located upstream of the power plant water intake. This arrangement has not caused any impact on drinking water supplies. Springs make excellent sources, as they can often be depended on even in dry weather and are usually clean. This means that the intake is less likely to become silted and requires less cleaning. Run of the river schemes require no water storage; the water is instead diverted by the intake weir into small settling basin where the suspended sediment can settle. A grid to prevent the flow of large objects such as logs, which may damage the turbines, usually protects the intake. The diverted water is drawn via a channel into forebay; a tank. The channel is usually a concrete or steel pipe along the side of a valley to maintain its elevation. The tank holds sufficient water to ensure that the penstock is always fully submerged to prevent suction of air to the turbine. It also acts as water reservoir during dry season. The water flows from the forebay tank down a closed pipe called the penstock. The penstock is often made of high density materials and exposes the water to pressure; hence the water comes out of the nozzle at the end of the penstock as a high pressure jet. The power in the jet, called hydropower (hydraulic power), is transmitted to a turbine wheel, which changes it into mechanical power. The turbine wheel has blades or buckets, which cause it to rotate when they are struck by the water jet due to momentum transfer. Hydro-turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, a grain mill or some other useful device. The water returns back to the same stream via the tailrace in the power house. The electricity generated is delivered to load centers through a distribution system or power lines connected to the households. Depending on the generation voltage level and distance of the load centers from the power house, distribution transformers can be used for stepping up (at the source) and stepping down (at the end user) voltage [14]. The installed capacity and energy output is calculated using standard equations:

$$P = (Q \times \rho \times H \times g \times \eta)/1000 \text{ ……….. Equation 2.4}$$

Where:
P = power or installed capacity in kilowatts
Q =discharge rate in cubic meter per second
ρ = density of water in kg per cubic meter
H = effective head in meters
g = acceleration due to gravity and is 9.81 m/s^2
η = efficiency of hydro turbine generator in %

And Annual Output Energy (kWh) = P x hr x CF….Eq 2.5

Where:

P = power or installed capacity in kilowatts
hr = Annual continuous generating duration (8760 hours in a year)
CF = Plant Capacity Factor (typically 95% for run-of-the-river type systems)

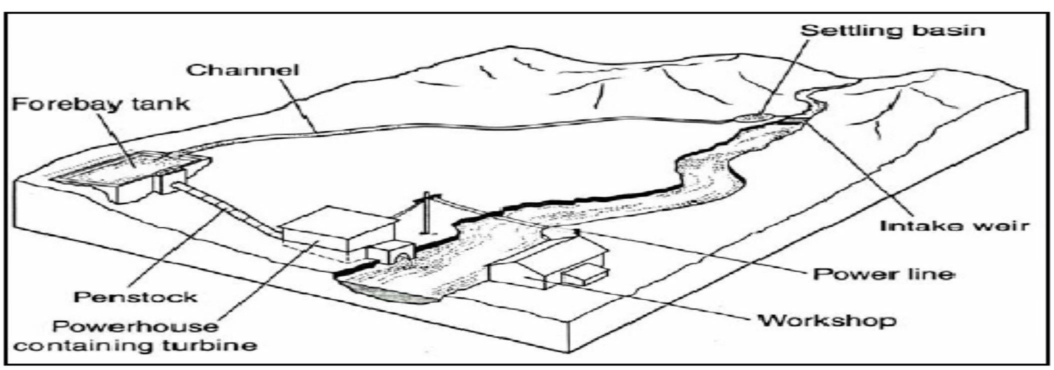

Figure1. Layout and components of a typical micro hydropower installation

Turbine Types and Selection

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Turbines are divided into two main types based on the efficiency of the turbine and the power output to be obtained from the river. They are:

a. Reaction turbines
b. Impulse turbines

Reaction Hydro Turbines

Reaction hydro turbines are the most commonly used turbines around the world. As their name suggests, they are not powered from a direct impulse, or push, rather a reactive force. Reaction turbines absorb the water's energy as it passes through lowering the pressure in the process. To be effective, the turbines must be made to contain huge volumes of water pressure. They are more commonly seen in areas with low and medium head applications.

Francis Turbine

The Francis hydro turbine is the most used form of hydropower in the world and is primarily installed for electricity generation. It was developed by James Francis, it can reach between 83 and 1000 revolutions per minute (RPM) depending on its size which ranges from 10-750MW

Otammiri River

The Otamiri River is one of the main rivers in Imo state, Nigeria. It has its source at Egbu community in Owerri North Local Government Area and passes through Owerri town and other sub-urban and rural communities of Nekede, Ihiagwa, Obinze, Mgbirichi, Eziobodo etc

HOMER

Homer micro power optimization software is a computer model that was developed by National renewable energy laboratory (NREL) in the U.S.A. One of the major applications of HOMER is the design of micro power systems for the efficient evaluation of various renewable energy power generation technologies. It compares a wide range of equipment with different constraints and sensitivities to optimize the system design. In the early phases of planning and decision making in rural electrification projects, HOMER can be of significant use for the designing of the system due to its flexibility. Its analysis is based on the technical properties and the Life cycle cost (LCC) of the system. The LCC is comprised of the initial capital cost, cost of installation and operation costs over the system's life span.

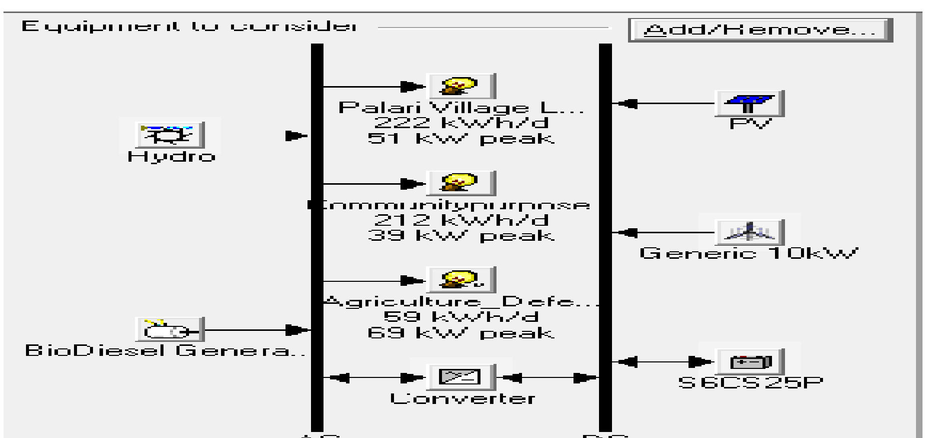

Figure 2. A simple modelling configuration

The user can input varying data and compare different designs based on their technical and economic factors. HOMER also considers the effects of uncertainty in its modeling. Figure 2 is an example of a model.

It allows modeling of grid-connected or off-grid systems, generating electricity and heat from various combinations of PV Modules, Wind turbines, biomass based power generation, micro-turbines, fuel cells, batteries, hydrogen storage, and generators with various fuel options.

Designing a micro power system with various design options and uncertainty issues to obtain optimal performance is a challenge. HOMER was designed to overcome these challenges and also the complexity of the RES (Renewable energy source) being intermittent, seasonal, non-dispatch able and having uncertain of availability.

Simulation, Optimization and Sensitivity analysis are the three major actions run by HOMER. In the simulation process, different micro power system configurations for every hour of the year are generated with their technical feasibility and LCC. In the optimization process, HOMER selects one system configuration out of all configurations generated in the simulation process that satisfies all technical constraints and has the lowest LCC.

In the sensitivity analysis, multiple optimizations are performed on the selected configurations by HOMER with a range of uncertain input parameters that are assumed to affect the model inputs with time. For the different variables known to the system designer- that is, the mix of system components and their respective quantity and size - the optimization process allows to calculate the optimal value. There are, however, also unknown factors such as uncertainties or changes in the variables outside the designer's control (for example, rises in the fuel price or changes in brightness factor etc). The effects of these can be analysed with the help of the sensitivity analysis.

One of the results of HOMER's simulation is the Economical Distance Limit (EDL) in kilometres, where creating a renewable stand-alone/mini-grid system is cost-competitive with a grid extension. HOMER has advantages over the usual statistical models, since its high processing speed allows it to run and evaluate an hourly simulation of thousands of possible system configurations, whereas statistical models usually only compare the average monthly performance of the configurations. Simulations modeled by HOMER are thus more accurate [15].

ANALYSIS OF DATA

Physical Modeling

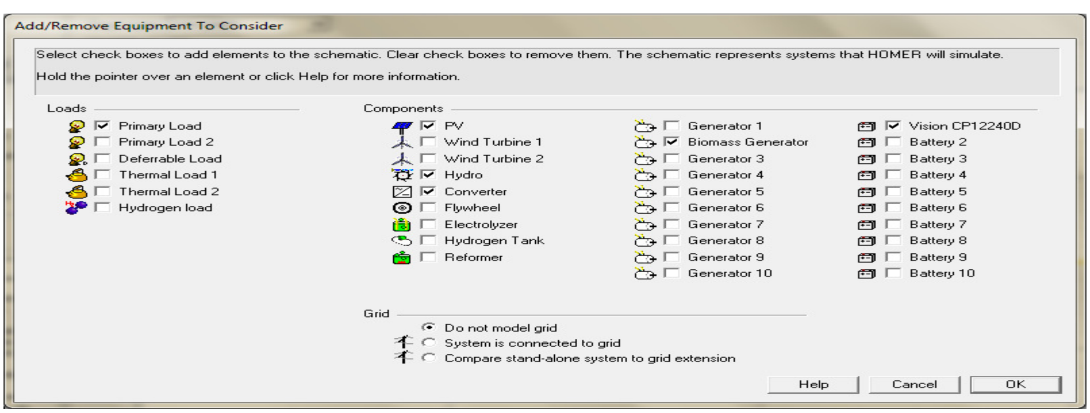

Figure 3.Shows componenets selected

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The various input parameters required to model the system is inputted into HOMER as shown in figure 3.The electricity load demand that the system has to serve, the selected energy components to generate electricity, the various energy resources associated to the selected components, and how this hybrid combination operates to serve the loads. Figure 3 shows the types of loads and the number and types of components selected for the system in this study. It also shows that this simulation is selected to run as a standalone

Electrical Load Assessment

The ICT building has its peak period during office hours. This will be determined during hourly calculation of loads. The basic energy requirements in this building can be classified into primary load. The primary load include radio, computers, fluorescent lamps, bulbs, ceiling fans, table fans, air- conditioners, refrigerators etc. The hourly load demand is carefully inputted into the HOMER software as shown in figure 4.

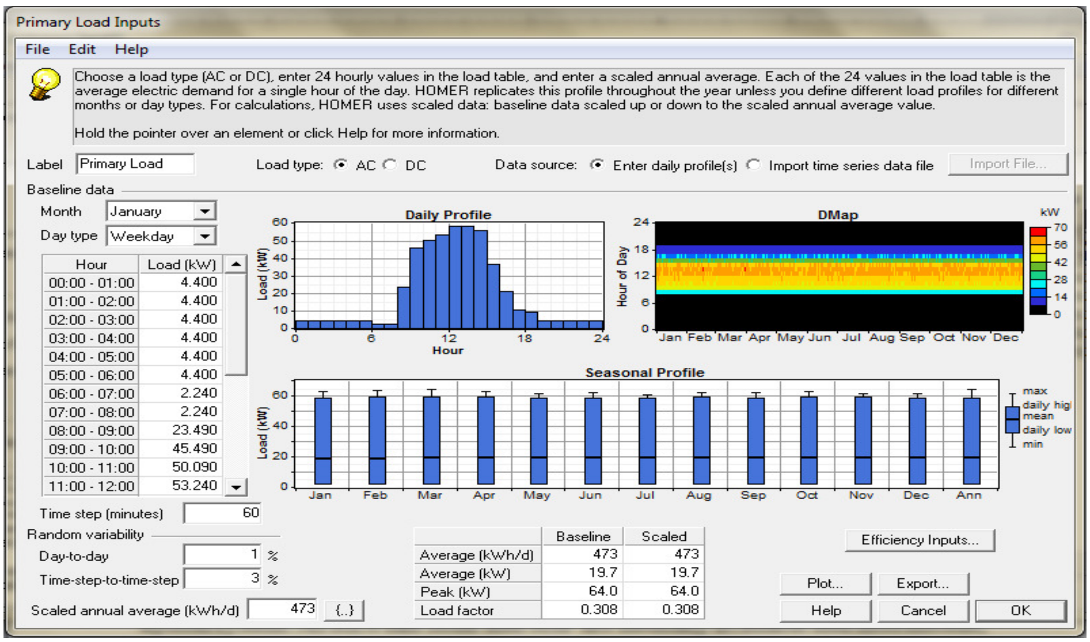


Figure 4. Hourly load of new ICT building

Resources Assessment

In the system designed by HOMER, resources are anything that can be used to generate electricity and comes from outside the system. RES available at a location can differ considerably from site to site and this is a vital aspect in developing the hybrid system. As RES like solar and hydro are naturally available, they are the best option to be combined into a hybrid system.

Solar Energy Resource

The solar resource used at a location of 5°26' N latitude and 7°2' E longitude was taken from NASA Surface Meteorology and Solar Energy [16]. The figure 5 shows the solar resource profile considered over a span of one year.

From figure 5 annual averages solar radiation was found to be 4.466kWh/m^2/Day and the average clearness index was found to be 0.448.The graph in figure 5 shows that solar radiation is available throughout the year; therefore a considerable amount of PV power output can be obtained.

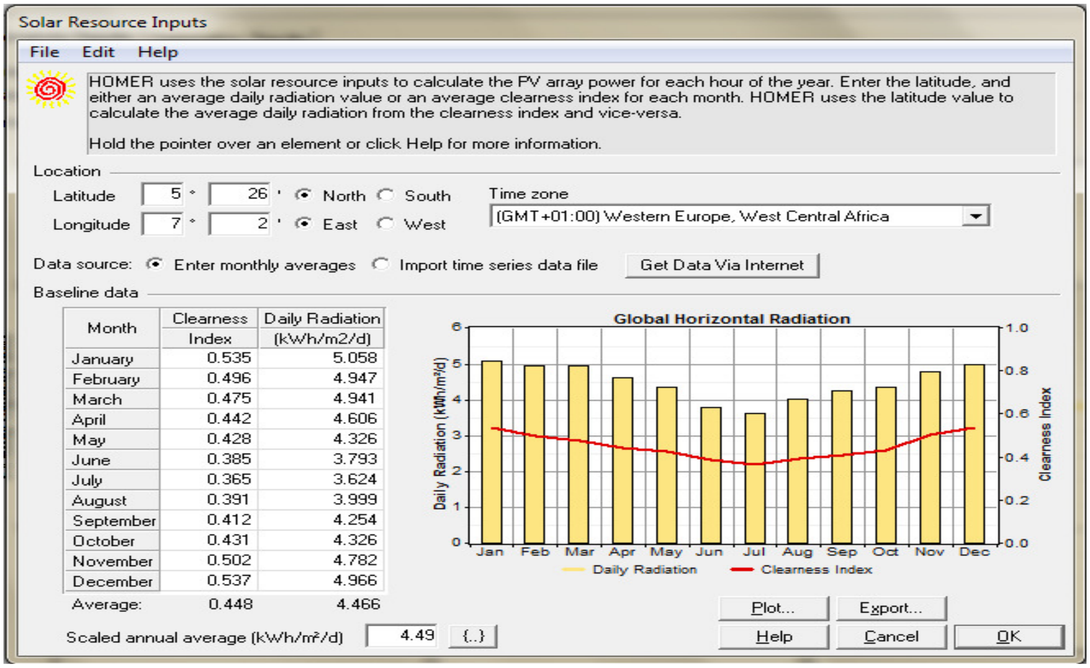
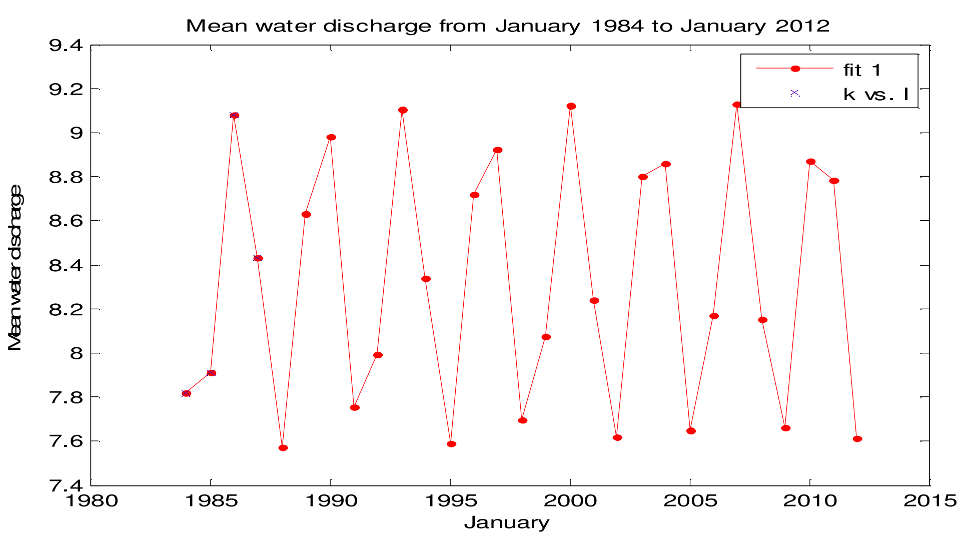


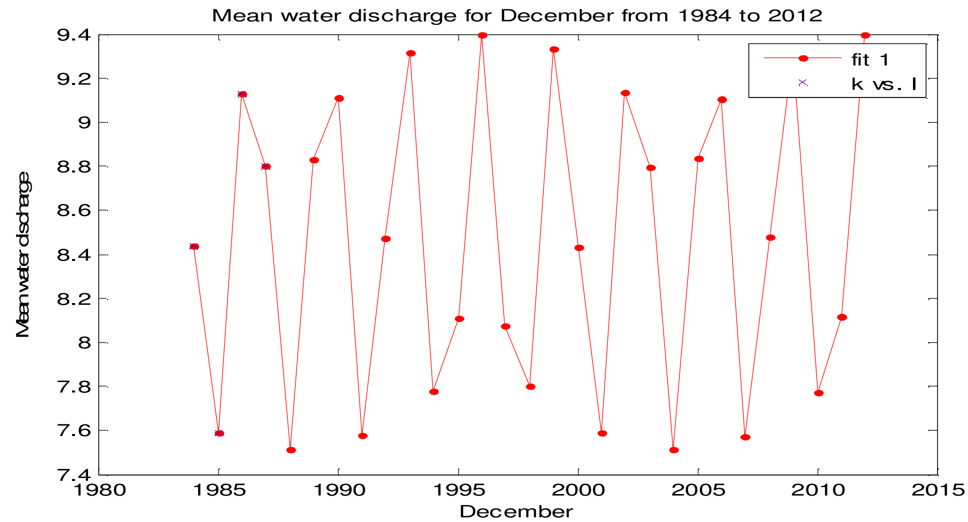
Figure 5. Solar energy resource

Hydro Power Resource

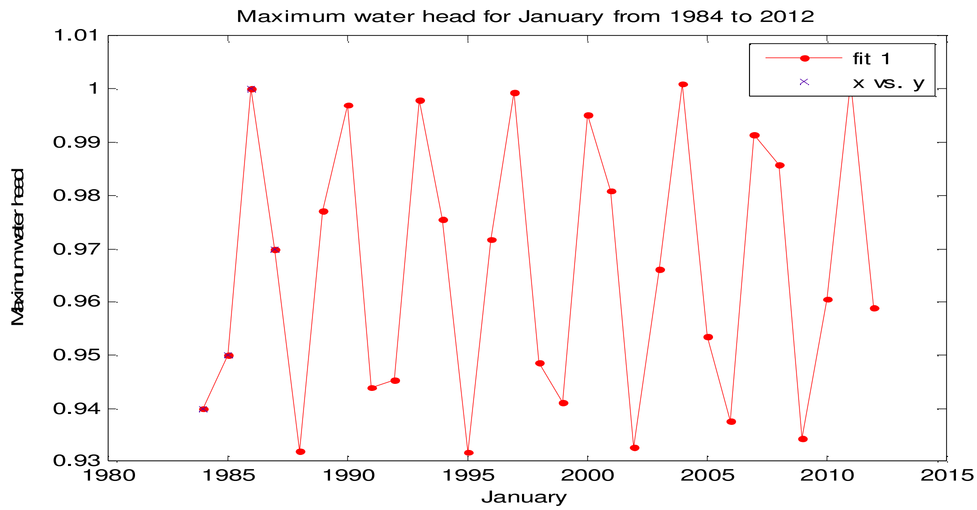
The Hydro power capacity of the river was determined by taking flow measurements on the river using the valeports' model 106 manual/direct current meters. The hydro electric power capacity of the river was determined based on the measurements to be about 77KW at 1.09 meters of head without damming the river. Monthly forecast using MATLAB-curve fitting were carried out in obtaining values through the hydrological data (water discharge and water stage) 1984 to 1987, till 2012 from the hydrological department, Anambra Imo River Basin Development Authority. The forecast presented below is for January and December only for want of space.



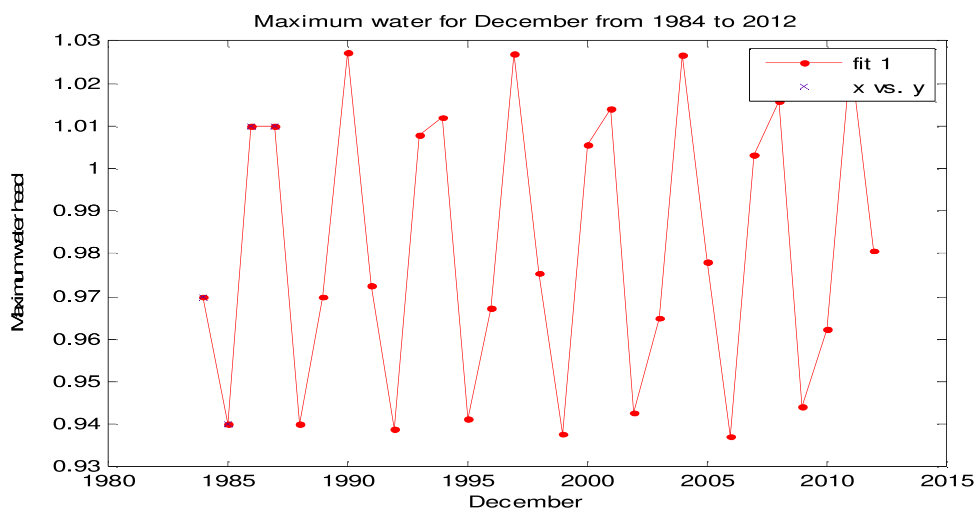
Graph 1.January



Graph 2.December

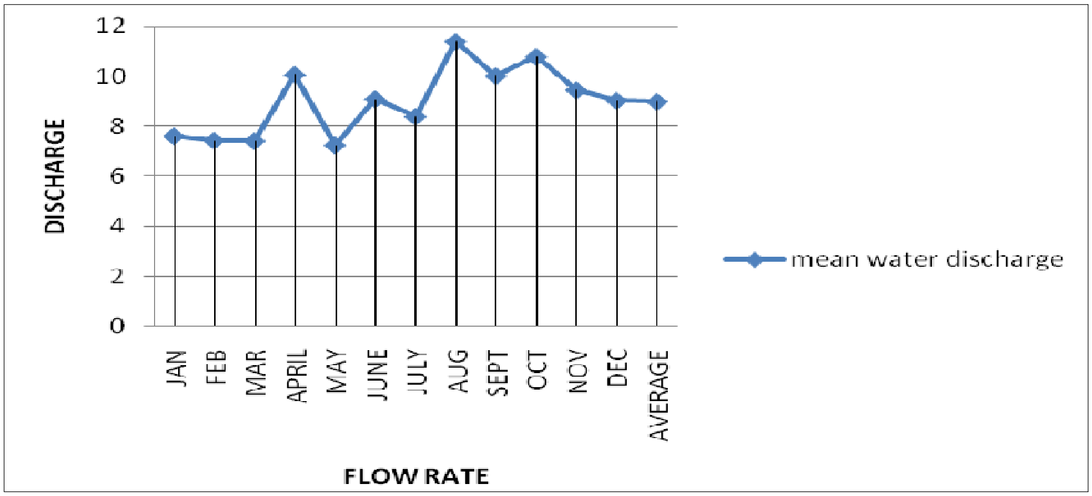


Graph 3. January



Graph 4 December

The output of the discharge is given below



Graph 5.Monthly discharge

The values gotten from the forecast was confirmed by carrying out field work (flow measurements) in 2012. The values obtained from the mean water discharge from the month of January to December, served as inputs to the hydro resource of HOMER, The figure below shows the hydro resource that can be converted to electricity.

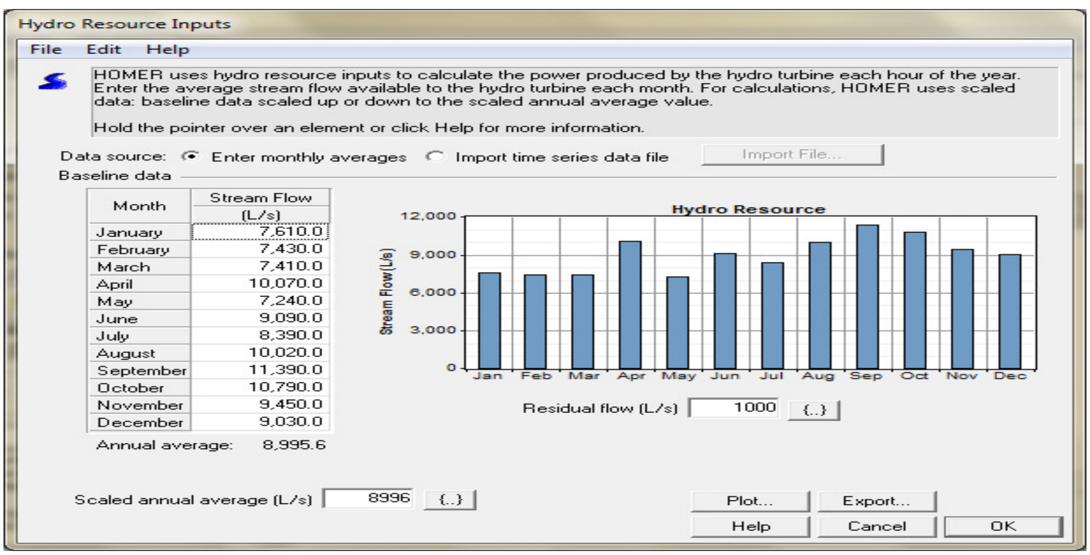


Figure 6.Hydro discharge input

The figure 6 shows both the monthly and annual average flows at the Otammiri River, the latter being scaled as 8996l/sec.

Biogas Fuel Source

The production of methane during the anaerobic digestion of biologically degradable organic matter depends on the amount and kind of material added to the system. The efficiency of production of methane depends, to some extent, on the continuous operation of the system. As much as 1000l of gas (containing 50-70 percent methane) can be produced from 1000l of volatile solids(1000kg/m^3) added to the digester when the organic matter is highly

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biodegradable (e.g., night soil or poultry, pig, beef-cattle faecal matter or human municipal waste)[17].

Calculations on biomass resources in FUTO

The following results were obtained from the anaerobic digestion of biomass wastes using human wastes to produce methane

Since 1kWh = 3415btu, a simple gas turbine has a fuel consumption of 3415/0.34 =10000Btu/kWh, where 0.34 is the plant factor.

Net heating value of methane = 21433Btu/pound

Thus the methane consumption in a simple gas turbine would be: 10000/21433 = 0.47pounds/kWh = 0.21kg/kWh

1000litres = 1m^3

22.4litres = 1mol

Molar mass of methane is 16g per mole

Therefore 16/1mol ×1000l/m^3×1/22.4l = 714g/ m^3

Volume of human waste from hostel A = 43.2 m^3

Volume of human waste from hostel B = 43.2 m^3

Volume of human waste from hostel C = 43.2 m^3

Volume of human waste from hostel D = 43.2 m^3

Volume of human waste from hostel E = 43.2 m^3

Volume of human waste from hostel PG hostel = 3.75m^3

Total volume = 43.2 × 5 + 3.75 = 219.75m^3 = 219.75 m^3

219.75 m^3 × 0.714 = 154.76kg

If 1000 liters of human waste produces 1000litres of biogas, 219.75 m^3 will produce 219.75 m^3 of biogas. Energy produced from 154.76kg of biogas will be 154.76kg /0.21kg/kWh = 73695kWh

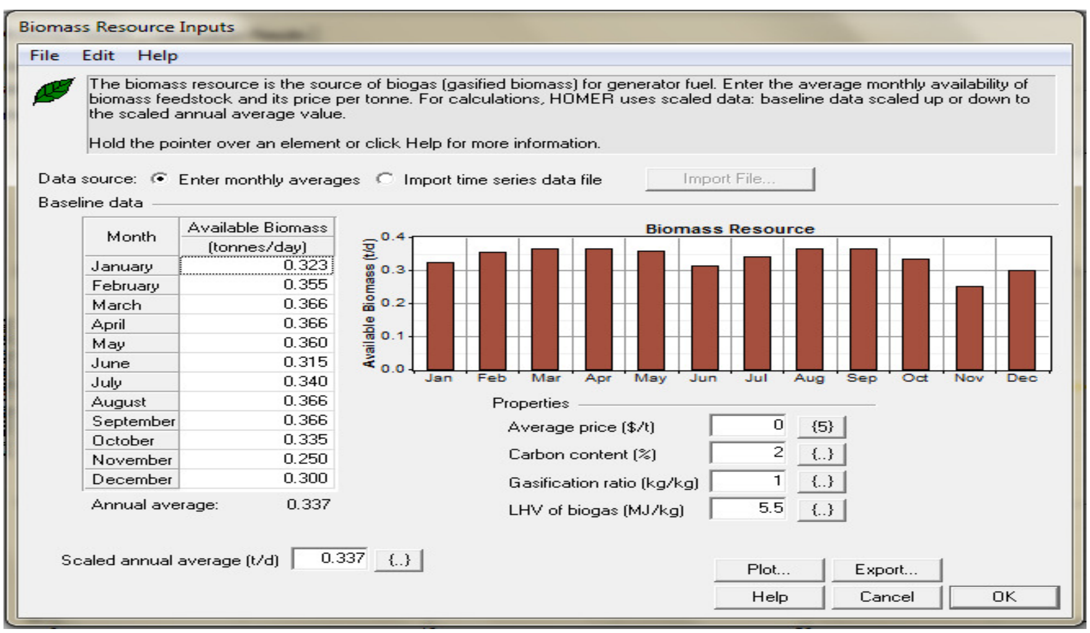

Figure 6. Biomass input in tonnes/day

Recommending a 1kW biogas generator, the generator can run for 73695/24h = 30.7 i.e. approximately a month.

The density of human waste is approximately equal to the density of water = 1000kg/ m^3.

Mass of human waste = 1000 × 219.75 = 219750kg

Since the hostels' suck away pits are dislodged after every two months, the mass per month = 109875kg

The mass per day = 3662.5kg. The available biomass waste in tonnes per day is given as: 3662.5/1000 = 3.66tonnes per day and this varies according to when students are around in school. The variations are used as inputs into the HOMER.

Components Cost Assessment

Different set of performance and cost parameters are used by HOMER to characterize each of these different components [18]. The components' technical and cost parameters for this study are based on data collected from different renewable energy market website, previous published literatures, information from world known manufactures, and reaonable assumptions**.**

Solar Photovoltaic

The SPV panels are connected in series parallel. They are positioned south of the equator. When the sunlight is incident on a SPV panel it produces electricity. The capital cost and replacement cost for a 1kW PV is taken as $4000 and $3500 respectively. As there is very little maintenance required for PV, only $10/year is taken for O&M costs [19]. Like for all other components considered in the following sections, the per kW costs considered include installation, logistics and dealer mark-ups. The Figure below shows that the PV is connected to a DC output with a lifetime of 20 years. The difference between the capital cost and replacement cost is also shown in the cost curve in the figure. The derating factor considered is 90% for each panel to approximate the varying effects of temperature and dust on the panels. The panels have no tracking system and are modeled as fixed tilted south at 5°20' N latitude of the location with the slope of 45°.

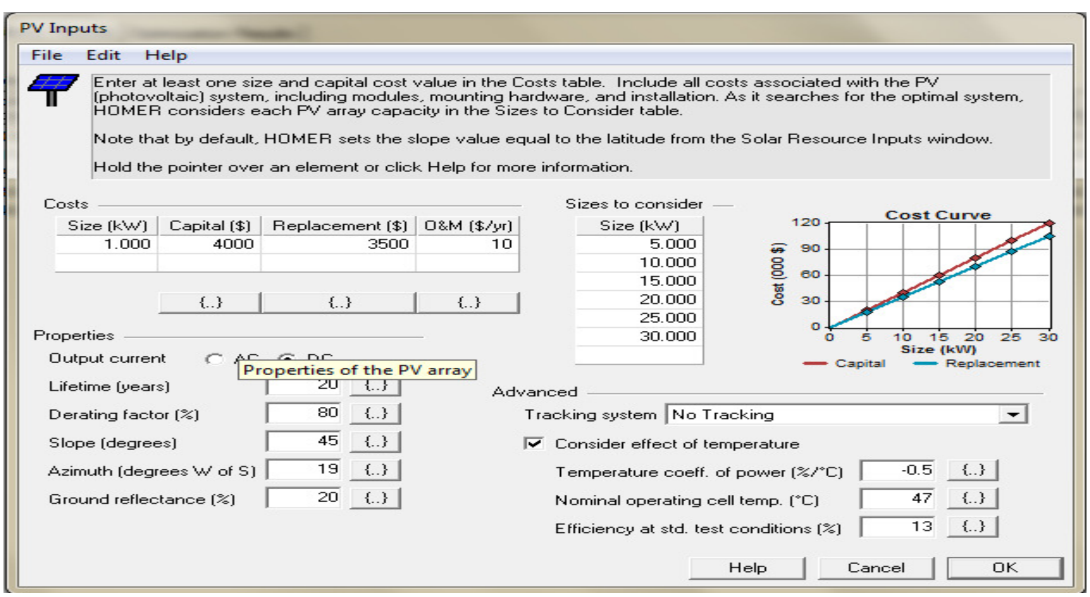

Figure 7. PV input

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Hydro Power

The hydro power is designed for a power output of 67.4kW depending on the resources from Otammiri. The figure 8 shows that the turbine is designed for a net head available of 1.09m and has a design flow of 7000 L/s. The turbine efficiency is 90% and has a pipe head loss of 0.012%.

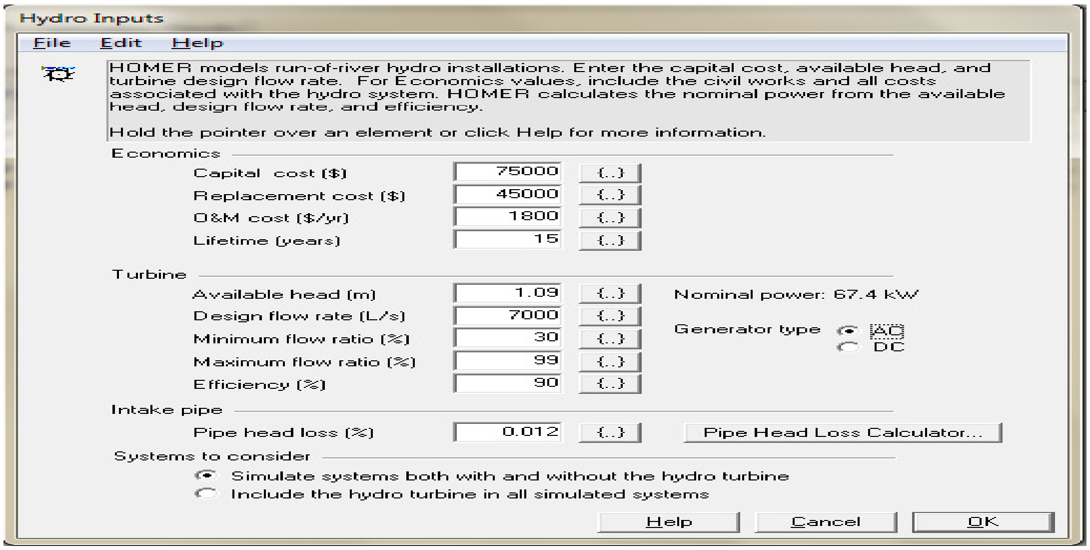

Figure 8. turbine input

The hydro power is AC connected and has a lifetime of 25 years. The capital cost for a 67.4kW plant is taken as $75,000 while the replacement cost and O&M cost are considered to be $45,000 and $1800 respectively [43].

Biogas Generator

As there is a variety of methane Generator available from various manufacturers and distributors, it is difficult to compare all the different information. As shown in figure 9, the capital cost, replacement cost, O&M costs of a 1kW biogas generator are taken as $12900, $10200, and $0.15/hr respectively [20].The costs include the costs of installation, logistics and dealer mark-ups.

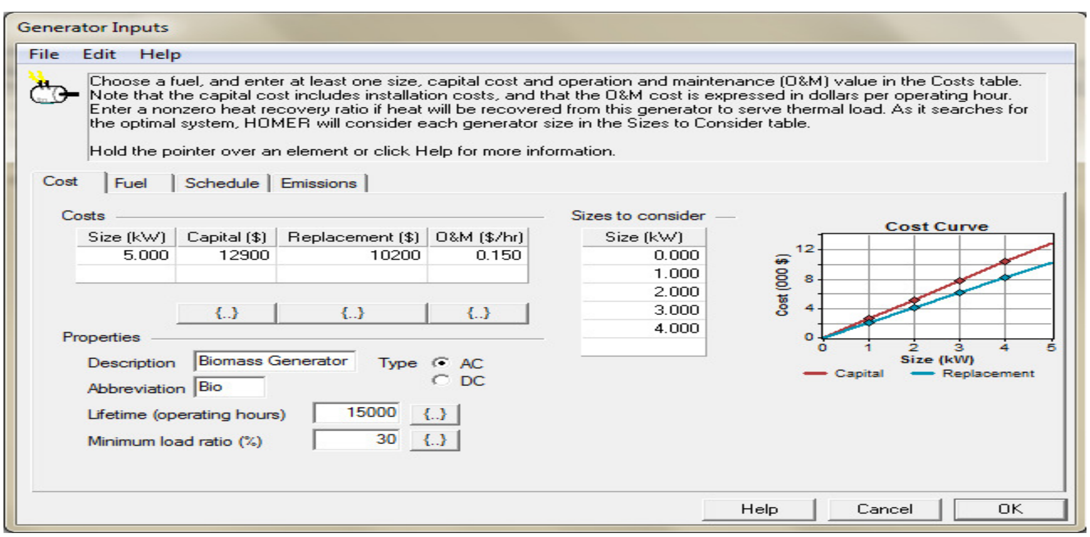

Figure 9. Generator input

The figure 9 also shows the cost curve of the generator, connected to an AC output with a lifetime of 15,000 operating hours. The minimum load ratio is taken to be 30% of the capacity; moreover, HOMER requires the partial load efficiency to simulate this component. HOMER calculates the total operating cost of the generator based on the amount of time it has to be used in a year [21].

Battery

Batteries are used as a backup in the system and to maintain a constant voltage during peak loads or a shortfall in generation capacity. HOMER models a number of individual batteries to create a battery bank connected in series-parallel. The battery chosen for this study is Vision CP12240D as shown in figure 10

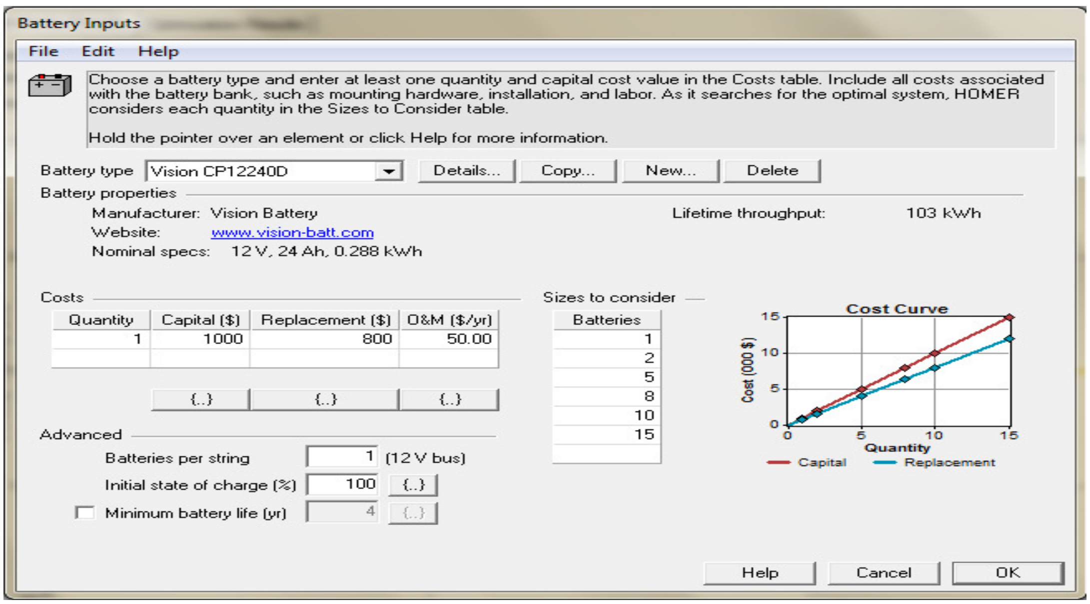

Figure 10. Battery cost parameters

It is a 12V battery with a nominal capacity of 1,156 Ah (6.94 kWh). It has a lifetime throughput of 9,645kWh. The capital cost, replacement cost and O&M costs for one unit of this battery were considered as $1000, $800, and $50/year respectively [22]. HOMER models the batteries on charging and discharging cycles.

Converter

A converter is an electronic power device that is required in a hybrid system to maintain the energy flow between AC and DC electrical components. It has an inverter and a rectifier to do the conversions from DC to AC and inverter for AC to DC. The figure below shows converter technical and cost parameter.

Figure 11 shows the capital cost, replacement cost and O&M costs for 1kW systems, which were estimated at $700, $550, and $100/year respectively [23]. The figure 11 also shows the cost analysis curve, the lifetime of the converter of 15 years, inverter efficiency of 90% and rectifier efficiency of 85%. In this hybrid system HOMER simulates the system with the inverter and AC methane generator to operate simultaneously whenever required.

HOMER also considers factors like economic inputs, economic modeling, system constraints, load priority, operating reserve etc [15].

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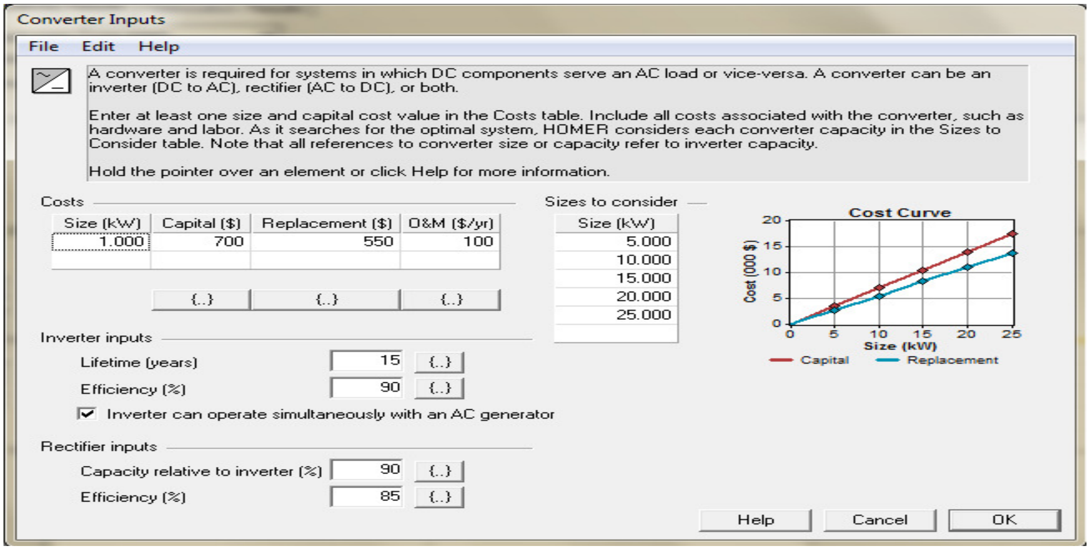


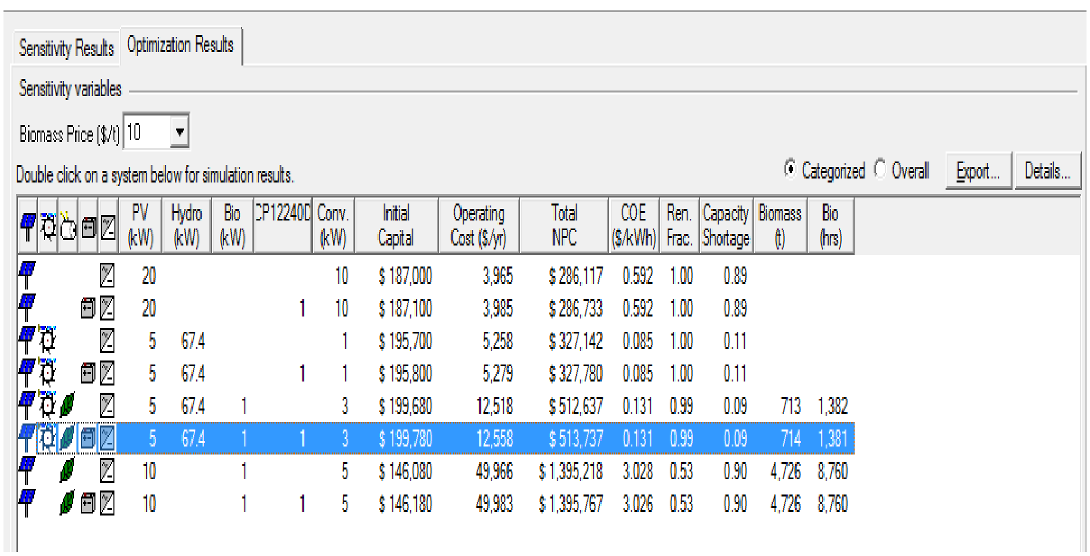
Figure 11. Converter technical and cost parameter

RESULTS AND DISCUSSION

The renewable energy potential and economic analysis of electricity generation with a hybrid RET system using the new ICT building has been performed using HOMER. Different scenarios have been considered and the costs for RET have also been taken into account. The sizing of the various components paid regard to the necessity of an operation reserve to enable the system to provide reliable energy supply and also allows for a rising energy demand in the future. The system's feasibility and its independence of the grid are furthered by the sinking costs for RES, which allows for meeting the load's daily energy demand.

Optimization Results

For the stand alone system, various combinations have been obtained of hybrid systems with hydro plant, PV, biogas generator, batteries and converters from the HOMER Optimization simulation. This is shown in figure 12


Sensitivity Results | Optimization Results

Sensitivity variables

Biomass Price ($/t) 10

Double click on a system below for simulation results. Categorized Overall Export... Details...

PV (kW)	Hydro (kW)	Bio (kW)	CP12240D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Biomass (t)	Bio (hrs)
20				10	$ 187,000	3,965	$ 286,117	0.592	1.00	0.89		
20			1	10	$ 187,100	3,985	$ 286,733	0.592	1.00	0.89		
5	67.4			1	$ 195,700	5,258	$ 327,142	0.085	1.00	0.11		
5	67.4		1	1	$ 195,800	5,279	$ 327,780	0.085	1.00	0.11		
5	67.4	1		3	$ 199,680	12,518	$ 512,637	0.131	0.99	0.09	713	1,382
5	67.4	1	1	3	$ 199,780	12,558	$ 513,737	0.131	0.99	0.09	714	1,381
10		1		5	$ 146,080	49,966	$ 1,395,218	3.028	0.53	0.90	4,726	8,760
10		1	1	5	$ 146,180	49,983	$ 1,395,767	3.026	0.53	0.90	4,726	8,760

Figure 12. optimisation result details

HOMER uses the total Net resent Cost (NPC) as its main selection tool. All the possible hybrid system configurations are listed in ascending order of their total NPC in the figure shown above. The technical and economical details of all the configurations of the hybrid systems from the optimization process are shown in detail in figure 12, where the best possible combination of hydro power, PV, biomass and batteries is highlighted in blue. The blue highlighted combination is able to fully meet load demands at the lowest possible total NPC.

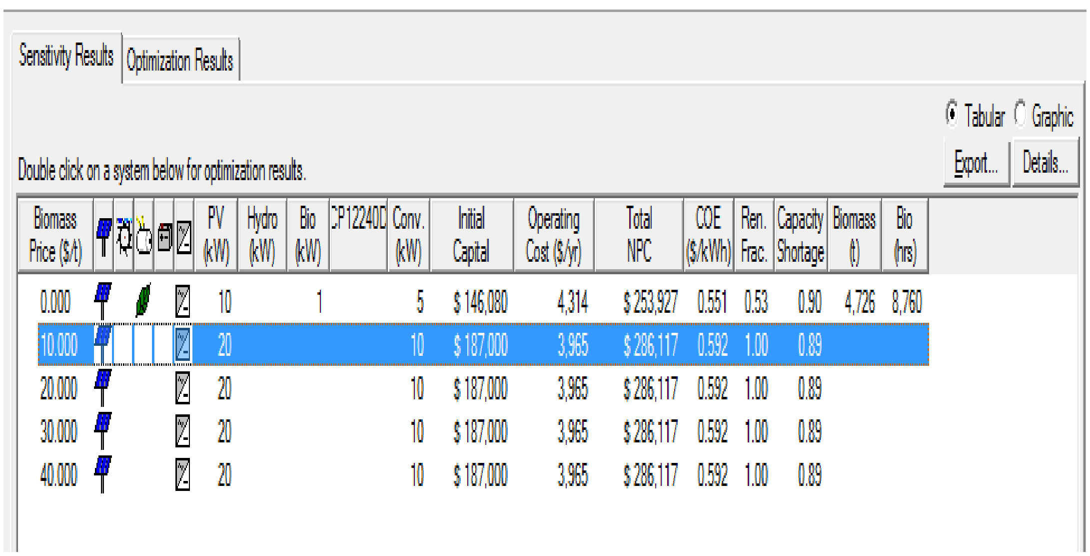
According to the optimization results, the optimal combination of RET system components are a 5kW PV-Array, 67.4kW hydro power, 1kW Bio, 1vision CP12240D Battery, 3kW Inverter and a 3kW Rectifier. The total NPC, Capital cost Operation and Maintainance cost and COE for such a hybrid system are $513,737, $199,780 and $0.131/kWh, respectively. COE of $0.131/kWh is approximately ₦ 20.96/kWh from this hybrid system which is less than that of ₦22/kWh of grid energy.

Table 1 shows the annualized cost of the proposed system's components. It can be seen that the costs for the Biogas generator and PV are distributed completely opposite to each other over both component's lifespan. Almost 50% of the annualized cost goes to the PV arrays. Once installed, however, PV is cheap to maintain and operate compared to the biogas generator.

Table1. Annualized cost of the proposed system's components

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	20,000	17,500	1,250	0	-13,125	25,625
Hydro	75,000	45,000	45,000	0	-15,000	150,000
Biomass Generator	2,580	4,080	1,036	172,174	-1,425	178,445
Vision CP12240D	100	800	125	0	-8	1,017
Converter	2,100	1,650	7,500	0	-550	10,700
Other	100,000	0	47,950	0	0	147,950
System	199,780	69,030	102,861	172,174	-30,108	513,737

Sensitivity Results



Biomass Price ($/t)	PV (kW)	Hydro (kW)	Bio (kW)	CP12240D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Biomass (t)	Bio (hrs)
0.000	10		1		5	$ 146,080	4,314	$ 253,927	0.551	0.53	0.90	4,726	8,760
10.000	20				10	$ 187,000	3,965	$ 286,117	0.592	1.00	0.89		
20.000	20				10	$ 187,000	3,965	$ 286,117	0.592	1.00	0.89		
30.000	20				10	$ 187,000	3,965	$ 286,117	0.592	1.00	0.89		
40.000	20				10	$ 187,000	3,965	$ 286,117	0.592	1.00	0.89		

Figure 13. Sensitivity analyses details

ISSN-L: 2223-9553, ISSN: 2223-9944
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Sensitivity analysis eliminates all infeasible combinations and ranks the feasible combinations taking into account uncertainty parameters. HOMER allows taking into account future developments, such as increasing or decreasing load demand as well as changes regarding the resources, for example fluctuations in the river's water flow rate, the biodiesel prices. Here, the various sensitivity variables are considered to select the best suited combination for the hybrid system to serve the load demand. Figure13 shows the sensitivity analysis detail. It can be observed that with change in the sensitive variables, the configuration of the system changes. Even in this analysis, HOMER ranks the configurations in descending order of their total NPC.

In figure 13 the least cost configuration is marked in blue, further suitable configurations follow in ascending cost of the NPC. The other rows show how the configuration changes with changing sensitivity variables. The COE for this hybrid configuration of 5kW PV, 1kW Bio &1 battery is noted to be $0.592/kWh.

CONCLUSION

In this study, it has been shown that a considerable amount of energy using renewable sources as cheap as $0.131/kWh can be feasible. Resource assessments and demand calculations have been carried out and the COE per kWh has been ascertained for different possible configurations. A combination of hydro, PV, biogas generator and battery has been identified as the cheapest and most dependable solution with a COE of $0.131/kWh. Another finding of this study is that a combination of different RETs is better suited for the back-up electrification of the ICT center than the use of one single RES.

The best suited RET for providing electricity to remote locations is hydro (provided the resource is available).

All in all, HOMER has proved a valuable tool in this study especially because of its ability to simulate numerous components and load combinations. The graphs created by HOMER make the simulation's results clear and easy to understand. One drawback of HOMER, however, is that its optimization process is based on identifying the cheapest technology. This, however, requires the system designer to specify the exact costs of different components etc., which is usually very tasking.

RECOMMENDATIONS

According to the study carried out in FUTO, these are recommendations we suggest:

1. Poultry Farms should be built in the school containing thousands of birds as this will improve biogas generation from the droppings from the birds. It can also make up for when students are on holiday.
2. The cattles should be housed so as to make it easy to collect their dungs for biogas generation.
3. Otammiri River should be dammed so as to improve the electrical output.

In general, Off-grid electricity generation based on hybrid RET systems can play vital roles in addressing the energy issues of a country. Efforts must be geared towards encouraging research in this area. Especially local governments can play important roles in promoting RETs: These can be taken into account in their decision making, planning.

Accordingly further work is recommended in: -

1. Promotion of RETs by best-practice policies at state and local levels.

2. Promotion of RETs with the help of financial instruments such as micro-finance and consumer credits.
3. Creating local infrastructure for the installation, O&M of RET systems.

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