Comparative cost-benefit analysis of renewable energy resources for rural community development in Nigeria

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Dedication

This dissertation is dedicated to my parents, loving wife and baby boy – Tobi Michael Ogunlade.

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First and foremost, I would like to thank God Almighty, the Creator of Heavens and Earth, for without Him, none of this would be possible.

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Abstract

Rural development by means of providing uninterruptible power supply has become a priority among developing countries. Nigeria especially has on its top agenda the mandate to provide clean and cost-effective means of energy to the rural communities, hardest hit by wave of incessant outages of electricity supply. Renewable Energy (RE), a clean form of energy that can be derived from natural sources is widely available throughout Nigeria but is not harnessed.

In this dissertation a Cost-Benefit Analysis (CBA) framework is proposed for renewable energy towards rural community development in Nigeria as indicated in the 18-point recommendations of Energy Commission of Nigeria (ECN). Moreover, a cost-benefit analysis tool is formulated and developed from the CBA framework in order to analyze comparatively the costs and intangible benefits of renewable energy projects for rural application. A case study demonstrating the working methodology of the proposed framework is presented in order to establish the cost-benefit components by assessing the comparative cost-benefit analysis of RE at a rural site of Nigeria.

Erinjiyan Ekiti rural area is located for CBA assessment with three RE resources (solar, wind and small hydro) selected for consideration. Through the application of Contingent Valuation Method (CVM), the respondents' willingness to pay for RE supply is obtained and RE benefits in monetary terms computed. Using three economic decision criteria namely: Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR); the three RE resources are ranked according to their economic viability.

The result of the analysis provides useful insight to investors and decision makers into how RE projects in rural community should be conducted. Foremost, it is revealed that all three RE options will be economically viable if implemented, though adequate caution must be taken when making a decision. Based on the CBA assessment, the Small-Hydro Power (SHP) option is ranked as the most viable option. However, this is swiftly negated if RE social impact, such as the spiritual belief of the rural dwellers, who rely on the only potential river as a medium of communication with their ancestors, are taken into consideration. Furthermore, a sensitivity assessment of the three RE options revealed that only solar photovoltaic (PV) option is marginally viable, thus turns negative upon an assumed increase in discount rate of only 17%.

Herein, the proposed CBA framework provides a useful insight into an efficient method of appraising RE projects in rural communities. A CBA simulation tool is formulated and adapted from the CBA framework to enable quicker, reliable and automated means of assessing RE projects with a view to making wise investment decision.

Keywords: *Nigeria; Rural community development; Renewable energy resources; Renewable energy technologies; Cost-benefit analysis; Cost-benefit analysis framework; Net present value; Benefit-cost ratio; Internal rate of return.*

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List of Abbreviations

BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
CO_2	Carbon-dioxide
CVM	Contingency Valuation Method
ECN	Energy Commission of Nigeria
EIA	Energy Information Administration
GDP	Gross Domestic Product
GEF	Global Environment Facility
IEA	International Energy Agency
IRR	Internal Rate of Return
JPOI	Johannesburg Plan of Implementation
MDGs	Millennium Development Goals
NGOs	Non Governmental Organizations
NPV	Net Present Value
O&M	Operations and Maintenance
PV	Photovoltaic
PVB	Present Value of Benefits
PVC	Present Value of Costs
RE	Renewable Energy
RETs	Renewable Energy Technologies
SHP	Small-Hydro Power
UN	United Nations
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial development Organization
WEA	World Energy Assessment
WSSD	World Summit on Sustainable Development
WTA	Willingness to Accept
WTP	Willingness to Pay

Chapter 1

Research Introduction

Chapter One introduces the research study. The research context is described to provide background for the research undertaken. The goals of the research and the research methodology adopted are presented. Finally, the thesis organization is outlined.

1.0 Introduction

The importance of energy in the socio-economic development of any nation cannot be over-emphasized. Renewable Energy (RE), a popularly growing form of energy harnesses naturally occurring non-depletable sources of energy. Energy sources such as solar, wind, biomass, hydro, tidal wave, ocean current and geothermal, produce electricity, gaseous and liquid fuels, heat or a combination of these energy types (DME RSA, 2003: 1). Renewable Energy Technologies (RETs), therefore, may play a significant role in sustainable development and poverty eradication in developing countries, where access to basic and clean energy services is essential for provision of major benefits in the area of health, literacy and equity. Simply put, the developing world needs more access to energy while at the same time the world as a whole needs to rely on less polluting forms of energy if the Millennium Development Goals (MDGs) are to be met. The UN Commission on Sustainable Development has termed "access to renewable energy" a requisite step to take for halving the proportion of people living on less than US$ 1 per day by 2015; a problem which is evident among the people living in Africa (CanREA, 2006: 2).

In Nigeria, energy from fossil and large-hydro sources form predominantly the major sources of power generation of which its current reliability is very low. Rural community regions which are greatly affected by the power unreliability and power energy inaccessibility are underdeveloped. Renewable Energy (RE), which is in abundance throughout the Nigerian federation, can serve as leverage in place of the current energy mix but its implementation and sustainability in the rural regions suffer from weak investment and popularity. Appropriate decision-making tools for analyzing RETs in rural community areas need to be developed. A **Cost-Benefit Analysis (CBA)** tool may, for example, be used to compare the various alternative forms of RETs possible in rural community settings for the purpose of assisting investors in making better investment decisions.

This chapter provides an introduction to the research investigation. To set the background for the research study, the research context is explored. The goals of the research and research methodology adopted are then presented. Finally, the thesis organization is outlined.

1.1 Research Context

The development of energy supply infrastructure in Nigeria has remained depressingly static in the last three decades. Nowadays, endemic power outages are more frequent while the electrical energy sector operates well below its total installed estimated capacity which is accessed at 5.9 GW (EIA, 2007: 11). Nigeria is the most populous country, not only in West Africa, but the whole of Africa with a population of approximately 150 million occupying a total land area of 932,770 km^2 (UNPD, 2007). About 51.7% of the total population is concentrated in rural areas while the rest live in urban areas (UNPD, 2007). According to the EIA (2007: 11) analysis report; about 40% of the Nigerian population has access to electricity, the majority of whom reside in urban areas (82% urban and 10% rural). The rural community areas are the worst hit with little or no access to the national electrical energy grid. This, in turn, has added considerably to the suffering of people living in these rural community areas as they live in abject poverty.

At the World Summits on Sustainable Development (WSSD) forum held in Johannesburg, South Africa, it was reaffirmed that the lack of access to clean, affordable and efficient energy services, is a major barrier to achieving meaningful and long lasting solutions to poverty (UNIDO, 2002: 3). This major barrier to poverty alleviation can be removed, only if poor people, especially in the rural community area, can obtain access to convenient and efficient energy services (UNIDO, 2002: 3).

In retrospect, Nigeria has had eight power generating facilities – comprising of three hydro power stations and five thermal power plants – all with a combined installed capacity of 5.9 GW for about 20 years. This electrical energy supply has, however, steadily declined over the years. The gradual shortage in the energy supply mix has made the clamor for RE resources to increase. Nigeria has in abundance natural resources yet untapped that can sustain renewable energy technologies which are fast becoming popular all over the world. The renewable energy potential base includes: biomass (animal, agricultural and wood residues), solar, small-hydro, wind and geothermal.

These thus present potentials of RE for the country's disadvantaged rural communities to access energy services and foster sustainable rural development with practically no net emissions or greenhouse gases to the environment. Also, of all the energy resources, only biomass (traditional bio-fuel) and hydro power (mainly large hydropower) have been and are still exploited (Ishmael, 2003: 53).

In the pursuit of a steady and sustainable energy supply for its citizenries, the Nigerian government has reiterated its commitments to harness the full potential and benefits of RE resources. The exploitation of these resources in turn will help to alleviate poverty by creating employment and generating income opportunities for the rural population (UNIDO, 2002: 4). A National Stakeholders Forum on Rural Industrialization and Development through RETs, organized by United Nations Industrial Development Organization (UNIDO) and the Energy Commission of Nigeria (ECN) provided an 18-point recommendation on how Nigeria can access clean, affordable and efficient energy services (Ishmael, 2003: 53). Top on the list of the recommendations is the need for the government of Nigeria to formulate an energy policy which will emphasize the development of renewable energy resources and technology to be put in place (development of this policy is still yet to be released). Further, of specific interest in the 18-point recommendation is the need to: "Prepare a standard and codes of practices, maintenance manuals, life cycle costing and *cost-benefit analyses tools for renewable energy technologies in rural community development in Nigeria* to be undertaken on urgent priority" (Ishmael, 2003: 53).

Consequently, lack of statistical information and data which is creating a market distortion that results in higher risk perception by investors and stakeholders has been identified by the Global Environment Facility (GEF, 2005: 27) – a non-governmental organization – as potential threats to renewable energy projects and investments in Nigeria.

1.2 Problem Statement and substantiation

Due to the epileptic trend in power generation in Nigeria, renewable energy has gained popularity among experts as an alternative method and technology that could improve on the challenges Nigeria is facing in its power sector.

The question that comes to mind is, despite the abundance of natural resources available to support the expansion of renewable energy technology in Nigeria (which will in turn help to alleviate poverty by creating employment and generating income opportunities for better health and living conditions, especially to the rural population), ***why has Nigeria not accelerated growth, development and investment in RE despite the huge potential base for RE resources.***

The answer to the above question was proffered by GEF (2005: 27), which established that indeed no cogent and reliable statistical information regarding the benefits, economic potentials and viability of renewable energy markets in Nigeria exist. This challenge has, therefore, hampered the growth of renewable energy project development as this has generated an increase in risk perception among investors, Non Governmental Organizations (NGOs) and stakeholders. Consequently, it is, therefore, critically necessary to build an information pool where benefits and economic statistics of potential renewable energy projects will be made available to intended investors for the purpose of assisting them to make a good investment decision (GEF, 2005: 27).

Additionally, this identifies with part of the 18-point agenda recommended by the Energy Commission of Nigeria (ECN) to urgently, as a matter of priority, "Prepare a standard and codes of practices, maintenance manuals, life cycle costing and *cost-benefit analyses tools for renewable energy technologies in rural community development in Nigeria*" (Ishmael, 2003: 53).

Therefore, as part of an effort to aid development in the rural community areas through renewable energy resources, it is proposed that research on a *comparative cost-benefit analysis of renewable energy resources for rural community development in Nigeria* be carried out. The resultant output of the research will be made available to intended investors and stakeholders who wish to invest in the energy driven markets in Nigeria.

In view of this, this dissertation will compare the estimates as well as totalize the equivalent money value of the benefits of implementing renewable energy technologies for rural community projects. The scope of the dissertation will be delineated to only solar, wind and small-hydro renewable energy technologies, respectively.

This research analysis and recommendations stand to benefit:

- The stakeholders, Federal Government, NGOs, foreign and local investors to make wise investment decisions through the availability of cost-benefits statistical information which previously has been scarce and in-turn has discouraged them from contributing into the energy markets in Nigeria.
- The rural community areas by promoting development through its economic viability potential campaign.
- Engineering body of knowledge through contributions regarding the outcomes of this dissertation.
- The researcher through the knowledge that will be gained researching this project in the field of study of renewable energy.

1.3 Research Aims and Objectives

The aim of this study is to analyze comparatively the benefit-cost ratio i.e. the estimates and summation of equivalent money value of all benefits and costs involved in implementing renewable energy projects for rural community development in Nigeria. Several economic and financial models will be consulted to determine all the cost elements and the present day valuation of the benefits involved in implementing renewable energy technologies in the rural community areas only. This dissertation will be carried out with the following objectives in mind:

- Preparing a standard and codes of practices … and ***cost-benefit analysis framework*** *for renewable energy technologies towards rural community development in Nigeria as indicated in the 18-point recommendations of ECN* (Ishmael, 2003: 53).
- To formulate and develop a cost-benefit analysis tool that can analyze comparatively the costs and intangible benefits of renewable energy projects for rural application.
- Establishing comparative cost components by determining the costs and money value of all the benefits required to implement renewable energy technologies in rural areas of Nigeria. The outcome will be made available to potential investors, shareholders and the Federal Government of Nigeria. This is to assist them to make wise investment decisions through

several alternatives whose statistical information will be made available through the outcomes of this research for the purpose of rural community development.

1.4 Thesis Organization

The thesis is organized into the following chapters:

Chapter 1: Research Introduction

This chapter introduces the research study. The research context is described to provide background for the research. The goals of the research, and the research methodology adopted are presented. Finally, the summary of the result will also be presented.

Chapter 2: RETs for Rural Community Development in Nigeria

This chapter explores in details a wide range of literature on the need for rural community development in developing countries with focus on Nigeria and investigates how renewable energy resources can play a vital role in the rural community development process. Various challenges faced in implementing RETs in Nigeria are also delved into.

Chapter 3: Proposed Cost-Benefit Analysis Framework for RE resources.

The concept of economic valuation method of accessing renewable energy resources is reviewed and discussed. A proposed cost-benefit framework for the analysis of renewable energy resources for the main purpose of rural community development is developed.

Chapter 4: Empirical Investigation

A selected rural site where the CBA will be carried out using three renewable energy resources are analyzed and compared.

Chapter 5: Interpretation of results and findings

The interpretative discussion and outcomes of comparative CBA of RE resources on the selected rural site are discussed in-depth.

Chapter 6: Conclusion and Recommendation

The overall dissertation is concluded where further development and recommendations are proffered.

Chapter 2

RETs for Rural Community Development in Nigeria

This chapter explores a need for rural community development in developing countries with focus on Nigeria and investigates how renewable energy resources can play a vital role in the rural community development. Various challenges faced in implementing RETs in Nigeria are also reported.

2.0 Introduction

While the main focus of this dissertation is on comparative CBA of renewable energy resources, the overall concept of rural community development in Nigeria should not be forgotten. This chapter therefore reviews the subject of energy in rural development, and the need for cleaner energy source in a broader scope. The modern use of RETs for rural community development and the current RETs adaptation in Nigeria are also presented.

In this chapter, indications have been provided on the following:

- Local energy situation in Nigeria
- Renewable Energy Technologies (RETs)
- RETs situation in Nigeria
- RE potential and application in Nigeria
- Barriers to RE utilization in Nigeria

2.1 Energy in Rural Development

It is believed that many years ago, the evolution of life as researched by Ferry and House (2006: 1286), started through the conservation of energy. The world's present population of over 6 billion is sustained and continues to grow through the use of energy. From the perspective of society, energy is not an end in itself. The energy system is designed to meet demands for a variety of services in which people are interested in, and not in the energy itself.

The term 'energy services', is used to describe the benefits that energy use offers. Fundamentally, these benefits are crucial to all the three pillars of sustainable development namely: the economic, social, and environment (UNDP, 2005: 2; Semadeni, 2002: 3). Some typical household benefits derived from energy services include lighting, room heating or cooling, automation, industrial products, education, transportation, communication and household appliances. All of the aforementioned services could be referred to as the *energy chain* as shown in Fig. 2.1 below. Semadeni (2002: 3) explains the process of energy chain which begins with the extraction or collection of primary energy sources that, in one or several steps may be converted into energy carriers that are suitable for end use. Energy carriers include fuels and electricity and can be derived from both conventional and renewable energy sources (Semadeni, 2002: 3). From the end-user's perspective, it is the availability and affordability of energy services, not merely the source of energy itself that is important.

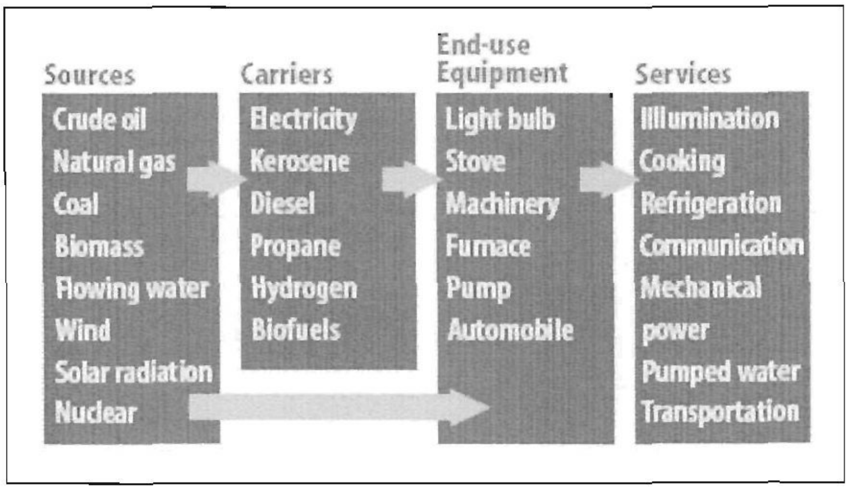

Figure 2.1: Energy chain from energy source to energy services (Semadeni, 2002)

Energy's importance to rural development is not merely a matter of conjecture or fallacy. UNDP (2005: 6) established an empirical basis to the symbiotic relationship that exists between access to modern energy and human development; for better clarity on this relationship, it is helpful to think of energy in terms of some measure of development.

Fig. 2.2 graphically explains, the relationship between a country's Human Development Index (HDI) ranking and per capita energy use, with energy consumption used as a proxy for energy services (IEA, 2004).

This presents a very strong link between energy and human development as evidenced by the upward sloping trend in the graph. The graph also illustrates that those countries that develop over time, as with the pattern with most developing countries, do so relative to improvements in energy. UNDP (2005: 6) reported that no country in modern times has substantially achieved reduction in poverty without having to increase considerably its use of energy.

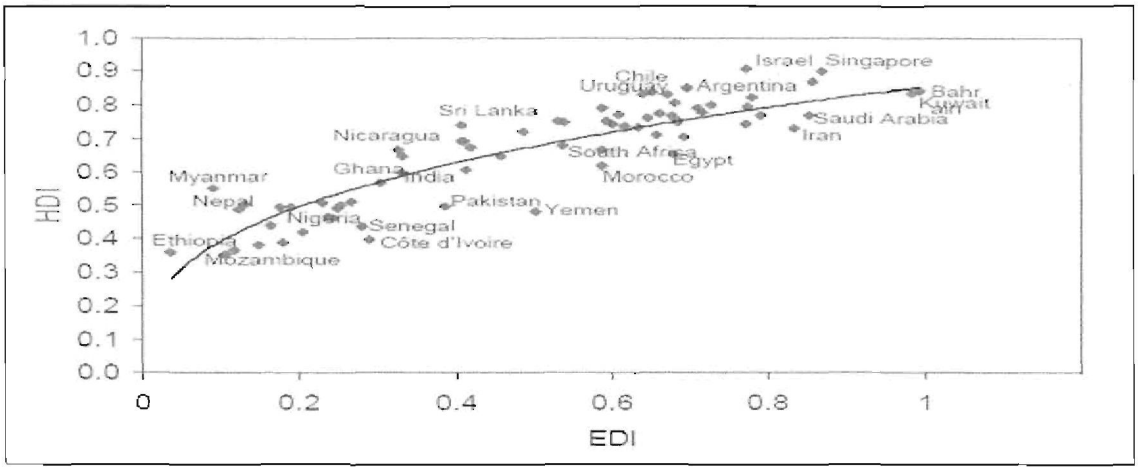

Figure 2.2: ENERGY CONSUMPTION and HDI among a group of countries (IEA, 2004).
HDI - The Human Development Index (HDI) is an index combining normalized measures of life expectancy, literacy, educational attainment and GDP per capita for countries worldwide.

The importance of energy services to the rural people cannot be overemphasized. Poverty which has been identified as the major barrier facing the rural people can be conceptualized in a number of ways. Traditionally, poverty is expressed in economic terms as income of less than $1 a day or in social terms, which represents lack of access to adequate levels of food, water, clothing, shelter, sanitation, health care and education. Pachauri *et al.* (2004: 2083) acknowledges the linkage between energy and poverty. In any case, it is possible to identify an energy dimension to poverty: energy poverty. Energy poverty as defined by Clancy *et al.* (2003: 3) in "*The gender - energy- poverty nexus*", depicts the absence of sufficient choice in accessing adequate, affordable, reliable, clean, high quality, safe and environmentally benign energy services to support economic and human development.

The link between energy services and poverty reduction was also explicitly identified by the WSSD in the JPOI (UN, 2005: 5) during the Johannesburg Summit on MDGs, which called for the international community to: "*Take joint actions and improve efforts to work together at all levels to improve access to reliable and affordable energy services for sustainable development sufficient to facilitate the achievement of the MDGs, including the Goal of halving the proportion of people in poverty by 2015, and as a means to generate other important services that mitigate poverty, bearing in mind* ***that access to energy facilitates the eradication of poverty***".

Energy, like food and shelter, is considered a composite service for humanity throughout the world. Electricity is needed to power small industries and enterprises, run health clinics and light rural homes and schools. However, as the 21st Century begins the UNDP (Takada *et al.* 2007: 3) estimates that approximately 1.6 billion people in the world, mostly in rural areas, still have no access to electricity. Another 2.5 billion people still rely on traditional biomass fuels such as: firewood, dung and agricultural residues needed to meet their daily heating and cooking needs, having serious impacts on the environment and people's health. Kabariti (2005: 9) recently reported that over hundreds of millions of women and young girls spend hours every day gathering fuel wood, and then spend additional hours cooking with poorly vented stoves. This wasted time could be used to have opportunities for education or more productive income generating activities. Consequently, about 3%, of the global burden of disease, corresponds to over 1.6 million premature deaths annually from exposure to indoor air pollution caused by burning solid fuels in poorly ventilated spaces (Gustafson *et al.* 2006: 23). This contrasting statistics presents a situation that severely limits economic opportunities and the ability to overcome poverty.

Access to energy services to supply basic needs such as cooking, lighting and heating is therefore fundamental and indispensable if sustainable development and poverty reduction must be achieved. Without access to adequate quantity and quality of modern-day energy services, the achievement of the MDGs and poverty reduction will be impossible. Electricity is needed to power small industries and enterprises, run health clinics and light schools. Without it, rural poverty will not be eradicated.

2.2 Local Energy Situation in Nigeria

Nigeria occupies a strategic location in the West African region, and is an important geographical location for regional energy integration in Africa (refer to *Annexure A*, for country's political map). The country occupies a land mass 932,770 km^2 with an entire population of about 150 million, making it the most populous country in Africa (UNDP, 2007). Nigeria is blessed with abundant primary energy resources, which include reserves of crude oil and natural gas, coal, tar sands and renewable energy resources such as hydro, fuelwood, solar, wind and biomass.

However, since the late 1960s, the economy has been solely dependent on the exploitation of fossil fuels to meet its development expenditures (Ikuponisi, 2004: 5). The EIA (2007) ranked Nigeria as the largest oil producing country in Africa, the 12th in the world. The national energy supply is at present almost entirely dependent on fossil fuels and firewood (conventional energy sources) which are depleting fast. In 2004, Nigeria's energy supply mix was dominated by oil (58%), followed by natural gas (34%) and hydroelectricity (8%). Coals, nuclear and RE sources which are in abundance are currently not exploited.

Between 1984 and 2004, EIA (2007) reported the share of oil in Nigeria's energy mix to have decreased from 77% to 58%, where natural gas consumption increased from 18% to 34% as presented in Fig. 2.3.

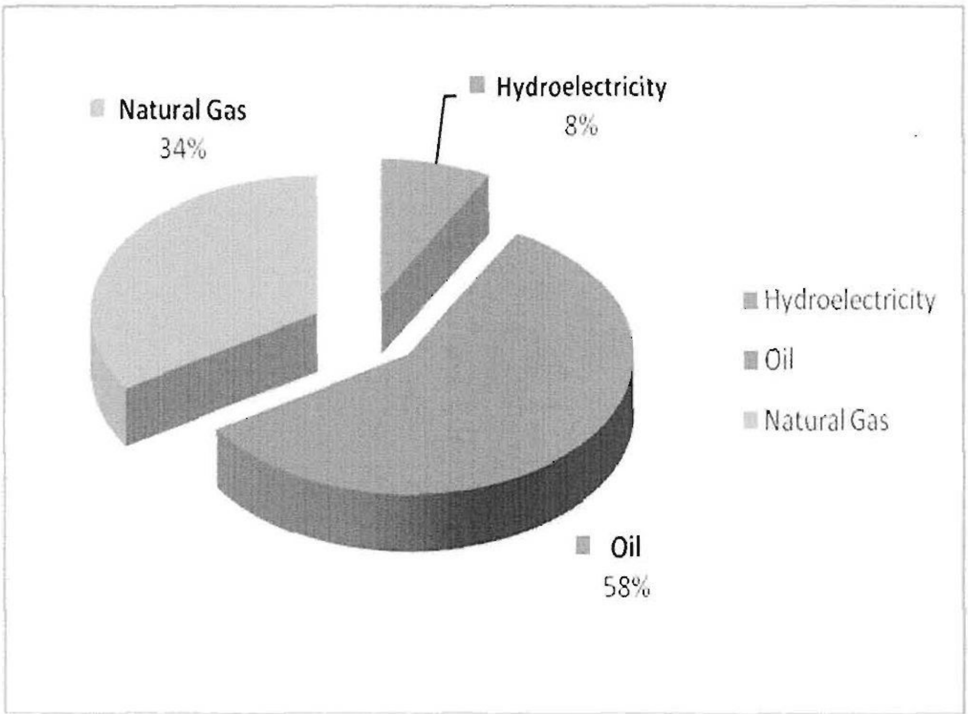

Fig 2.3: Total energy consumption in Nigeria, by type (2004) (EIA, 2007).

However with this national energy consumption pattern, it is predicted that the likely depletion time for fossil fuels is 20 – 30 years from now, and natural gas is estimated at 180 years (Ikuponisi, 2004). According to Ikuponisi (2004) report, crude oil reserve was estimated at about 23 billion barrels in 1998 and natural gas at 4293 billion m^3 at the beginning of 1999, made up of 53% associated gas and 47% non associated gas. Tables 2.1 and 2.2 show various conventional and non-conventional energy sources and their estimated reserves in Nigeria.

Table 2.1: Nigeria's conventional energy resources (Ikuponisi, 2004)

Resources	Reserves	Resources in Energy units (billion toe)	% Total Conventional Energy
Crude Oil	23 billion barrels	3.128	21.0
Natural Gas	4293 billion m^3	3.679	24.8
Coal & Lignite	2.7 billion tones	1.882	12.7
Tar Sands	31 billion barrels of oil equivalent	4.216	28.4
Hydropower	10,000 MW	1.954 (100 years)	13.1
Total	Conventional/commercial Energy Resources	14.859	100%

Table 2.2: Nigeria's non-conventional energy resources (Ikuponisi, 2004)

Resources	Reserves	Resources in Energy units (billion toe)
Fuelwood	43.3 million tonnes	1.6645 (over 100 years)
Animal Wastes & Crop Residue	144 million tonnes / Year	3.024 (over 100 years)
Small Hydro Power	734.2 MW	0.143 (over 100 years)
Solar Radiation	1.0 kW per m^2 land area (peak)	-
Wind	2.0 – 4.0 m/s	-

Note:

- 1000 kWhr (primary energy) = 0.223toe
- 1 Tonne of Fuelwood = 0.38toe
- 1 Tonne of Agric waste = 0.28toe
- 1 Tonne of Drug Cakes = 0.21toe

Hydroelectricity has seen a slight increase as well from 5% to 8% but the total installed electricity capacity is assessed at 5.9 GW with only about 40% of the population having access to electricity, majority of whom are concentrated in the urban areas (82% urban and 10% rural) (Ishmael, 2003). Total electricity generation during 2004 was estimated at 19 billion kilowatt-hours (Bkwh), while total consumption was 18 Bkwh. Despite the low capacity electricity power supply to only the privileged 40% of the populace, power outages and endemic blackouts are frequent occurrences (EIA, 2007). To compensate for the power outages, the commercial and industrial sectors are increasingly using privately operated diesel generators to provide an alternative for power electricity supply. Fig. 2.4 shows the evolution of electricity generation by fuel from 1971 to 2004 in Nigeria.

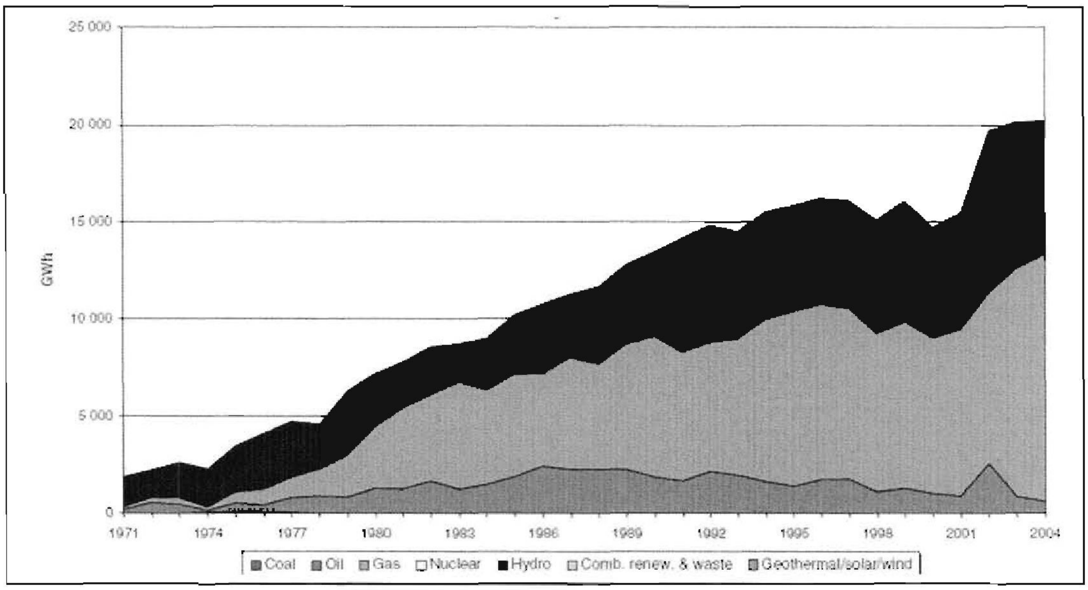

Fig. 2.4: Evolution of electricity generation by fuel from 1971 to 2004 in Nigeria (IEA, 2006)

According to a presidential report released through the ECN (2003: 5), over-dependence on oil has slowed down the development of alternative fuels (renewable energy). The Federal Government of Nigeria reiterated his commitment to diversify on other alternative fuel sources to achieve a wider energy supply mix which will ensure greater energy security for the nation (ECN, 2003: 5). It was further noted that the domestic demand for petroleum products is growing rapidly; therefore, the development of alternative fuels from locally available energy resources will be vigorously pursued.

The rural populaces, whose needs are often basic, depend to a large extent on traditional sources of energy, mainly fuelwood, charcoal, plant residues and animal wastes. This class of fuel energy constitutes over 50% of total energy consumption in Nigeria (ECN, 2003). Fuelwood supply or demand imbalance in some parts of the country is now a real threat to the energy security of the rural communities.

Moreover, the growing environment concern in terms of pollution and mass deforestation is gaining international condemnation. Hence, special attention is being paid to the diversification of the energy supply mix in the rural areas (ECN, 2003: 5). Although adequate and diversified energy supply options in the country exist, the problem of unreliability of supply constitutes a huge drain on the national economy. This leads to energy insecurity and had constituted a major characteristic of the energy crisis experienced by the country over the last decade, especially with regards to the supply of electricity and petroleum products (ECN, 2003).

Therefore, this presents a huge potential base for RE which is in abundance in Nigeria. The fact that RE offers a sustainable and environmental advantage over other sources of energy being exploited in Nigeria till date makes it a preferable fuel source. Although, implementation in some rural areas is gaining popularity, the urgency of energy in rural poverty control makes the implementation in Nigeria necessary to move at a faster pace.

2.3 Renewable Energy Technologies

RETs, most especially hydropower, traditional biomass, solar thermal and wind, are well established in world markets (or are rapidly establishing themselves, e.g. photovoltaics), and have established industries and infrastructures.

Meanwhile, other RETs are gradually becoming competitive in widening energy markets, and some have already become the lowest cost option for stand-alone and off-grid remote applications such as small rural community application (IEA, 2002). Consequently, IEA (2002) reported that the capital costs for many RETs have reduced considerably over the last decade, and further decrease in costs are expected again over the next decade. The following Table, prepared for the World Energy Assessment (WEA), provides an overview of the renewable energy sources, the technologies involved and their uses (see Table 2.3).

Table 2.3: Categories of renewable energy conversion technologies (UNDP, 2000).

Categories of Renewable Energy Conversion Technologies		
Technology	**Energy Product**	**Application**
Biomass energy		
Combustion (domestic scale)		
Combustion (industrial scale)	Heat (cooking, space heating)	Widely applied, improved tech. Available
Gasification/power production	Process heat, steam, electricity	Widely applied; potential for improvement
Gasification/fuel production	Electricity/heat (CHP)	Demonstration phase
Hydrolysis and fermentation	Hydrocarbons, methanol, H2	Development phase
	Ethanol	Commercially applied for sugar/starch crops;
Pyrolysis/production of liquid fuels		production from wood under development
Pyrolysis/production of solid fuels	Bio-oils	Pilot phase; some technical barriers
Extraction	Charcoal	Widely applied; wide range of efficiencies
Digestion	Biodiesel	Applied
	Biogas	Commercially applicable
Wind Energy		
Water pumping and battery charging	Movement, power	Small wind machines, widely applied
Onshore wind turbines	Electricity	Widely applied commercially
Offshore wind turbines	Electricity	Development and demonstration phase
Solar Energy		
Photovoltaic solar energy conversion	Electricity	Widely applied; rather expensive; further development needed
Solar thermal electricity	Heat, steam, electricity	Demonstrated; further development needed
Low-temperature solar energy use	Heat (water and space heating, cooking, drying) and cold.	Solar collectors commercially applied; solar cookers widely applied in some regions;

		solar
Passive solar energy use	Heat, cold, light, ventilation	drying demonstrated and applied
Artificial photosynthesis	H2 or hydrogen-rich fuels	Demonstrations and applications: no active parts
		Fundamental and applied research.
Technology	**Energy Product**	**Application**
Hydropower Energy		
	Power, electricity	Commercially applied; both small and
		Large-scale applications.
Geothermal Energy	Heat, steam, electricity	Commercially applied
		Ocean energy

2.4 RETs Situation in Nigeria

Nigeria is known to be well endowed with variety of RE resources which are well distributed throughout the country. The renewable energy potential base includes biomass (animal, agricultural and wood residues, fuelwood) solar, hydro, wind and geothermal (Iloeje, 2004: 4). However, it is only biomass (largely wood-fuels) and hydro power (mainly large hydropower) that have been and are still currently exploited (Ishmael, 2003: 24). Ishmael (2003: 24) further estimated that the total installed electricity capacity is assessed at 5.9 GW with only approximately 40% of the Nigerian population having access to electricity (82% urban and 10% rural). The small proportion of the rural areas that even have access suffers erratic electricity supply. Observation has shown that the present capacity is less than the installed capacity due to incessant disruption of raw materials, such as gas supply to the power stations. Meanwhile, the technologies for harnessing some of these RE resources have been developed or domesticated whereby, the viability of RETs as option for meeting small isolated or rural energy supply needs, have been proven (Iloeje, 2004: 3).

Additionally, a number of researches and development works on new and renewable energy sources are in progress in the nation's renewable energy research centers. Various studies including Iloeje (2004: 3) and Ishmael (2003: 25) have shown that there is a small but growing RE market in Nigeria.

2.4.1 RE Potential and Application in Nigeria

Nigeria lies within a high sunshine belt and, within the country solar radiation is fairly well distributed. A modest estimate of the technical potential of solar energy in Nigeria with 5% device efficiency is put at 15 x 10^{14} kilojoules (KJ) of useful energy annually (Ishmael, 2003: 25). This translates to approximately 258.62 million barrels of oil equivalent and 4.2 x 10^5 GWh of electricity production annually.

Fig. 2.5 below shows the yearly average of daily sums of global horizontal irradiation throughout Nigeria.

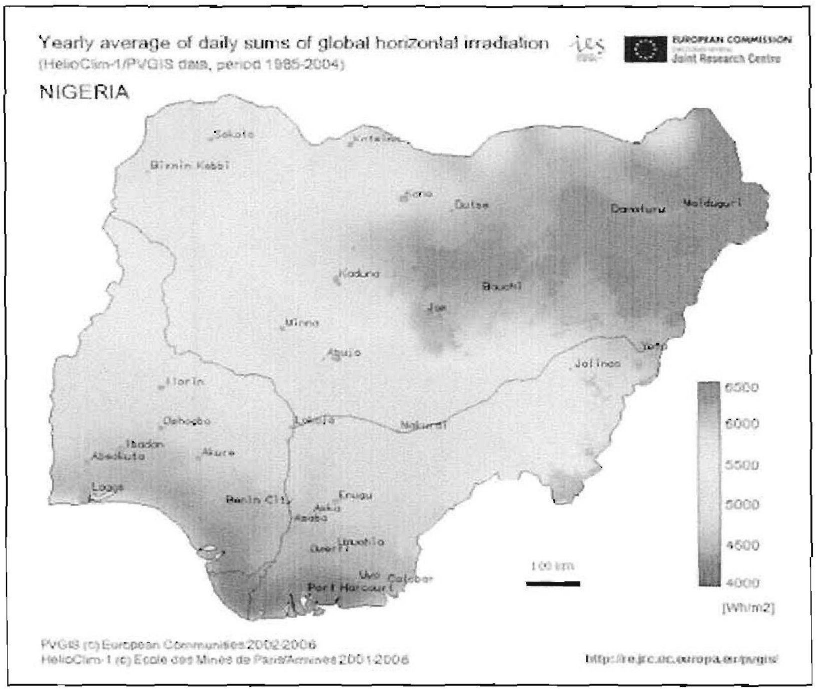

Figure 2.5: Annual average of daily global solar radiation, kWh/m/day (PVGIS & HelioClim-1, 2008).

The average solar radiation intensities as published by Iloeje (2004: 5) ranges from 3.5 to 7.0 kWh/m^2-day while daily sunshine duration ranges from 4.0 to 9.0 hours/day. This gives an average annual solar energy intensity of 1934.5 kWh/m^2-yr; thus, over a whole year, an average of 6,372,613 PJ/year (approximately 1,770 thousand TWh/year) of solar energy falls on the entire land area of Nigeria (ECN & UNDP, 2005: 13).

Based on the land area of 924 x $10^3 km^2$ for the country and an average of 5.5 kWh/m^2 per day, about 342 x $10^3 km^2$ (3.7%) of the national land area is needed to be utilized in order to annually collect from the sun an amount of energy equal to the nation's conventional energy reserve (Ikuponisi, 2004: 10). This presents a huge potential for rural applications in Nigeria as reported by the ECN and UNDP (2005). Opportunities which exist in the solar technology for rural applications include solar photovoltaic water pumping systems, solar powered vaccine refrigerators as well as telecommunication repeater stations that are powered by solar photovoltaic (Iloeje, 2004: 9). Other potentials include solar chick brooding, solar refrigeration, solar drying, solar water purification, solar air and water heating.

Various studies including Ikuponisi (2004: 8) have acknowledged Nigeria's Small Hydro Power (SHP) potential which is currently been assessed at 734MW, out of which only 4% have been exploited. From the estimate given by the ECN and UNDP (2005: 13), the gross hydro potential for the country is approximately 14,750 MW. Current hydropower generation is about 14% of the nation's hydropower potential and represents some 30% of total installed grid- connected electricity generation capacity. From a 1980 survey, it was established that some 734 MW of Small Hydro Power (SHP) could be harnessed from 277 sites (ECN & UNDP, 2005; Ikuponisi, 2004).

Unfortunately the database on SHP in Nigeria is limited, incomplete and substantially obsolete (ECN & UNDP, 2005). No new surveys have been conducted since those undertaken in only three northern states 20 years ago, to either confirm or verify earlier data or extend the work over the uncovered states and region, which, incidentally, occupy the most promising south-western and southeastern regions (ECN & UNDP, 2005). Fig. 2.6 highlights a map of Nigeria showing the major river basins for SHP potentials (Okoye & Achakpa, 2007: 25).

Figure 2.6: Map of Nigeria showing major rivers (Okoye & Achakpa, 2007)

Wind power energy utilization in Nigeria is practically minimal. Some studies have shown that the potential for wind energy abound mostly in northern Nigeria and the coastal areas of the southern region (ECN & UNDP, 2005: 16; Iloeje, 2004: 7). Ikuponisi (2004: 10) estimated the maximum energy obtainable from a 25m diameter wind turbine with an efficiency of 30% at 25m height to be about 97 MWh $year^{-1}$ for Sokoto, a site in the high wind speed regions, 50 MWh $year^{-1}$ for Kano, 25.7 MWh $year^{-1}$ for Lagos and 24.5 MWh $year^{-1}$ from Port Harcourt. Wind energy technology is one of the cost effective renewable energy technologies available today, costing between 4-6 cents per kilowatt-hour, depending on the wind resource base and financing of the particular project (ECN & UNDP, 2005). The construction period of wind energy technology is less than other energy technologies, it uses cost-free fuel, the operation and maintenance (O & M) cost is very low and easy scalability in modular form, making it adaptable to increasing demand.

However, several economic, policy, technical and market barriers militate against the rapid adoption of wind power in Nigeria (ECN & UNDP, 2005). These barriers must be addressed if the potentials identified and the targets set for electricity from wind power are to be realized. Table 2.4, presents an overview of the initial costs of electricity generating systems using some RETs while Table 2.5 presents a comparative assessment of operation and maintenance costs of some RETs.

Table 2.4 Initial costs of electricity generating systems (ECN & UNDP, 2007)

Technology	Size (KW)	Initial Capital Cost (S/KW)
Engine Generator Gasoline	4	760
Engine Generator Diesel	20	500
Small Hydro	10 - 20	1,000 – 2,400
Solar Photovoltaic	0.07	11,200
Solar Photovoltaic	0.19	8,400
Wind Turbine	0.25	5,500
Wind Turbine	4	3,900
Wind Turbine	10	2,800

Table 2.5: Operation, maintenance, and fuel costs for different technologies (ECN & UNDP, 2007)

Technology	O&M Costs (cent / KWh)	Fuel Costs (Cent / KWh)*
Engine Generator	2	20
Small Hydro	2	0
Photovoltaic	0.5	0
Wind Turbine	1	0

* Assuming Diesel Fuel Price of 5 US$/L

2.4.2 Barriers to RE Utilization in Nigeria

Key challenges to the deployment of Renewable Energy Technology (RETs) in Nigeria as identified by Okoye and Achakpa (2007: 71) are as follows:

1) **Technological Incapability:** With the exception of solar thermal and biogas technologies, no other RETs have been developed in Nigeria. Most of the technologies have to be imported, thereby further escalating the already high investment cost;

2) **High cost of Energy Infrastructure:** Small-hydro power, central and residential solar technologies, etc., have not penetrated the Nigeria's energy supply system because of their relatively high investment costs. This barrier has also been found to be the major obstacle to widespread adoption of family-sized biogas digesters in the country.

3) **Financial Constraints:** There are limited funds available for the deployment of RETs. In the absence of any serious private sector involvement in the development and the dissemination of the technologies, this posed a serious barrier to the RETs;

4) **Low Level of Public Awareness:** Public awareness of RE sources and technologies in Nigeria and their benefits, both economically and environmentally are generally low. Consequently, the public is not well-equipped to influence the government to begin to take

more decisive initiatives in enhancing the development, application, dissemination and diffusion of renewable energy resources and technologies in the national energy market; and

5) **General absence of comprehensive national energy policy:** Nigeria has never formulated a comprehensive energy policy; only sub-regional policies are usually being formulated. Since such a policy is pivotal to using energy efficient resources and RETs, this has to a large extent contributed to the lack of attention for the RETs.

2.5 Chapter Summary

Poverty is one of the world's most fundamental issues, and urgently needs to be addressed. Consequently, rural people voice the need for the means to provide themselves with adequate livelihoods. These livelihoods should be sustainable, in the sense that they can withstand stresses and shocks, and they should maintain, or even enhance capabilities and assets without undermining the natural resource base. Energy plays a fundamental role in uplifting the standards of living of the rural people. Meanwhile, RE resource which is derived from a non-exhaustible source will be beneficial to these rural people if it can be sustained. However, the survey conducted on Nigeria has shown that RETs is not fully utilized despite its potentials. The level of RE resource endowment, capacities to utilize RETs, and the economics of the RETs are all issues that challenge the optimal utilization of the various sources of renewable energy in the country. Although, costs are critical to the overall success in developing a particular RE resource base however, they might not be adequate enough to justify the selection of an RET until the benefits are put into proper consideration.

The chapter that follows will explore how these benefits can be quantified in monetary terms relative to the costs involved in typical RETs project, using a cost-benefit analysis tool by formulating a conceptual framework for decision making purposes.

Chapter 3

Proposed Cost Benefit Analysis Framework for Renewable Energy Resources.

Chapter three describes the history of cost-benefit analysis and reviews the fundamental and methodology issues that should be acknowledged before evaluating a CBA. It also presents a brief comparative review of some other economic studies relative to CBA. The proposed CBA framework that will be adopted in this dissertation is finally presented.

3.0 Introduction

Cost-benefit analysis (CBA) as defined by Hosking and Du Preez (2004: 144) is a standard method of comparing the social costs and benefits of alternative projects or investments. Costs and benefits in this context are measured and then weighed up against each other in order to generate criteria for decision-making (Hosking & Preez, 2004: 114). One or more of such decision criteria often used are:

- Net Present Value (NPV);
- Benefit-Cost Ratio (BCR);
- Internal Rate of Return (IRR).

According to the above criteria, a project may be deemed to be viable if the NPV is positive, or the BCR exceeds a digit of 1, or the IRR exceeds the applicable discount rate (Hosking & Preez, 2004: 114). Typically, there are four basic elements to CBA (Hosking & Preez, 2004: 114) which will be considered in the analysis of this dissertation. The four basic elements are: time considerations, costs, benefits and the social discount rate; all of which will be discussed in details later in this chapter.

This chapter describes the history of Cost-Benefit Analysis (CBA) and reviews the fundamental and methodology issues that should be acknowledged before embarking on a CBA. It also presents a brief comparative review of some other economic studies relative to CBA. The proposed CBA framework that will be adopted in this dissertation is finally presented.

3.1 History of CBA

Although, the practical application of CBA can be traced back to the impetus provided by the American Federal Navigation Act of 1936, but a British economist, Alfred Marshall, was the person known to have first formulated some of the concepts that are at the foundation of CBA today (Håkansson, 2007: 11; Watkins, 2007: 1). This act gave the U.S. Corps of Engineers then, the responsibility of carrying out projects for the improvement of flood control system and a mandate to carry out projects to provide flood protection, if the total benefits of a project to whomsoever they accrue exceed the costs of that project (Håkansson, 2007: 11; Watkins, 2007:

1). Håkansson (2007: 11) asserted that this was seen as a requirement to estimate all possible values a project could generate and not only values from a business economic point of view.

In any case, the U.S. Corps of Engineers later developed a systematic method for measuring projects' benefits and costs, upon which the CBA method of today was solely built on. Meanwhile, all these were done without the assistance of the economic professionals, until about twenty years later in the 1950's that economists tried to provide a rigorous and consistent set of methods for measuring benefits and costs with a view to deciding a project viability (Håkansson, 2007: 11).

Nevertheless, there exist some limitations in the use of CBA which have not been totally resolved up till now but however, the method still remains one of the most accurate tools to use where investment decision is concerned (Watkins, 2007: 1). CBA limitations exist in the form of intangible considerations and equity concerns where, some costs and benefits cannot be assigned with monetary values (Federal Management Group, 2006).

However, a reliable way of mitigating this is to separately present these intangibles to the decision-maker for assessment in conjunction with the quantified estimate of the net social benefit of the activity or rather, Cost-Effectiveness Analysis (CEA). Contingent Valuation Method (CVM) may be incorporated into the CBA procedures to present a more flexible way of quantifying benefits and costs in monetary value (Federal Management Group, 2006: 2; Treasury Board of Canada Secretariat, 1998: 8).

3.2 Introduction to Financial and Economic Analysis

Many decades ago, several economic and financial analytical tools were developed by economic professionals to address challenging issues. One of such issues is having an effective tool that can help investors make wise economic decisions from seeming alternative options in a public sector domain.

In the business context, some economic analytical tools exist that could proffer solutions to the challenging issue mentioned above. Typical examples of these economic tools are: Life Cycle Assessment (LCA), Local Economic Impact (LEI), Cost-Benefit Analysis (CBA), Cost

Effectiveness Analysis (CEA), Economic / Financial Valuation (EV), conjoint analysis, real options, emergy analysis, etc. Out of all the techniques mentioned above, none have attracted more attention than cost-benefit analysis where investment appraisal of public projects is concerned (Hough, 1993: 6). Hough (1993: 6) emphasized the usage of CBA in this context as a methodological technique used often in education decision making. However, several literatures have confirmed its popularity in the other sectors, especially RE sector.

Financial Valuation (FV) for instance, is closely related to CBA; nevertheless there still exit some notable differences. According to the Financial Management Group (2006: 3), an FV is always conducted from the viewpoint of the individual organization rather than from the Society's perspectives. It provides answer to questions like: *'what is the net benefit of this technology or project to the individual organization'*. Whereas, a CBA will provide answer to the question: *'what is the net benefit of this technology or project to the community as a whole?"* (Financial Management Group, 2006: 3). In contrast, FV and CBA share some similarities in the use of money to measure both inputs and results.

Similarly, Cost Effectiveness Analysis (CEA) is another financial tool that is closely related to CBA. CEA differs from CBA in three respects. First and foremost, it does not provide a complete measure of the benefit of the project or policy to the economy (Financial Management Group, 2006: 3). This tends to limit its application in comparing a wide range of activities. Secondly, for the alternatives or options under consideration to be assessed according to a particular set criterion of effectiveness, the alternatives must be similar in nature (Financial Management Group, 2006: 3). Finally, benefits are expressed in physical terms rather than in monetary terms. This is so because costs are often incurred close to the start of the activity, which are simply summed rather than being discounted (New Zealand Treasury, 2005: 8; Financial Management Group, 2006: 3).

3.2.1 Why Cost-Benefit Analysis?

Difficult choices that confront investors or policymakers have to be made. In Nigeria for instance, limited financial resources are involved in proffering a sustainable development in the rural areas in terms of renewable energy power electrification. Uncertainties in the viability of setting this type of technology always daunt the interest of susceptible investors. Likewise, accurate decision has to be made on the part of the government in government financed RE projects and where tax payers' money has to be justified and accounted for.

Nevertheless, quantitative analysis of probable outcomes of alternative courses of action can diminish the uncertainty and improve the decision-making process. Brief reflection on the criteria to be considered by investors include: which of the RETs will provide the rural communities the best benefits; which of the RETs will be the most cost-effective solution; which of the RETs will provide the earliest Return on Investment (ROI) to the investor and, which of the RETs will be most sustainable over a certain period of time. These enable the investor to provide the most solid basis for those decisions.

The above defining criteria often considered by the investor, capture the essential focus of CBA as the economic method of choice when alternative decisions are complex or the financial data uncertain. According to Treasury Board of Canada Secretariat (1998: 8), CBA technique is advantageous in:

- Identifying alternative options;
- Defining alternatives in a way that allows fair comparison;
- Adjusting for occurrence of costs and benefits at different times;
- Calculating dollar or *money* values for things that are not usually expressed in dollars;
- Coping with uncertainty in the data; and
- Summing up a complex pattern of costs and benefits with a view to guide decision-making.

Given the positive attributes of CBA in weighing alternatives of both costs and benefits in terms of monetary value, makes it the preferred choice of economic analytical tool applicable to this dissertation.

3.2.2 Fundamentals of Cost–Benefit Analysis

The fundamentals of CBA are best described as a process whilst the sequence of steps in undertaking it will be delved into briefly. There are no restrictive rules in conducting a CBA.

A flow sequence of steps involved in the analysis of a CBA is shown in Fig 3.1 below:

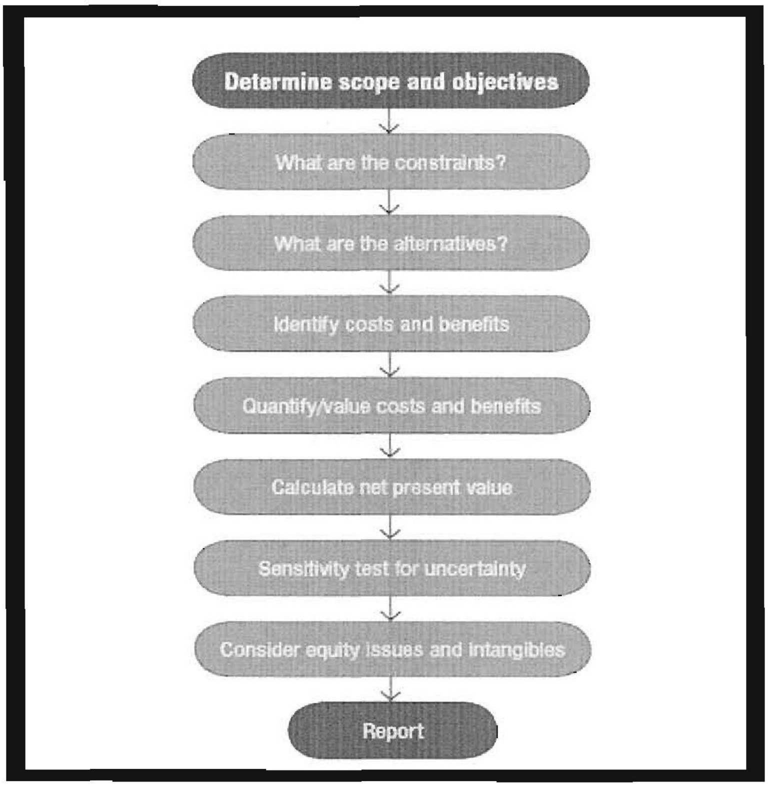

Figure 3.1: Steps involved in a CBA process (Federal Management Group, 2006: 9)

Each of these common steps is further explained below (Federal Management Group, 2006: 8; Treasury Board of Canada Secretariat, 1998: 9; Menegaki, 2007: 2):

(a) What is the problem?

The first step entails an investigation of needs, objectives, and formulation scopes and targets. Broader perspective of the project might first be drawn before narrowing it down to specific deliverables and beneficiaries. Gainers and losers are also identified.

(b) What are the constraints?

All the constraints that could be encountered in meeting the objectives should be identified to ensure that feasible alternatives exist. Identified constraints must be as clear as possible.

(c) What are the alternatives?

Alternatives must be generated and should be sufficient enough to provide the decision-maker a clear vision of the scope. Subsequently, a *'do nothing'* alternative otherwise known as the *'base case'* option should also be considered. Costs and benefits are incremental variables and should be compared with what would have happened if nothing had been done.

(d) Identify the costs and benefits.

A list of all the costs of all the alternatives should be drawn. Examples of such costs include:

- Capital costs;
- Operating and maintenance costs for the entire expected economic life of the project;
- Labour costs;
- Material costs
- Research and development costs; and
- Opportunity costs covering land usage and/or facilities already in the public domain or environmental costs arising from air pollution.

Similarly, a list of the benefits that will be gained from the proposed project should be identified.

(e) Quantify / Value costs and benefits.

A common measure, preferably dollar, is often used in comparing costs and benefits in CBA. Usually, in a rural community project like the RETs, actual market prices are often used to express the value of costs and benefits in social terms, since costs and benefits will reflect the gains and losses to the economy of the community, rather than to individual persons or groups.

As it is known in economic terms, the key to all capital investment decisions is based on the concept of time preference. From the viewpoint of the decision maker or investor, paying or income cost of any transaction that takes place in the future is by far less important than one that takes place in the present. This is so because a dollar's consumption in the future is usually valued less than a dollar's consumption today, therefore, future costs and benefits must be discounted to a 'present value' (Federal Management Group: 2006). Thus, consistency has to be shown between the cost-benefit rule and net present value rule.

Philips LeBel (2000: 16) in one of his papers which examines the economic efficiency of alternative renewable energy technologies in Botswana emphasized that valuation of future versus present costs and benefits must be taken into accounts when one is making useful comparisons of whether a given technology is economical. This creates a linkage to the term known as the *discount rate* which defines the decision maker's time preference while valuing the future versus the present costs and benefits (LeBel, 2000: 16).

Equations 3.1 through 3.7 illustrate the concept of discounting in CBA as adapted from the works of Philips LeBel (2000) in the *Financial and Economic Analysis of Selected Renewable Energy Technologies in Botswana.* Take for example, if we are to determine a cumulative Present Value of Benefits (PVB) that are payable in annual installments over a period of five years is given as:

$$\mathbf{PVB} = \frac{B_0}{(1+R)^0} + \frac{B_1}{(1+R)^1} + \frac{B_2}{(1+R)^2} + \frac{B_3}{(1+R)^3} + \frac{B_4}{(1+R)^4} \quad \cdots\cdots\cdots\cdots\blacktriangleright \quad \mathbf{3.1}$$

Where B is the economic value of benefits in each time period, and R is the discount rate, then we can express *equation 3.1* in a unified format to obtain:

$$\mathbf{PVB} = \sum_{i=0}^{n} \frac{B_i}{(1+R)^i} \quad \cdots\cdots\cdots\cdots\blacktriangleright \quad \mathbf{3.2}$$

Where, n represents the present value period of time to be considered. In this example, n represents *4*.

It must be noted that the initial time period is not always discounted, though it appears in the formula. This is so because the exponential of 0 carries the value of 1. The result of using the above discount rate illustrates that by using a discounted value for each benefit for each period of time, one has an accurate way of aggregating the benefits that are expected in the future time period with the present time benefits.

Similarly, the same set of mathematical expression is needed to obtain the present value of costs (PVC):

$$\textbf{PVC} = \frac{C_0}{(1+R)^0} + \frac{C_1}{(1+R)^1} + \frac{C_2}{(1+R)^2} + \frac{C_3}{(1+R)^3} + \frac{C_4}{(1+R)^4} \quad \cdots\cdots\cdots\blacktriangleright \quad \textbf{3.3}$$

Where *R* depicts the same discount rate in *equation 3.3*, and *C* is the economic value of costs in each time period.

Also, express equation 3.3 in a unified form to get:

$$\textbf{PVC} = \sum_{i=0}^{n} \frac{C_i}{(1+R)^i} \quad \cdots\cdots\cdots\blacktriangleright \quad \textbf{3.4}$$

Where *Ci* represents the cost in the *ith* time period and, *n* again represents the present value period of time to be considered. Equations 3.3 and 3.4 give the present value of the cost of the RET over lifetime cycle of the technology. The present value figure here is also known as the life cycle cost of the good.

Since Equations 3.2 and 3.4 are determined, they provide the basis for the determination of the three criteria often used to determine if an investment is economical. They are Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR). In the case of NPV, simply by subtracting the present value of costs from the present value of benefits gives a net present value. NPV is important in determining if an investment decision is economical. A positive net present value indicates the investment decision is viable. Equation 3.5 below shows the mathematical expression of an NPV:

$$\textbf{NPV} = \sum_{i=0}^{n} \frac{B_i}{(1+R)^i} - \sum_{i=0}^{n} \frac{C_i}{(1+R)^i} \quad \cdots\cdots\cdots\blacktriangleright \quad \textbf{3.5}$$

A second criterion that is often used to measure if an investment decisions is viable is the Benefit-Cost Ratio (BCR). The benefit-cost ratio is the ratio of present benefits to present costs, which is derived from equations 3.2 and 3.4, defined as:

$$\textbf{B/C Ratio} = \frac{\sum_{i=0}^{n} \frac{B_i}{(1+R)^i}}{\sum_{i=0}^{n} \frac{C_i}{(1+R)^i}} \quad \cdots\cdots\cdots\cdots\blacktriangleright \quad \textbf{3.6}$$

Benefit-cost ratio is always interlinked with the outcomes of the net present value measure. For instance, if the net present value of an investment is positive, the benefit-cost ratio will be greater than one, in which case the project is considered viable. For a minimum level result of acceptability, a zero net present value and a benefit-cost ratio of one is used.

Thirdly, investment evaluation also depends on the use of an Internal Rate of Return (IRR). Equation 3.7 shows the mathematical expression of an IRR:

$$\textbf{IRR} = \left[\sum_{i=0}^{n} \frac{Bi}{(1+R)^i} - \sum_{i=0}^{n} \frac{C_i}{(1+R)^i} \right] = 0 \quad \cdots\cdots\cdots\cdots\blacktriangleright \quad \textbf{3.7}$$

In interpreting the internal rate of return, a project is considered viable if the IRR is greater than or equal to the opportunity cost of investment resources. From a businessman's perspective, a project is only deemed viable if the percentage return on investment is greater that the lending rate he has to pay to borrow the money in the first place (Department of Environmental Affairs and Tourism, 2004: 6).

However, in terms of this research project analysis, all the three decision rules will be employed in order to adequately present the required information for the basis of solid decision making. Greater difficulties are always encountered in the actual measurements of costs and benefits, as well as selection of an appropriate discount rate. In view of this, more emphasis will be shown in the section that follows by discussing some of these measurement issues in the context of the evaluation of RETs.

3.3 Cost–Benefit Analysis Methodology

The methodology used to assess the renewable energy technologies covered in this dissertation is cost-benefit analysis. Only three RETs, namely: wind, solar and small-hydro will be selected for analysis in a rural Nigerian setup where valid comparisons and conclusions can then be drawn only, by taking into consideration the life cycle of the technologies rather than its initial capital cost; for this reason CBA is used.

Most of the basic steps and tools that will be used in the analysis are combinations of one or more financial tools to cater for the limitations of the conventional CBA identified above. Further, the CBA analysis framework will adopt the '*with and without*' approach to CBA as illustrated in Fig 3.2.

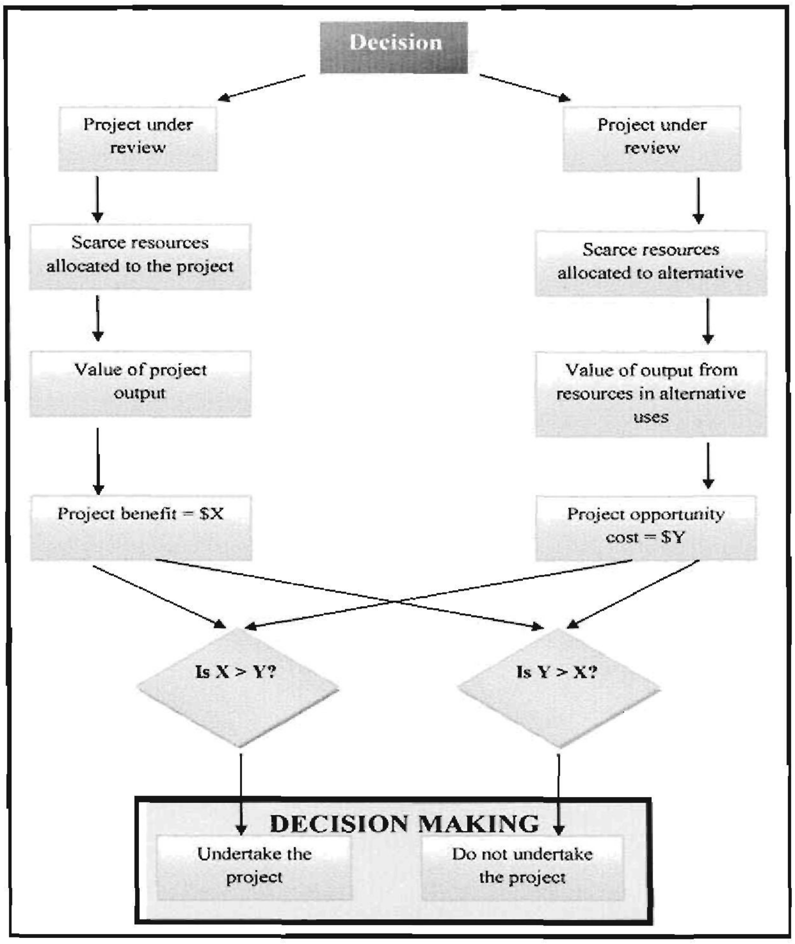

Figure 3.2: The "with and without" approach to cost-benefit analysis (*adapted from* Campbell & Brown, 2003: 6).

3.4 Proposed Cost–Benefit Framework for RE Resources

In conducting a CBA for RE, various steps are involved. The first step entails a detailed definition of the project and various alternatives under consideration, along with the relevant rural community population i.e. those individuals whose welfare is considered relevant and affected.

The alternatives to be considered are: solar, wind, small-hydro and a 'do-nothing' alternative. In the second step, relevant impacts of the RE project to the rural community and its alternatives are identified, using the CBA criterion whether they constitute a cost, a benefit or a redistribution of welfare. Furthermore, all stakeholders that will be beneficiaries (either positively or negatively) are identified.

In the third step, relevant costs and benefits are valued in monetary terms. Costs will cover investment costs (residual value of fixed assets like land, buildings where the technology will be sited), operating costs and revenue (cost include raw materials, labour, maintenance of supporting equipment), etc. Shadow prices will be used for all RET component prices as against market prices which have been distorted since market prices do not always reflect the opportunity cost of a good. If prices are distorted, they do not represent a suitable indicator of welfare. Therefore, in order to correct this imperfection in the market prices, a shadow exchange rate will be used for the domestic currency (Naira) to internationally traded RE components and services. Marginal cost will be used for non-marketed goods such as the land, local transport services, etc. For costs like job employment, Nigerian minimum wage will be used as reference measurement.

In the fourth step, benefits and costs are aggregated over time by means of discounting. Discounting expresses future costs and benefits in terms of their present value. The United States Public Service Electric & Gas suggests 15 years as a reasonable minimum time frame for RE based investments[i] since RE is considered to be a long-term capital investment project. Besides, it allows for a test of financial sustainability of RE over a longer time frame. However, 20 years will be used in this analysis. The discount rate of 12.3% will be used in the analysis based on the Minimum Rediscount Rate (MRR) on capital in Nigeria which is put at 14% (Central Bank of Nigeria, 2008).

$$\mathbf{d} = \frac{i}{1+i}$$ *Where: **d** represents the discount rate, and **i** the CBN interest rate.*

For example, if i =14%, d = 12.3% (Wikipedia, 2000a).

The fifth step of a CBA involves testing for viability and this will be divided into three parts. First part will compare the total discounted benefits with total discounted costs, to produce a Net Present Value (NPV). Second part will calculate the discount rate at which a stream of costs and benefits has a net present value of zero to give the Internal Rate of Return (IRR). Alternatively, the third part will be presented in form of a Benefit-Cost Ratio (BCR).

The final step consists of conducting a sensitivity analysis on important parameters such as the discount rate, project life-span, and cost and benefit estimates.

3.4.1 Synopsis of the Conceptual CBA Framework for RE

The development of the conceptual CBA framework is mainly based on the review of existing CBA methods taking into consideration the related analysis of statisticians, energy technology experts and energy socio-economists.

Foremost, the scope of the RE project is identified and determined, where emphasis is placed on only wind, solar and small hydro RE resources. Power utilization pattern of the rural site is also determined.

The conceptual framework further outlines the costs and benefits that will be involved in the analysis. These costs and benefits were identified through scholarly research. The variables within the framework are designed to address costs and benefits of the RE project for rural application.

Further, valuation of cost and benefits are conducted. It is expected that the cost data will be sourced through RETs consultants while benefit data will be valued through a detailed Contingent Valuation Method (CVM), upon which the core premise of the conceptual framework lies. The CVM is a non-market valuation method using surveys to elicit respondents' values directly on public or environmental amenities, which is based on preferences revealed through the survey and is suitable for valuing goods with non-use values and without associated markets (King *et.al*, 2000; Quan, 2004: 41).

Quan (2004: 41) further explains CVM as a method that is consistent with welfare economics as it queries for an estimate of their Willingness to Pay (WTP) or Willingness to Accept (WTA) compensation for a new practice or service. The WTP is the maximum amount of money which can be paid by the individuals for a higher level of utility, while the WTA is the minimum amount of money asked by individuals after their utility level is lowered from changes of environmental amenities to return them to the initial utility level (Quan, 2004: 41).

In order to determine the rural people's WTP, a questionnaire survey instrument will be used to obtain their welfare profile. The next chapters will delve into the methodology of how the survey will be conducted. WTP responses will be statistically analyzed to obtain an estimate of mean WTP (MWTP), which is multiplied by *n*, the size of the population affected by the proposed RE implementation, to produce total WTP (TWTP). The total WTP can then be taken as the benefit derived from the proposed RE in monetary units (FAO, 2000: 13). Equations 3.8 and 3.9 show the mathematical expressions of both MWTP and TWTP.

$$MWTP = \frac{1}{n}\sum_{i=1}^{n} y_i \qquad \text{3.8}$$

$$\mathbf{TWTP} = \mathbf{MWTP \times n} \qquad \text{3.9}$$

Where n is the rural population under review, y_i is the WTP of the i^{th} respondent

The next step involves discounting both cost and benefit over a time frame of 20 years at a discount rate of 12.3% (Nigerian discount rate).

The fifth step involves economic evaluation (NPV, BCR and IRR) of the cost and benefit components of the three RETs to aid decision making. The outcome of the economic evaluation is tested through sensitivity analysis to determine how sensitive the outcomes of each of the alternatives are by varying the inputs. Finally, the results are compared for decision making. Fig. 3.3 outlines the proposed conceptual CBA framework for RE projects.

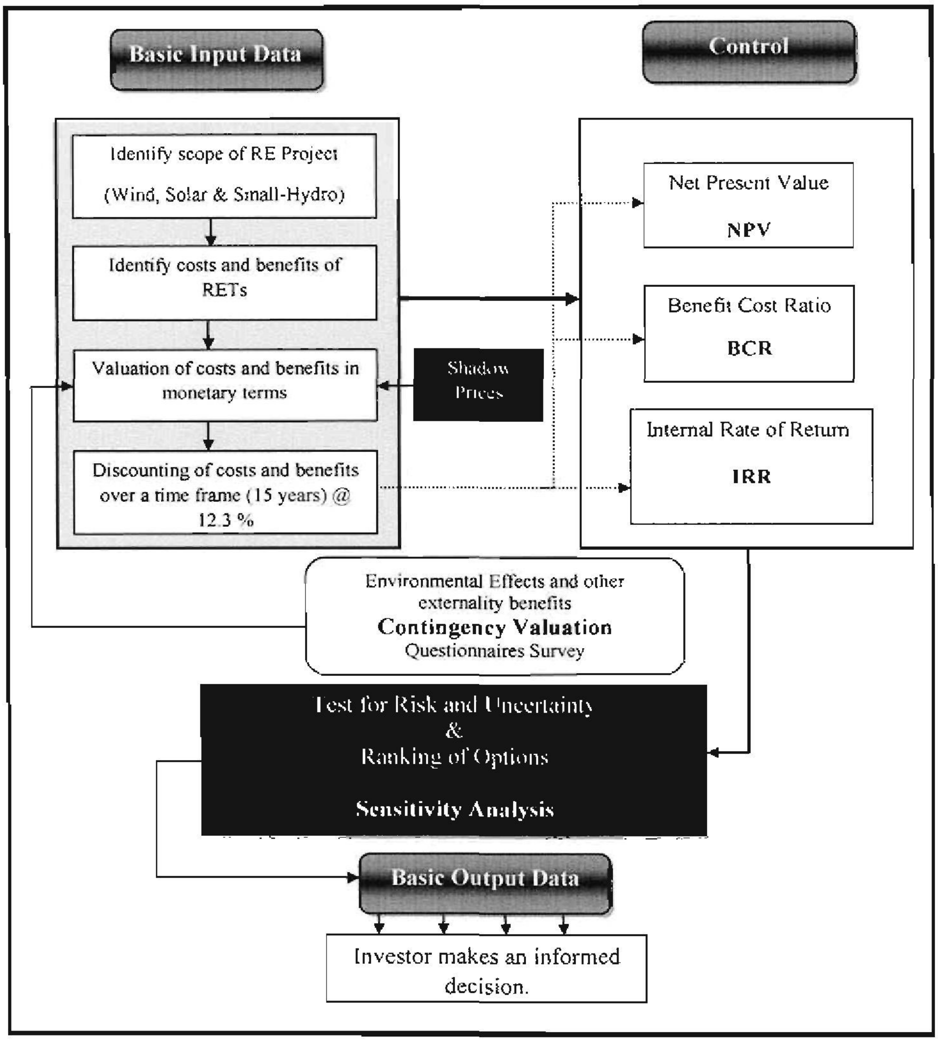

Figure 3.3: Conceptual CBA framework for RE resources for rural development (*adapted from* Federal Management Group, 2006; Brent, 2006; Hokin, 2007a; Hokin, 2007b).

3.5 Chapter Summary

In summary, making capital investment decision requires a tool that can provide investors with detailed qualitative information. Capital investment like RE is believed to be noncompetitive when compared to other forms of power generation, like fossil power generation (Menegaki, 2007: 2). Menegaki (2007: 2) further argued that the cost of RETs will sufficiently drop if the benefits, intangibles and other environmental externalities which are difficult to quantify are recognized. Flexibility in application of CBA in quantifying these benefits makes it an attractive feature to decision makers since it offers a variety of criterion to evaluate a project. In particular, the proposed CBA framework in this dissertation can assist an investor make investment decisions based on the output of its NPV, BCR and IRR criterions.

The methodology used to measure the costs and benefits for this project are discussed in the next chapter. It further reviews a case study of a rural community in Nigeria with RE potentials where the analysis of the CBA framework will be carried out.

Chapter 4

Empirical Investigation

In the previous chapters, various issues and challenges confronting the adaptation of RETs in Nigeria were reviewed and also a CBA framework was proposed. This chapter introduces a selected rural site in Nigeria where the CBA framework was carried out using three RE resources, namely: solar, wind and small-hydro power. The research design and the approaches used therein are also addressed.

4.0 Introduction

Now that the cost-benefit analysis framework has been discussed and conceptualized, the focus turns to a practical case where it is applied. This chapter focuses on the research design and methodology of the empirical investigation carried out in achieving the objectives of this dissertation.

To serve as a reminder, the main objective of this project is: *"to quantify all benefits and costs involved in implementing renewable energy projects for rural community development in Nigeria by using CBA framework where Erinjiyan Ekiti rural area will serve as a case study."* Consequently, the resultant outcome of this analysis is expected to aid an investor in making an informed investment decision. Due to time constraint, only three Renewable Energy Technologies (RETs) were selected for this study, namely: **solar, wind and small hydro power technologies**. Moreover, these were particularly relevant to the rural area under observation because of the potentials of these resources in the area. There are some considerable differences to note between these types of RET in terms of infrastructure requirements and scales, which are important to consider alongside their contribution to the rural development.

Both qualitative and quantitative research methodologies are adopted and described as the most appropriate approaches to analyzing real-life rural RET project environments. The chapter then describes the case study – scenario design used as well as a CBA framework methodology adopted in the rural RET project. The research design aspects include the research techniques, data collection methods, reliability and validity of data derived.

4.1 Scenario Design

4.1.1 Case Study

4.1.1.1 Demographic Information

The demographic information of Erinjiyan Ekiti as published on Ekiti State website by Adetule (2008) depicts "Erinjiyan Ekiti as a rural community area otherwise known as the Golden City. The rural area is situated 30 km north-west of Ado-Ekiti (the capital of Ekiti State of Nigeria) and 50 km from Ile-Ife, believed to be the cradle of Yoruba race, the source of civilization and capital of Yoruba Nation". Fig. 4.1 shows the political map of Erinjiyan Ekiti as captured by Microsoft Encarta, 2008. Additionally, the rural area is 300 km from Lagos, the commercial nerve centre of Nigeria.

Geographically, Erinjiyan Ekiti is situated entirely within the tropics, and is located between latitude 7.61[1] north of the equator, as well as 5.05[1] east of the Greenwich meridian (Microsoft Encarta, 2008). From the 1991 Census statistics, the population of Erinjiyan Ekiti was estimated to be approximately 87,000 (for a 7 km radius), representing approximately 10,900 households with an average population of 8 people per household (Falling Rain Genomics, 2004).

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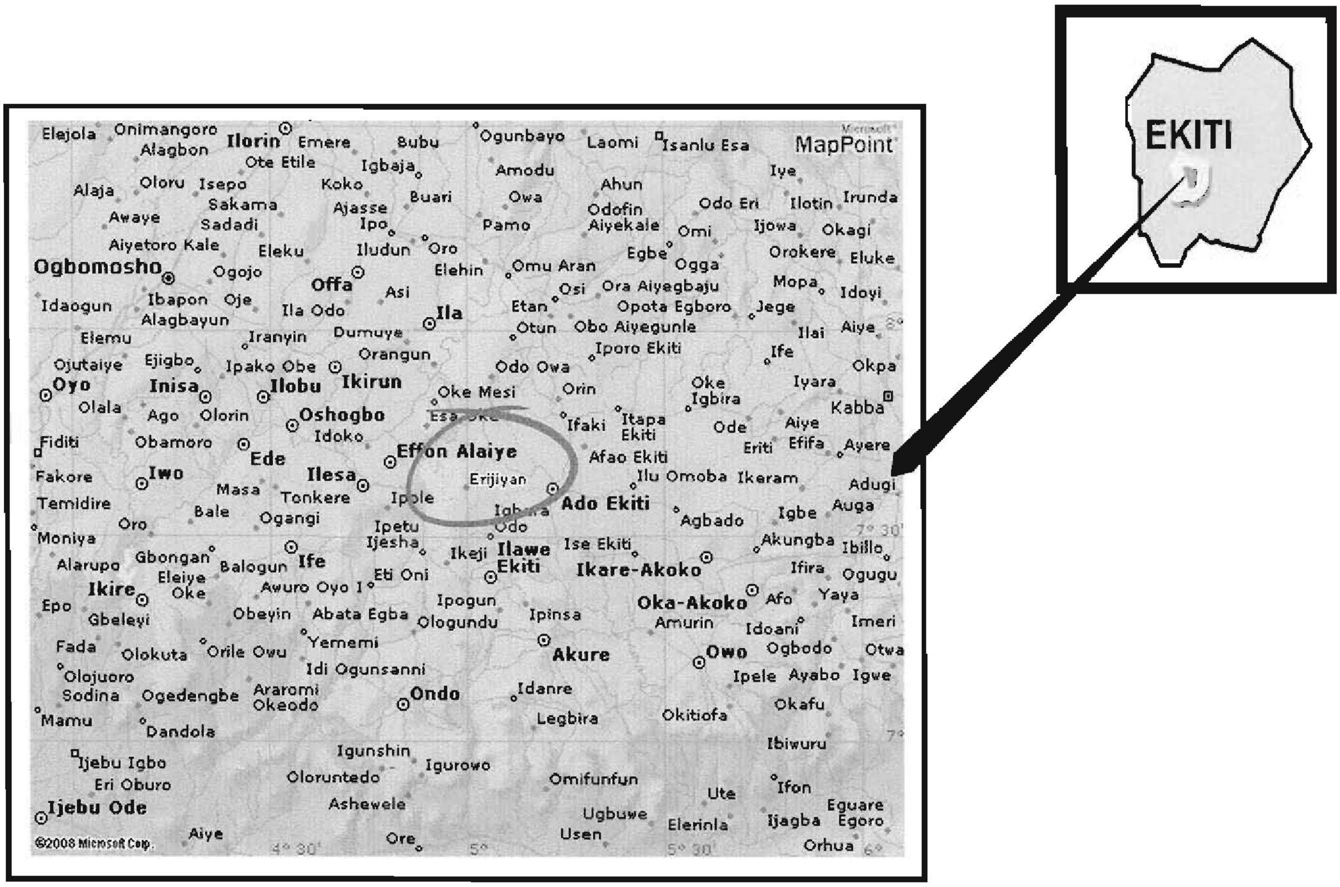

Figure 4.1: Map of Erinjiyan Ekiti rural community area (Microsoft Encarta, 2008).

The area is also endowed by nature which consist mainly an upland zone rising of over 350m above sea level; Erinjiyan Ekiti has a rhythmically undulating surface (Adetule, 2008). Further, the landscape consists of ancient plains broken by steep-sided outcropping dome rocks. The community enjoys a tropical climate with two distinct seasons (Adetule 2008). These are the rainy season (April - October) and the dry-cold-windy season (November - March). Temperature ranges between 21°C and 28°C with high humidity (Ekiti State of Nigeria, 2008). The south-westerly winds and the north-east trade winds blow in the rainy and dry-cold-windy (harmattan) seasons, respectively. Erinjiyan Ekiti in conjunction with its surrounding villages and hamlets is one of the 140 towns and villages that make up Ekiti State, fondly called and addressed as the fountain of knowledge". Predominantly, the occupation of the dwellers of this community is primarily peasant farming and small scale agro-allied businesses.

4.1.1.2 Environmental Data

To get an optimum design for the rural community, it was crucial to collect the meteorological data for the site under observation. Erinjiyan Ekiti rural area is highly endowed with various RE potentials. The presence of river basin (river Erin), strong wind current and high sunshine radiation makes it feasible for small hydro power, wind and solar technology in the area. Moreover, the availability of these resources makes the rural area a suitable choice for analysis in this dissertation.

- **Solar Technology Potential**

Solar radiation is fairly well distributed in Erinjiyan Ekiti. According to a survey analysis conducted between 1984 and 2004 by PVGIS and HelioClim-1 (2008) and similar findings published by Iloeje (2004: 6), the annual average of daily solar irradiation is estimated at approximately 4.5 - 5.07 kWh/m^2/day radiating for an average of 5 hours daily. This translates to a total annual realizable solar radiation of about 8.2 X 10^3 kWh of energy per day from the sun.

- **Small-Hydro Power (SHP) Technology Potential**

Erinjiyan Ekiti is also endowed with some presence of river basins, like river Erin which is associated with several historical beliefs. The river is rich in fauna lives and its strong water current provides huge potential for small-hydro power. It is often believed that it is a taboo to consume any fishes originating from this river as marine lives are worshipped by some of the villagers. However, this must be taken into consideration before implementing SHP in this area.

- **Wind Power Technology Potential**

Since Erinjiyan Ekiti is located in the southern area of Nigeria, the total exploitable wind speed at 10m height is assessed at approximately 3.0m/s (Iloeje 2004: 7). Peak wind speeds of 4.5m/s generally occur between April and August for most sites (ECN & UNDP 2005: 16).

4.2 Research Design

The research design provides a logic that links the data to be collected and conclusions that are to be drawn, to the initial research questions of the study (Yin, 2003: 19). The approach and design adopted are deterministic since empirical evidences were used in the course of the analysis. The research design made use of both qualitative and quantitative methods of analysis.

Various studies as conducted by Okoye and Achakpa (2007), Sambo (2005: 16) have shown that the need for RE in rural development ranges from domestic, agricultural production, community, to industrial / commercial needs. In view of this, the scope of this research analysis will be delineated to focus on the domestic needs only.

4.3 Research Techniques

This pertains to specific details used in conducting the research design. Due to constraints such as very large target population size, cost and time involved, it was impractical to conduct the research on the entire rural community. Therefore, only a small subsection of the rural community was selected, researched and surveyed. This subsection includes Ogunna, Igbeyin, Iwaro, Aafin, Aaye, and Oketere settlements of Erinjiyan Ekiti rural area. In order to ensure that the results of the survey were adequately representative, a stratified selection scheme was considered. The selection of these settlements reflected similar range of income and family characteristics. The sampling of households in each settlement was also designed to reflect the wide range of energy users and their different characteristics. Given the dense population and spatial distribution of these settlements, the survey is adequately representative. A sampling layout was prepared to address the following issues;

- CBA framework methodology
- Data requirements

- Population of study
- Sampling unit
- Sampling technique/method
- Sampling frame

4.3.1 CBA Framework Methodology

The methodology used to assess the renewable energy technologies covered in this dissertation is cost-benefit analysis framework (CBA). The CBA framework was conceptualized in the previous chapter, however, in the section that follows all the basic steps and tools used in the analysis are utilized so that one can readily interpret the results. As expressed in the earlier chapter, only three RETs namely: wind, solar and small-hydro power technologies were selected for analysis in Erinjiyan Ekiti rural community.

Since CBA is often referred to as a quantitative technique, a quantitative approach was adopted. For simplicity, the CBA framework was divided into three data streams comprising of: *basic input data, basic control data, and basic output data.*

1) **Basic Input Data**

   The following activities were carried out:

   - Identification of the scope of RE project under review (Erijiyan Ekiti) with emphasis on only wind, solar and small-hydro RE resources. Also in general, power demand analysis of each household and the settlements (Ogunna, Igbeyin, Iwaro, Aafin, Aaye, and Oketere settlements) in Erinjiyan Ekiti must be known.
   - Identification of all costs and benefits involved for each RETs.
   - Valuation of costs and benefits of RETs in monetary terms using contingent valuation method (CVM - for valuing benefits in monetary terms). *Each cost of RETs was valued through Requests for Quotations (RFQ) obtained from RETs consultants while benefits were valued through the use of CVM using survey instruments to gather relevant data for this analysis.*
   - Discounting of costs and benefits over a time frame of 20 years at12.3%.

2) **Basic Control Data** (pertains to the financial analysis of the input data realized in the dissertation):

   The following activities were carried out:

   - Determination of the Net Present Value (NPV) for each of the RETs
   - Determination of the Benefit-Cost Ratio (BCR) for each of the RETs
   - Determination of the Internal Rate of Return (IRR) for each of the RETs under review.
   - Performance of sensitivity analysis.

3) **Basic Output Data:**

   The following activities were carried out:

   - Result analysis, comparisons and decision making.

4.3.2 Data Requirements

Data requirements were identified for solar, wind and small-hydro RETs. In *Annexure B*, the general data requirements needed to conduct CBA for the three RETs in Erijiyan Ekiti are highlighted.

4.3.3 Population of Study

The first step in selecting a study population is to define the target population. Baridam (1990) defined 'target population' as a finite population - with fixed boundaries - described by time, geography and the characteristics of the individual members composing it, as well as the nature of the variables being studied. For the purpose of this dissertation, the target population was identified in the case study design as Erinjiyan Ekiti. The heterogeneity of the population and the sample size can affect the accuracy and robustness of the sampling significantly (Groves, 1989; Salant & Dillman, 1994). Consequently, a sufficiently large and representative sample size is needed for robust statistical inferences to represent a typical rural setting. Therefore, the total sample number was 50 households which were confined to Ogunna, Igbeyin, Iwaro, Aafin, Aaye, and Oketere settlements of Erinjiyan Ekiti. The sample size was chosen from the target population of 10,900 households following a process of non-probability sampling.

4.3.4 Sampling Techniques/Methods

The theoretical objective of the CBA framework is to compare the cost versus the benefits in economic terms while using wind, solar and small hydro technology for rural community electrification.

In order to ensure the selection of a representative sample, Dillman (2000) suggests the necessary principles for a correct sampling frame. There are two known types of sampling, these are: *the probability (or random) sampling* and *the non-probability (or non-random or purposive) sampling.* In this study, a non-probability sampling technique was preferred in selecting the sample. The type of non-probability sampling used is the judgment sampling. Judgment sampling involves guesses, which is subject to the researcher's inference (Millard & Neerchal, 2000: 15). In judgmental sampling the researcher deliberately selects the sampling units that are to be included in the study because he feels they are representative of the target population (Baridam, 1990).

The 50 households in Erijiyan Ekiti were selected for sampling based on the following reasons:

a) It was necessary to select households with similar energy requirements and consumption pattern.
b) Rigorous opinion surveys are not essential.
c) Most data like the meteorological information are readily available and could be retrieved via relevant sources.
d) Respondents should be accessible and generally cooperative.
e) Households are located along the same geographical axis thereby reducing the cost of conducting survey.

It is relevant to mention that this methodology introduces some potential preconceptions and assumptions into the data analysis as it is based on the judgment of the researcher, though explicit but objective.

4.4 Data Collection Method

Data were collected mainly through two methods, namely:

- Primary Sources; and
- Secondary Sources.

4.4.1 Primary Data Collection Methods

The primary data collection method depicts data collected personally during the course of this dissertation. Most of the data required were valuable to the basic input stream of the CBA framework where valuations of the RET benefits in monetary terms were needed. Primary data were sourced with the following objectives in mind.

- To establish the current energy pattern and distribution in the rural community.
- Understand the income status of the rural dwellers.
- Ascertain if the influx of RET will influence the way of life of the rural dwellers.
- To gather individual welfare estimates from the target population under review i.e. to determine people's *Willingness to Pay (WTP)* the RETs with respect to the environmental benefits it will proffer using contingent valuation.

The last objective is by far the most important to bear in mind, where the data gathered were aggregated to determine the monetary value of the RETs benefit to the whole target population whose environment or other externalities were of great concern i.e. the mean WTP. After examining the aggregate monetary value of benefits in accordance with changes in the environment for valuation, an aggregate demand curve was developed.

To achieve the set objectives, it was crucial to choose a proper survey instrument to gather enough accurate information from each respondent. There were several options available, namely: observation, personal interviews, questionnaire survey, telephone interview, and a mail survey.

Due to the remoteness of this area, it was impractical to conduct either telephone interview or mail survey. Also, conducting personal interviews will raise some ethical issues such as the validity of data, etc.

In view of this, a strong rationale exists to use both *observation* and *questionnaire survey* methods because of their efficacy against responding to socio-economic questions and more so, they are often efficient instrument that cover a large sample area within a short time frame.

4.4.1.1 Questionnaire Survey Approach

A questionnaire survey instrument was adopted to carry out a proper contingent valuation. The aim of the contingent valuation is to measure the compensating or equivalent variation for the three RETs under review with a view to value their benefits.

In conducting this survey, focus was given to each respondent's "*WTP*" for improvement or degradation in the quality of their lives and environment if any of the three RETs was to be implemented. Paper questionnaires were distributed amongst each of the 50 households with a view to obtain the welfare profile of each respondent (household).

4.4.1.1.1 Structure of the Questionnaire Survey Instrument

The household questionnaire includes four sections with focus on:

- General information about each household;
- Status of household energy demand and usage;
- Energy systems that each household is currently using; and
- Query respondents about their Willingness to Pay (WTP) for the proposed RETs plan. Information about each household attitude towards renewable energy options was surveyed. Since household is the unit of analysis, the reference income of the entire household was considered, rather than the respondent's income.

The questionnaire also concentrated on several areas such as:

- General demographic information;
- Aggregate economic and financial statistics;
- Household income levels and distribution;
- Existing energy and if electricity exist, to what extent.

The household questionnaire instrument template is reproduced in entirety in *Annexure C.*

4.4.1.2 Observation Approach

Observation allows the observer to investigate aspects of the project directly, through his involvement in project operations. The following factors were considered in the approach to observation

a) *Identification of who or what, to observe, when and for how long:* Direct or reactive observation was carried out on the target sample of 50 households belonging to Ogunna, Igbeyin, Iwaro, Aafin, Aaye, and Oketere settlements at Erijiyan Ekiti, together with their responses to the implementation of RETs in their community. An observation of the target sample took place between February 2008 and August 2008 on various research project field trips. Particular attention was given to:

- The current energy mix per household.
- Duration of energy use.
- The energy pattern of each household.

b) *Observation Equipment:* The following materials were used in each field trip observation:

- *Writing pad, pens, pencils, and highlighters* for taking observation notes
- *Interview questionnaires* for carrying out the actual survey.

4.4.2 Secondary Data Collection Methods

Most secondary data came largely from meteorological and environmental sources. Some data such as price information of RE equipment were also gathered through R*equest for Quotations* (RFQ) from RETs companies which are relevant for data analysis in this research.

4.5 Reliability and Validity of Survey Instrument

This is a non-statistical type of validity that involves systematic examination of the test content to determine whether it covers a representative sample of the behavior domain to be measured.

To ensure reliability and validity of the survey questionnaire, a first draft of the survey was developed and the contents were pre-tested by a panel of experts and professionals. This panel consisted of:

- Mr. Lucky E. Amorighoye: is a qualified and practicing Engineer working for Chevron Nigeria Limited, Escravos Gas to Liquids Project, Nigeria.
- Mr. Adebayo O. Ogunlade: a seasoned researcher at the North-West University, Potchefstroom, South Africa.
- Mr. Bruce E. Hokin: a global consultant on Cost-Benefit Analysis (CBA) in Australia. Mr Hokin Bruce has published several books on the concepts of CBA.
- Prof. I. E. Owolabi: a fellow member of the Institution of Engineering and Technology (IET), also a fellow member of the Nigerian Society of Engineers (NSE). He presently lectures at the University of Ado-Ekiti, Nigeria.
- Engr. Dr. Ayodele A. Esan: the regional Technical Director and CEO of UNIDO Small Hydro Power in Africa.
- Ms. Olamide O. David: is a Researcher at the University of Leeds, Leeds, United Kingdom.
- Dr. Prudence L. Tau: is a Senior Scientist with the Research and Development, Sasol Technology, Sasolburg in South Africa.
- Dr. Ibiyinka Ogunlade: She is presently a Senior Lecturer at the University of Ado-Ekiti, Nigeria. She has worked on several research projects in Nigeria and United Kingdom.

Their comments and reviews were solicited through e-mails and oral communication. Feedback and recommendations were adopted and survey contents were modified accordingly. Based on their remarks, a final draft copy of the questionnaires was finally developed for a pilot test.

In developing the questionnaires, adequate care was taken to ensure:

- Questions were written in a straightforward, direct language that is not caught up in complex rhetoric or syntax, or in a discipline's slang or lingo. Questions were specifically tailored for a group of respondents.
- Questions were kept short and simple. It was assumed that respondents should not be expected to learn new, complex information in order to answer questions.
- Questions were not overly personal or direct, this was to avoid respondents having a misconception that their privacies are being intrigued.
- Anonymity of respondents was ensured by asking respondent to use only their initials. This was to ensure that confidentiality of the respondent is guaranteed.

4.5.1 Pilot Survey

The last phase of validation was conducted through a pilot survey. The survey was administered amongst some few Chevron employees to test their understanding on the contents of the questionnaires. Their comments and feedback were used to amend the survey instrument accordingly.

4.6 Chapter Summary

In this chapter, the methodology and empirical investigation underlying this research were explicitly outlined. In addition, the research design provides a useful guideline which was used to effectively collect data, and also identifies an approach to analyzing it.

In conducting the CBA framework, both qualitative and quantitative research methodologies were adopted and described as the most appropriate approach to analyze real-life rural RET project. The conceptual framework extends the traditional CBA methodology. Foremost the functional requirements of both cost and benefit in the conceptual CBA framework are identified for the selected rural community. The project scope focuses only on the three RE resources namely: wind, solar and small hydro energy.

Secondly, a Contingent Valuation Method (CVM) technique was adapted to value RE benefits by querying respondents' Willingness to Pay (WTP) for each of the RETs. Fifty households WTP information were collected through a thorough questionnaire survey approach. In conducting CVM survey, individuals were asked what they will be willing to pay in exchange for a RET. The questionnaire approach goes directly to elicit individual welfare profile and valuation of RET. In addition, cost and benefit data are compared to determine the viability of each RETs using a three financial criterion of CBA namely: Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR). Subsequently, comparisons are made for decision purposes.

The next chapter focuses on the analysis and discussion of results of this dissertation.

Chapter 5

Interpretation of Results and Findings

This chapter presents the findings obtained from the research, by setting out the results of the rural households' questionnaire surveys to determine their total energy requirements and willingness to pay for RE. The comparative CBA results of the three REs (wind, solar and small-hydro power) are presented and discussed.

5.0 Introduction

This dissertation is designed to provide an economic comparison across a range of RET scenarios for rural development in Nigeria using a conceptual CBA framework. A rural site located in Nigeria, namely Erinjiyan Ekiti, was selected in the case study design to exhibit the working methodology of this framework.

Commentary bordering on the analysis of the questionnaire survey is discussed and the total willingness to pay for RE in the surveyed community will be extrapolated. This chapter also discusses the outcome of each financial decision tool of NPV, IRR and BCR.

The conceptual CBA framework was transformed into a simulation tool, an excel workflow spreadsheet, that can aid accurate and easy interpretation of data.

Finally, the limitations of utilizing the CBA framework for RETs are presented.

5.1 Techniques for Data Analysis and Interpretation

Different approaches were used for presentation, interpretation and analysis of data. The procedures adopted in analyzing the data on RETs for Erinjiyan Ekiti rural area in Nigeria are as follows:

a) Firstly, the primary data derived from the administered questionnaires were analyzed by a statistical software known as the Statistical Package for Social Sciences (SPSS). This package would assist in extracting data to determine:

- General information about each household;
- Current status of each household energy demand, usage and systems in order to provide adequate data for power demand analysis of the rural area;
- Respondents' Willingness to Pay (WTP) for the proposed RETs plan. The purpose of this approach is to obtain monetary value of RE benefits.

b) Secondly, electrical energy demand for the rural community was determined to ascertain the capacity sizing of each RETs under consideration.

c) Thirdly, a financial analysis was conducted using the conceptual CBA framework in order to assess each of the RE options for economic validity. The three decision criteria or hypotheses that were utilized are the NPV, BCR and IRR. The CBA framework concept was formulated into an excel spreadsheet simulation tool or template to aid in the accuracy, automation and quicker computation of data.

d) A comparative review of the outcome of each of the RE options is presented.

5.2 Questionnaire Survey - Analysis Results

A Contingency Valuation Method (CVM) questionnaire survey was conducted on the rural community of Erinjiyan Ekiti in Nigeria. The aim of the study was to assess the current energy consumption pattern and usage of the rural dwellers as well as determine their willingness to pay for RETs, if implemented in their community. The outcome of the survey is crucial in determining the monetary value of RET benefits in the overall structure of the proposed CBA framework.

The survey was aimed at a total sample size of 50 households; however, 42 household respondents successfully completed a fill-in questionnaire survey template. This figure represents a satisfactory response rate of 84% upon which conclusions, interpretations and inferences could be drawn.

Data were collected from individual survey instrument for each household, based on the survey objectives iterated in the previous chapter. The data collected were synthesized and interpreted in a format comprehensible by the SPSS software for preliminary statistical analysis. Annexure D captures the data in its entirety as extracted from survey questionnaires feedback.

5.2.1 Mean (SD) Characteristics of Household Respondents

In Table 5.1, a distribution of the surveyed rural population between the ages of 8 – 88 is presented. Key background characteristics presented alongside this population includes – age, educational level, occupation, household population, annual household income and annual household expenditure.

Table 5.1: Background Characteristics of Household Respondents

Descriptive Statistics						
Gender		N	Mean ($\bar{x}$)	Std. Deviation	Minimum	Maximum
Male	Age	35	48.7143	19.74331	8.00	88.00
	Educational Level	34	4.3824	1.87511	1.00	6.00
	Occupation	33	2.7576	1.11888	0.00	5.00
	Household Population	35	9.4286	6.05992	4.00	24.00
	Annual Household Income	35	₦575,948.57	5.74033	₦3000.00	₦3,000,000.00
	Annual Household Expenditure	35	₦439,990.00	4.63374	₦38,650.00	₦2,300,000.00
Female	Age	7	30.2857	21.06905	13.00	56.00
	Educational Level	7	4.0000	2.08167	1.00	6.00
	Occupation	7	3.1429	1.86445	1.00	6.00
	Household Population	7	5.2857	3.19970	4.00	10.00
	Annual Household Income	7	₦239,285.71	1.92493	₦0.00	₦500,000.00
	Annual Household Expenditure	7	₦124,857.14	1.73166	₦24,000.00	₦500,000.00

The table shows that a sizeable proportion of respondents have attended at least a senior middle school, thus reflecting the literacy level of the rural people of Erinjiyan Ekiti. The same however cannot be said about the income status of the respondents as it is not evenly distributed for both men and women. The average annual household income for men is estimated at ₦575,949.00 and women at ₦239,286.00. The difference can be attributed to a larger household population ascribed to men eliciting them to receive more income from multiple sources. Men alone are responsible to care for more than 9 members in an average household setting, whereas, women account for just an average of 5 households.

5.2.2 Energy Consumption Pattern

5.2.2.1 Energy Supply Mix

Findings from the survey analysis revealed that variation exists in the energy mix and consumption pattern of the rural community. The result of the analysis discloses that electricity from the national grid forms nearly 23% of the entire energy composition of the rural people, while kerosene fuel accounts for another 23% of domestic energy consumption. About 33.33%

of various energy blends are consumed annually together with diesel (14.29%) and others (2.38%). Fig. 5.1 typifies the current energy composition and consumption pattern as obtained from the respondents.

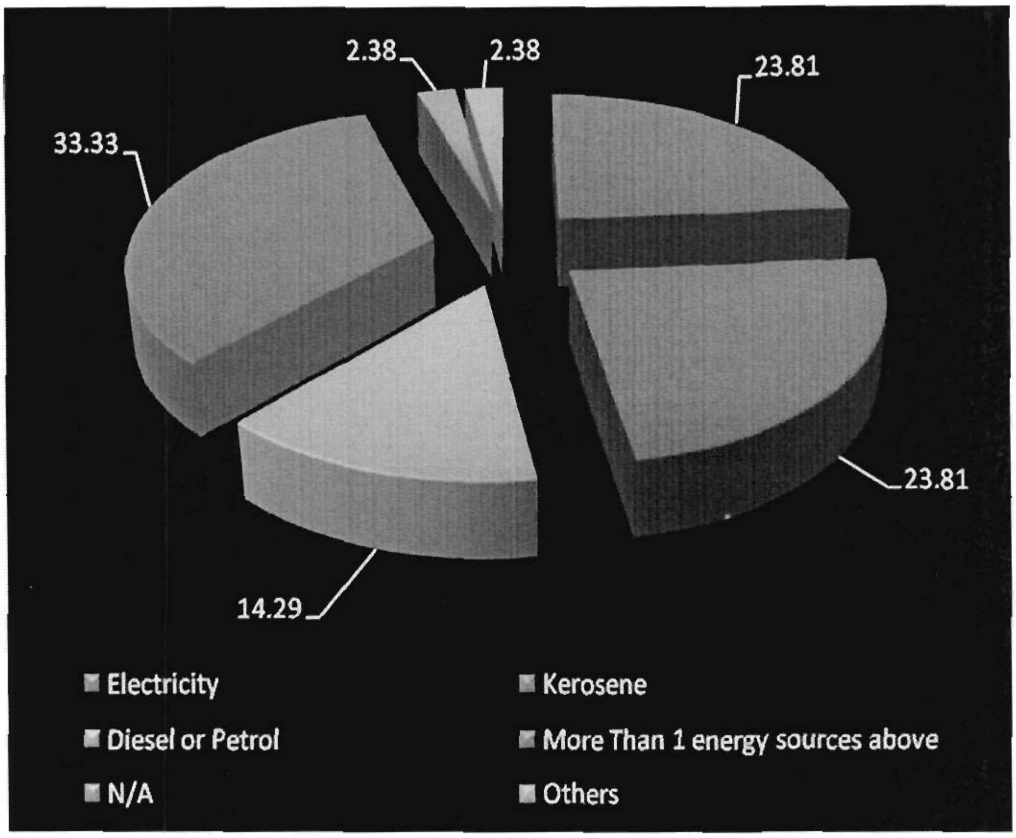

Figure 5.1: Energy consumption pattern of Erinjiyan Ekiti rural area, Nigeria

5.2.2.2 Household Cooking Energy

The analysis on the cooking energy pattern of the household respondents is even more revealing. Fig. 5.2 shows the analysis of the cooking energy profile of the entire household respondents. Firewood was found to be the predominant energy source for cooking, accounting for 50% of the entire household respondents' cooking energy source. This further confirms the findings of Akinbami (2001) that Nigeria's energy mix is made-up of two major splits, essentially hydroelectricity (3.05%) and traditional fuel wood (50.45%). Kerosene (20%) and gas (20%) are the second most used energy sources for cooking by the respondents. Kerosene is also used in lanterns for lighting purposes. The predominant type of lantern used is the wick-type that produces a bad level of luminosity.

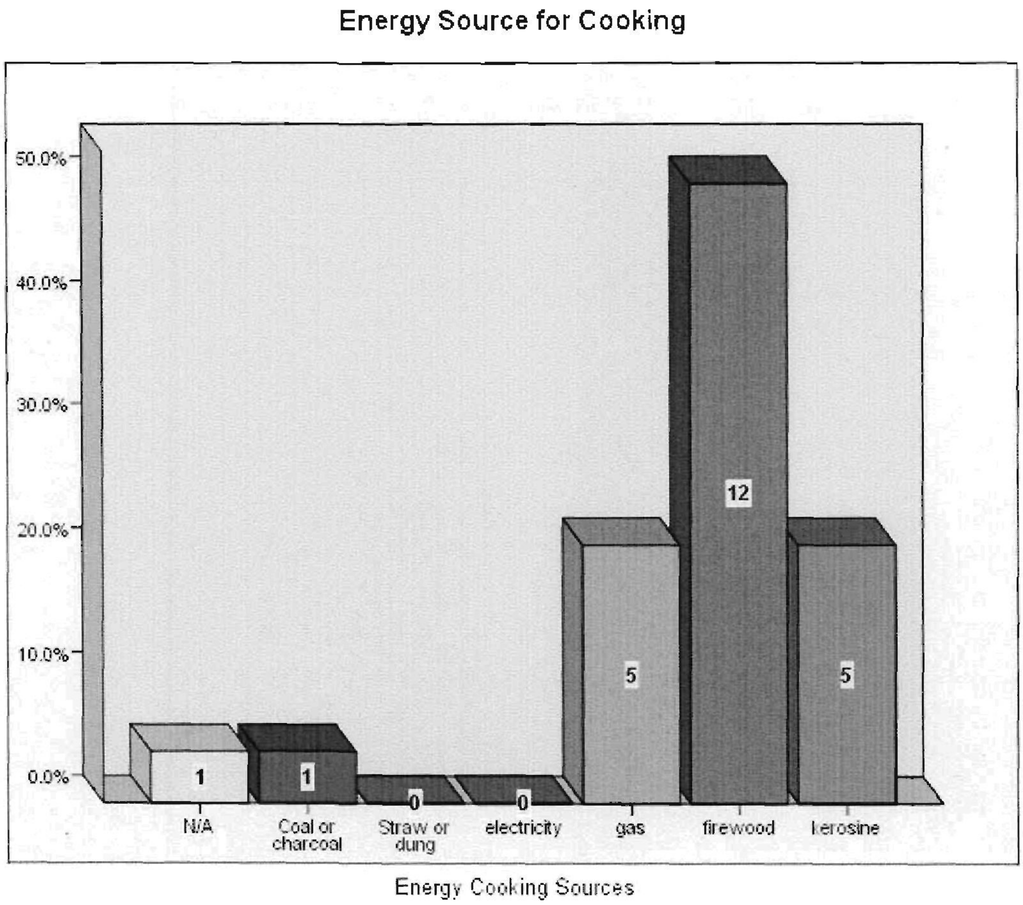

Figure 5.2: Cooking energy profile of household respondents

5.2.2.3 Inefficient and Unreliable Energy Supply System

There is a serious problem of power unreliability over the years such that most upper income households install expensive generating sets amounting to over half of the total installed grid capacity. A survey conducted on Erinjiyan Ekiti rural area to determine the quality of their power supply has shown that, nearly 83.7% of the respondents are not satisfied with the quality of electricity supply to their community. In the same vein, 97.7% indicated that the respondents enjoy poor quality energy supply in general. Table 5.2 summarizes the opinion polls of the household respondents on the quality of energy supply to them.

Table 5.2: Opinion polls on the quality of energy supply to household of Erinjiyan Ekiti

Descriptive Statistics					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Electricity Users	Male	32	86.5	86.5	86.5
	Female	5	13.5	13.5	100.0
	Total	37	100.0	100.0	
Non-Electricity Users	Male	3	75.0	75.0	75.0
	Female	1	25.0	25.0	100.0
	Total	4	100.0	100.0	
N/A	Female	1	100.0	100.0	100.0
Quality of Electricity Supply					
Valid	N/A	6	14.0	14.3	14.3
	Not satisfied	36	83.7	85.7	100.0
	Total	**42**	**97.7**	**100.0**	
Missing	System	1	2.3		
Quality of Energy Supply					
Valid	Not satisfied	41	95.3	97.6	97.6
	I do not care	1	2.3	2.4	100.0
	Total	**42**	**97.7**	**100.0**	
Missing	System	1	2.3		

The major factors contributing to unreliability and inefficiency can be attributed to:

- Frequent breakdown of generating plants and equipment due to inadequate maintenance and poor repairs;
- Lack of foreign exchange for timely purchase of needed spare parts;
- Obsolete transmission and distribution equipment which frequently breakdown;
- Lack of skilled manpower; and
- Many industries render inefficient services to the power sector.

5.2.3 Energy Demand Analysis

The electrical energy demand analysis depicts the estimated RE required to supply the rural household community in a sustainable way. This is achieved by benchmarking on the current and previous energy consumption profile of each household respondent.

The household sector as published by Oladosu and Adegbulugbe (1994) has consistently accounted for over half of Nigeria's total domestic energy consumption. The energy consuming activities in the sector are cooking, lighting and operation of electrical appliances (non-substitutable electricity). Further studies conducted by Sambo (2005: 16), Okoye and Achakpa (2007), have also shown that, the need for RE in rural development ranges from domestic, agricultural production, community, to industrial / commercial needs.

Consequently, the energy analysis in this dissertation was designed based on the view point of domestic needs of the household respondents, with specific interest in home lighting, one television set and radio energy requirements. The scope of the energy demand analysis covered was restricted to the sample size of 50 households as iterated in chapter 4. Several factors were taken into consideration while determining the system requirements, namely:

a) The energy consumption pattern of the rural household respondents;
b) The estimated daily electricity demand of each household;
c) The total load demand of the entire household respondents (in Watts);
d) Material cost implications such as inverter system module and battery storage sizing (solar PV array, turbine).

The energy consumption profile of the community as indicated in Fig. 5.2 has shown that a greater portion of energy is consumed through daily use of traditional fuel wood or firewood (cooking) and kerosene fuel (lantern for lighting).

The majority of the houses found in the rural areas of the Erinjiyan Ekiti were constructed with the intent of low electrical energy requirements, which are only needed for lighting and operation of small electrical appliances. Moreover, the likely daily energy demand was estimated based on the outcome of the survey on energy consumption pattern that was obtained from each household respondent. In view of this, the following energy requirements were projected for each household as shown in Table 5.3.

Table 5.3: Load demand analysis per household (CBA simulation tool for RETs).

Load Demand Statistics				
Home Energy Requirements	**Power Rating (W)**	**No of Units**	**Hrs / Day**	**Total Energy Demand / Day (Wh)**
Florescent Bulb for Light (AC)	8 watts	2	6	96 Wh
Television (AC) – B/W	20 watts	1	3	60 Wh
Radio (AC)	8 watts	1	4	32 Wh
Total Load demand / Household	**36 watts**	**4**	**-**	**188 Wh**
Total Load Demand for 50 households				**9400 Wh**
Drinking water motor + Pump [*]	860 watts	1	3	2580 Wh
Total Load Demand for the entire Household Respondents				**11980 Wh**

[*]Water pump sizing was obtained based on deductions made from the outcome of the survey conducted. Assumptions were also made in calculating the load demand for the community drinking water pump. The basic assumptions made are as follows:

Each household utilized an average of 60 liters of water daily. Therefore, the 50 households under review will require approximately 3000 liters/day or 700 gallons of water daily. Equation 5.1 represents the formula used in obtaining the pump size in terms of electrical power rating, (P_e):

$$P_e = \frac{\rho \times g \times h \times Q}{\eta_p \times \eta_m} \quad \text{......} \blacktriangleright \quad 5.1$$

- Water level depth = 30 m
- Height of storage tank from ground level= 3.5 m
- $g = 9.81\ m/s^2$
- h = 33.5 m (the height *h* includes the depth of water level underground + the height of the storage tank above the ground level)
- $Q = 1\ m^3/h$ (water discharge rate)
- η_p = 45% or 0.45 (pump efficiency)
- η_m = 85% or 0.85 (motor efficiency)

- $\rho = 1$ kg/L (water density)

$$P_e = \frac{1 \times 9.81 \times 33.5 \times 1}{0.45 \times 0.85}$$

$$P_e = 860\ W_p$$

Consequently, based on the analysis of table 5.3, the daily total peak load demand of electricity for the rural settlement is estimated at 11.98 kW, which is equivalent to 287.52 kWh of electricity consumption. The RE capacity size will be designed for 20 kW of energy per day (480 kWh) to forecast and cater for power growth demand.

5.2.4 Willingness to Pay analysis of RET in Erinjiyan Ekiti

Willingness to Pay (WTP) as defined by Quan (2004: 41) is the maximum amount of money which can be paid by an individual to enjoy a certain service or amenity. WTP is a key procedure necessary in the Contingent Valuation Method (CVM), that is required in the CBA framework to value benefits of RE in monetary terms. The approach as stipulated in equation 3.8 and 3.9 expressed that, the Mean WTP (MWTP) responses of all the household respondents must first be aggregated, then the Total WTP (TWTP) for RE can be calculated and computed as the benefit in monetary value for the respondents. The mean WTP was calculated based on the expression of equation 3.8 as shown below:

$$MWTP = \frac{1}{n}\sum_{i=1}^{n} y_i$$

A survey was first carried out to query respondent's interest in RE. Result has shown that about 97.6% of the respondents expressed their interest to pay more for electricity, if a reliable service was guaranteed. Consequently, the survey also pries to determine the respondents' monthly WTP for RE system, if implemented. Table 5.4 illustrates the outcome of the WTP survey obtained from the household respondents.

Table 5.4: Total WTP and mean WTP of respondents per month

Descriptive Statistics			
Willingness to Pay (WTP) Variable (₦)	**Solar PV** n	**Wind Turbine** n	**Small Hydro Power** n
N/A	0	0	0
3000	15	2	3
5000	13	1	1
10000	6	0	1
15000	2	0	0
20000	0	0	0
25000	0	0	0
Mean WTP	**₦3,888.88**	**₦3,666.66**	**₦3,500.00**
Total WTP for N respondents per month	**₦194,444.00 or $16619.17**	**₦183,333.00 or $1566.94**	**₦175,000.00 or $1495.72**

Where:

n = population WTP for a particular type of RET

N = population size affected by the proposed RET implementation

$1 = ₦117.00

It is necessary to emphasize that some basic assumptions were made in the interpretation of individual respondent's WTP. The first assumption made was equating each WTP variable to its maximum limits. For instance, if a respondent was willing to pay 'less than ₦3000.00' monthly for any of the RETs, then the value will assume the maximum limit value of '₦3000.00'. Table 5.5 summarizes the assumption made in the WTP variables scale.

Table 5.5: Assumed WTP for RE in Erinjiyan Ekiti

Willingness to Pay (WTP) Variable (₦)	Assumed Willingness to Pay (WTP) Variable (₦)
N/A	N/A
Less than 3000	3000
3001 - 5000	5000
5001 - 10000	10000
10001 - 15000	15000
15001 – 20000	20000
More than 20000	25000

Furthermore, the total monthly WTP was obtained by multiplying the mean monthly WTP by **N**, the population size affected by the proposed RET implementation.

5.3 Cost-Benefit Analysis of RE in Erinjiyan Ekiti Rural Area

This section discusses the result of CBA of RE in the surveyed rural community in Erinjiyan Ekiti rural area. The outcome will be compared to determine if it fulfils the three CBA decision criteria. The three RET options that were assessed are solar PV, wind turbine and small-hydro power respectively.

In order to aid in the accuracy and automation of the analysis, CBA simulation tool that was formulated and developed was utilized. The usability of the CBA simulation tool will be delved into, later in the chapter.

All the different cost elements required for the three RETs were sourced and obtained from the following RE consultants:

- **SUZHOU YUENIAO Machinery & Electronics Imp & Exp Co. Limited, China** (http://www.yueniao.com) – Small-hydro power (SHP) price quotes.
- **ENERGOTECH SA, Greece** (http://www.energotech.gr) – Wind turbine and solar PV price quotes.

- **BEB BioEnergy Berlin GmbH** (China office in Chengdu) (http://www.bebgmbh.cn)

A different approach was however used to obtain monetary variables for benefits. The first element of benefit was derived from the total WTP values of the respondents since total WTP constitutes a monetary value placed on the perceived service the respondents are likely to benefit from RE. The second element of benefit was employed using emission reduction approach, the cost of carbon-dioxide (CO_2) emission saved from RE against the base method (fossil fuels) of electricity generation to the community. According to the DEFRA guidelines (1995), the following expression is valid for determining CO_2 emission in tonnes:

CO_2 emissions (tonnes) = energy consumption (kWh) x Emission Conversion factor ($kgCO_2$/kWh) x 0.001

Where:

- Energy consumption (kWh) = 480 kWh
- Emission Conversion factor = 0.43 $kgCO_2$/kWh – For Nigeria, using marginal generation factor (NEF, 2008).

CO_2 emissions (tonnes) = 480 kWh x 0.43 $kgCO_2$/kWh x 0.001

CO_2 emission = 0.2064 tonnes CO_2 per day

A recent article published by Tol (2005), estimated the best estimation for marginal costs of CO_2 emission is \$5/tonne, representing a cost estimate of \$1 *(\$5/tonne x 0.2064)* saved daily for RE usage on every 480 kWh of energy consumed daily. In view of this, a marginal cost saving of approximately \$1 per day on CO_2 emission will be used as the second variable of benefit. Table 5.6 captures the cost breakdown of the three RETs in its entity as it was fed into the CBA simulation tool for analysis.

Table 5.6: Cost breakdown of RETs (solar PV, wind turbine and small-hydro power)

Base Case Option	
Capital Cost (in \$)	
Connection cost to the National Electricity Grid (NEPA)	N/A
Electricity meter (Ownership cost)	N/A
Backup alternative power supply (due to unreliable electricity grid)	N/A
Operation and Maintenance Cost (in \$)	
Backup alternative power supply (Annual Operation and maintenance cost)	N/A

Benefits	
Annual Willingness to Pay	N/A
Solar PV Option	
Capital Cost (in $)	
Bifacial photovoltaic panels with nominal power 20 kW, inverter 24V/230V with nominal power 2,5 kW and integrated battery charger	**$98,824.75**
Sealed gel rechargeable batteries 240V/500Ah (20 pieces of 12V/500Ah) [a]	**$41,662.08**
Operation and Maintenance Cost (in $)	
Replacement cost for Inverter	**N/A**
Replacement cost for Battery	**N/A**
Annual maintenance cost (1% of capital cost)[b]	**$1,404.86**
Benefits	
Annual willingness to pay for solar PV	**$19,942.97**
Annual CO_2 emission saved on solar PV	**$371.52**
Wind Turbine Option	
Capital Cost (in $)	
Wind generator with nominal power 20,0 kW, rated voltage 360 V, rotor diameter 10,0 m, fiber glass blades, free stand tower with height 18,0 m, with integrated sine wave inverter and battery charger [a]	**$41,517.42**
Maintenance free, deep cycle sealed gel rechargeable batteries 360V/600Ah (30 pieces of 12V/600Ah) [a]	**$41,662.08**
Operation and Maintenance Cost (in $)	
Replacement cost for inverter	N/A
Replacement cost for battery	N/A
Annual maintenance and operation cost (1.5% of Capital Cost)[c]	**$1247.69**
Benefits	
Annual willingness to pay for wind turbine	**$18,803.38**
Annual CO_2 emission saved on wind turbine	**$371.52**
Small Hydro Power Option	
Capital Cost (in $)	
XJ30-20SCTF4/6-Z Yueniao high head micro hydroelectric generator, water head 30-45m, From 60 to 80 litres of water flow, 20KW/3phase, inlet pipe diameter of 250-300, 80x60x62cm, 60kg [d]	**$9,079.00**
PVC pipes [e]	**$2050.00**
Transmission lines and cables (1 km length) [e][f]	**$1360.00**
Civil construction cost [e]	**$4,339.80**
Installation cost [e]	**$5,786.40**
Operation and Maintenance Cost	
Replacement cost	**N/A**
Annual Maintenance cost (4% of total project costs)[f]	**$904.61**
Benefits	
Annual willingness to pay for small-hydro power	**$17,948.71**
Annual CO2 emission saved on small-hydro power	**$371.52**

[a] ENERGOTECH SA, Greece (http://www.energotech.gr)
[b] Annual Operation and Maintenance cost is expected to cost 1% of the total installed costs (http://en.wikipedia.org/wiki/Photovoltaics)
[c] Annual Operation and Maintenance cost is expected to cost 1.5% of the total installed costs (http://www.windpower.org)
[d] SUZHOU YUENIAO Machinery & Electronics Imp & Exp Co. Limited, China (http://www.yueniao.com)
[e] BEB BioEnergy Berlin GmbH(China Office in Chengdu) (http://www.bebgmbh.cn)
[f] Williams (2008).

5.3.1 Decision Criteria or Test for Hypothesis

The core premise upon which the proposed CBA framework for RET is laid is based on three decision criteria, namely: Net Present Value (NPV), Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR). Analysis of the proposed CBA will be assessed with a view to provide a strong decision rationale to an investor. An investment lifecycle of 20 years was used for the RET options under review. Each decision criterion explores a three point scale for result interpretation as explained below.

5.3.1.1 Decision Criteria 1

The Net Present Value **(NPV)** depicts the total Present Value (PV) of a time series of cash flows. NPV is a standard method for using the time value of money to appraise long-term projects (Lin & Nagalingam, 2000). The expression in equation 3.5 is valid in calculating NPV. Table 5.7 summarizes decision criteria 1 with the NPVs in various situations.

Table 5.7: Decision criteria 1, net present value (NPV)

If...	It means...	Then...
NPV > 0	the RE investment is "VIABLE'	the RE project may be accepted
NPV < 0	the RE investment is 'NOT VIABLE'	the RE project should be rejected
NPV = 0	the RE investment would neither gain nor lose value for the firm	We should be indifferent in the decision whether to accept or reject the RE project. This project adds no monetary value. Decision should be based on other criteria, e.g. strategic positioning, intangible benefits or other factors not explicitly included in the calculation.

5.3.1.2 Decision Criteria 2

A Benefit-Cost Ratio (BCR) as defined in Wikipedia (2008b) is the ratio of the benefits of a project or proposal, expressed in monetary terms, relative to its costs, also expressed in monetary terms. Equation 3.6 in chapter 3 is applicable for determining BCR. Table 5.8 shows decision criteria 2, the BCRs in various situations.

Table 5.8: Decision criteria 2, benefit-cost ratio (BCR)

If...	It means...	Then...
BCR > 1	the RE investment is 'VIABLE'	the RE project may be accepted
BCR < 1	the RE investment is 'NOT VIABLE'	the RE project should be rejected
BCR = 1	the RE investment would neither gain nor lose value for the firm	We should be indifferent in the decision whether to accept or reject the RE project. This project adds no monetary value. Decision should be based on other criteria, e.g. strategic positioning, intangible benefits or other factors not explicitly included in the calculation.

5.3.1.3 Decision Criteria 3

Internal Rate of Return (IRR) depicts the discount rate that, when applied to its future cash flows, will produce a NPV of precisely zero (Atrill & McLaney, 2006: 348). In calculating IRR, equation 3.7 was used. For interpretation, IRR compares its value with the prevailing interest rates. Table 5.9 shows decision criteria 3, the IRRs in various situations.

Table 5.9: Decision criteria 3, internal rate of return (IRR)

If...	It means...	Then...
IRR > i	IRR exceed prevailing interest rates (discount rates), the RE investment is 'VIABLE'	the RE project may be accepted
IRR < i	IRR is less than prevailing interest rates (discount rates), the RE investment is 'NOT VIABLE'	the RE project should be rejected
IRR = i	IRR is equal to prevailing interest rates (discount rates), the RE investment would neither gain nor lose value for the firm	We should be indifferent in the decision whether to accept or reject the RE project. This project adds no

		monetary value. Decision should be based on other criteria, e.g. strategic positioning, intangible benefits or other factors not explicitly included in the calculation.

Note:

i, denotes the prevailing interest rate (discount rate). In this dissertation, 12.3% is used as Nigerian discount rates (Central Bank of Nigeria, 2008).

It is somewhat laborious to deduce the three decision criteria by hand. Fortunately, the three hypotheses or decision criteria were built into the *'Cost-Benefit Analysis simulation tool for RETs'* Microsoft Excel function for ease and precision in computation.

5.3.2 Comparative Review of CBA results

Based on the daily base load of 480 kWh per household per day, 20 years of service life of RE systems; and discount rate of 12.3%, Table 5.10 summarizes the CBA findings on Erinjiyan Ekiti:

Table 5.10: Comparative CBA result of RE in Erinjiyan Ekiti

Economic Parameters	Solar PV Option	Wind Turbine Option	Small Hydro Option
Present Value of Total Cost at 12.3%	$152,190.95	$93,574.21	$30,151.66
Present Value of Total Benefit at 12.3%	$169,243.42	$159,749.31	$152,628.91
Net Present Value (NPV)	$17,052.47	$66,175.09	$121.477.25
Benefit-cost ratio (BCR)	1.11	1.70	5.06
Internal Rate of Return (IRR)	15%	27%	335%
Payback Period	14 years	6 years	1 year
Comments	RE project Viable	RE project Viable	RE project Viable
Ranking	**3rd**	**2nd**	**1st**

Clearly, it can be seen that from an investment point of view, all the three RE options satisfied the economic viability of all the decision criteria of CBA. Of the three RE options, small-hydro power (NPV $121,477.25, BCR 5.06, IRR 335%) is by far the most viable of having a payback period of just one year. However, some further consideration may be required before making a final decision. History of Erinjiyan Ekiti rural area has shown that small-hydro power option might not be the most viable option after all. Studies on Erinjiyan Ekiti revealed the existence of historical ancestral belief, associated with the only feasible river for small-hydro power application. This belief is connected with the rural traditional worshippers who exploit the river as a medium of spiritual cleansing and communication with their ancestors. As a result, signifying that in conducting a CBA study, all intangible benefits relating to the impact of RE projects in an area must be thoroughly thought through and evaluated.

Consequently, sensitivity analysis conducted on all the RE options has shown that only solar PV option is marginally viable. A discount rate of 17% proves that solar PV will give a Net Present Value (NPV) of -$15,158.20 and Benefit-Cost Ratio (BCR) of 0.9. Fig. 5.3 reproduces in details, CBA computation as captured by the *CBA simulation tools for RETs*.

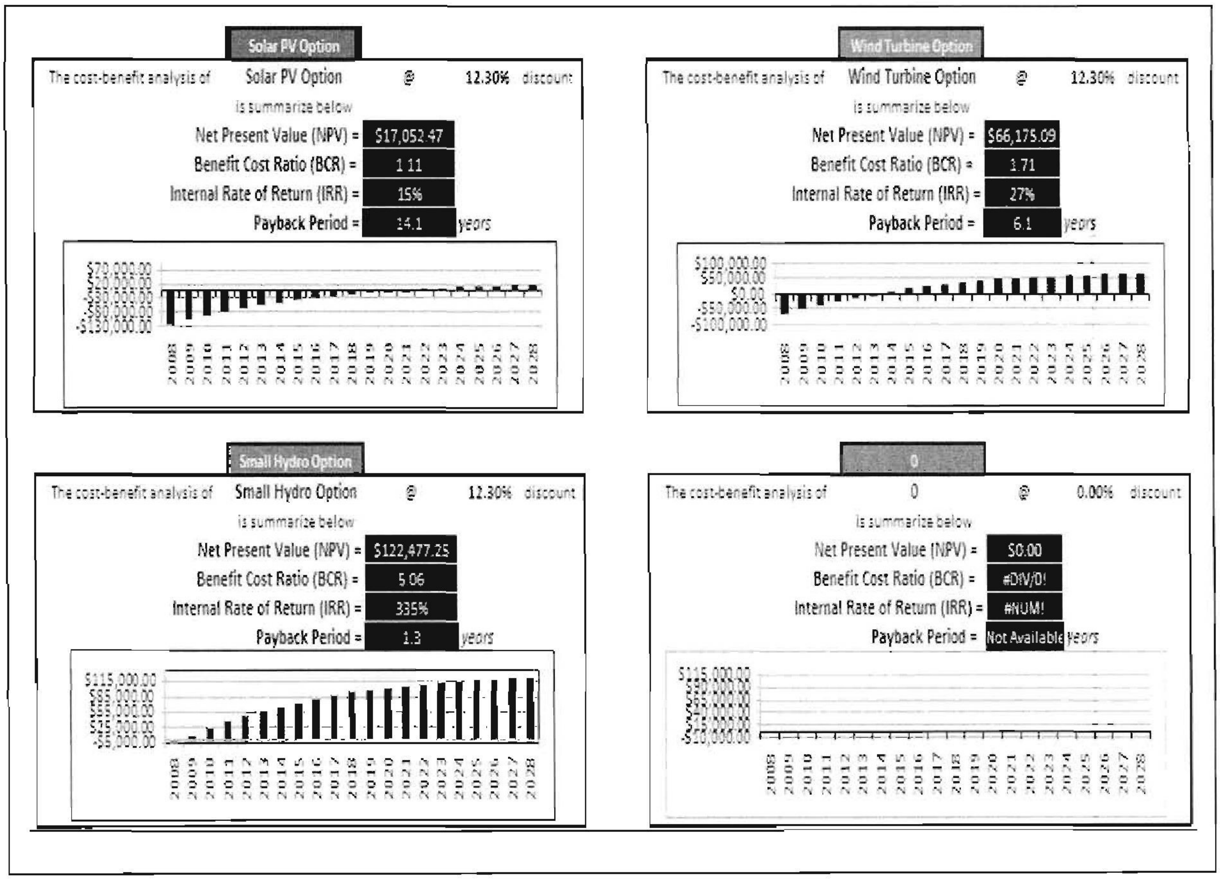

Figure 5.3: CBA summary of RET in Erinjiyan Ekiti (CBA simulation tool for RETs)

Wind turbine option remained economically stable, even with a higher discount rate. But a change in the weather condition could easily mitigate the advantages of this option.

It is obvious that small-hydro power is attractive for Erinjiyan Ekiti rural area, because there is a river that has exploitable features. For any other rural community area in Nigeria, there might not be such rivers, and wind profiles may also not be favorable. Solar devices can be installed anywhere as a result of abundant sunshine in the tropics. In spite of its high cost of implementation, solar may thus end up being the most viable alternative for most rural application in Nigeria.

5.4 Validation of Results

A similar scenario where a CBA study was conducted comparable to the instance used in this dissertation could not be established. Therefore, in an attempt to validate the conceptual CBA framework, a case study approach was employed where Erinjiyan Ekiti rural community in Nigeria was selected to verify the working methodology of the framework.

The first stage that elicits the validity of the framework is the procedure adopted in obtaining results from the survey instrument which was explicitly outlined in the previous chapter. Further results obtained from the economic model suggest that the framework can indeed be trusted. To ensure thoroughness and precision, each results obtained from the framework were verified and compared with results obtained by manual computation.

In conclusion, the CBA framework has been tested with a real-life rural RET project and the result reveals the flexibility demonstrated by the framework.

5.5 Limitations of CBA framework for RETs

Certain limitations were observed in the proposed CBA framework. Foremost, in determining the WTP through CVM analysis, there are concerns that respondents may not give accurate answers to their individual WTP for RE systems. Also, a close questionnaire structure that query individual's WTP was used; thus raising questions of information bias, as assumptions will have to be made during interpretation of individual's WTP. Rather, an open questionnaire structure should have been adopted which will reflect accurately an individual's WTP.

5.6 A Snap-view of CBA Simulation Tool for RE Projects

This simulation tool was developed such that investors or local officials interested in RE investment could evaluate the feasibility of installing RE in rural communities and determine its cost-benefit. The tool requires the user to go through a series of steps to provide information and then ultimately obtain a result that may or may not satisfy a criterion imposed by the proposed CBA framework. The tool is essentially an economic calculator of various alternatives under review whose results (net present value, benefit-cost ratio and a rate of return) should be compared to determine the most viable option.

Functionalities that will aid easy interpretation of analysis have been built into the simulation tool such that it can predict, based on the criteria of CBA, whether an RET will be economically viable or not. This tool accounts for a number of various factors:

- Introduction page
- Information page
- RET Assessment pages *(option 1, option 2, option 3 and option 4)*
- Sensitivity Analysis page
- Project Summary page
- Load Demand Analysis page
- CBA Framework overview page

The simulation tool users are required to fill in the information required on the various spreadsheets (in the green colored cells), the results of which are provided in the blue colored cells. The most important results are the Net Present Value (NPV), Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR) and payback period (for CBA simulation tool for RET version 1.1 only).

This tool should be used as a first step in determining whether installation of an RE is suitable for a particular site. The developer of this CBA simulation tool strongly believes that each potential site for RE should first be assessed for feasibility. Such an assessment may involve gathering meteorological data at the site for twelve months or longer, bringing in an expert to look at the terrain or have the ability to interface with the existing utility, etc. In any case, this instrument should not be the only measure of whether erection of an RE system is justifiable or not at a given location. However, load demand analysis function built into the tool can assist in determining the power requirements or demand for the site under assessment. Ultimately, the CBA simulation tool can be used to compare up to four different REs option in order to select the most viable alternative. The following procedures are developed to assist in utilizing the CBA simulation tool for RE projects.

Step 1

Open the Microsoft Excel file *"CBA Simulator tool for RET ver_1.0"* or *"CBA Simulator tool for RET ver_1.1"* (the latter file contains additional financial parameter called payback period). A Microsoft Excel® worksheet should appear on the computer screen. It must be ensured that the *"macro security"* mode is enabled through the option settings as it appears in Fig. 5.4.

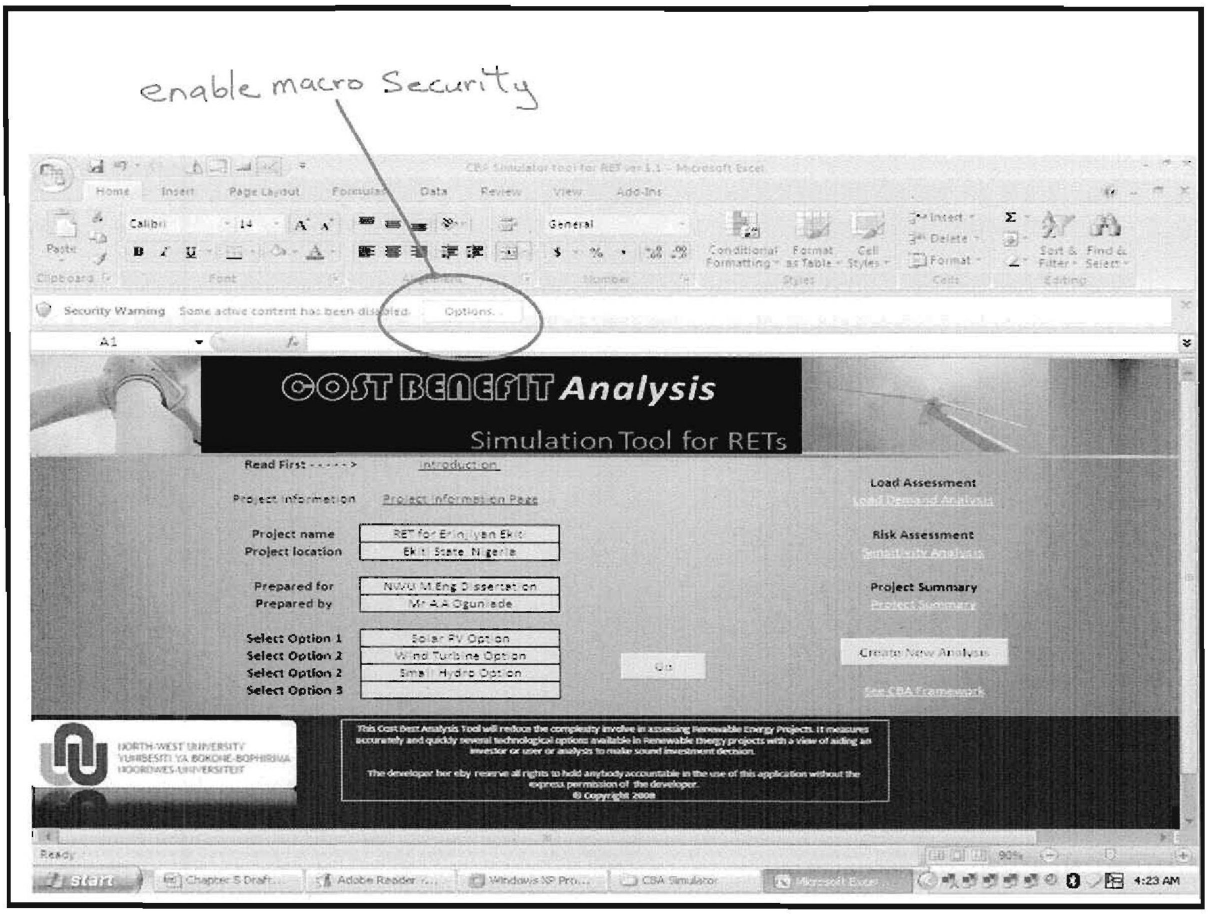

Figure 5.4: "Startup" page of the CBA Simulation Tool for RET version 1.1

The *"Startup"* page must be filled in according to the project specifications while RE options to be assessed can be selected from drop-down lists of four different RE options available in the tool.

Step 2

Using the computer mouse, click on *"Introduction"* (underlined blue font) in **step 1** to view the information contents about the simulation tool, similar to Fig. 5.5.

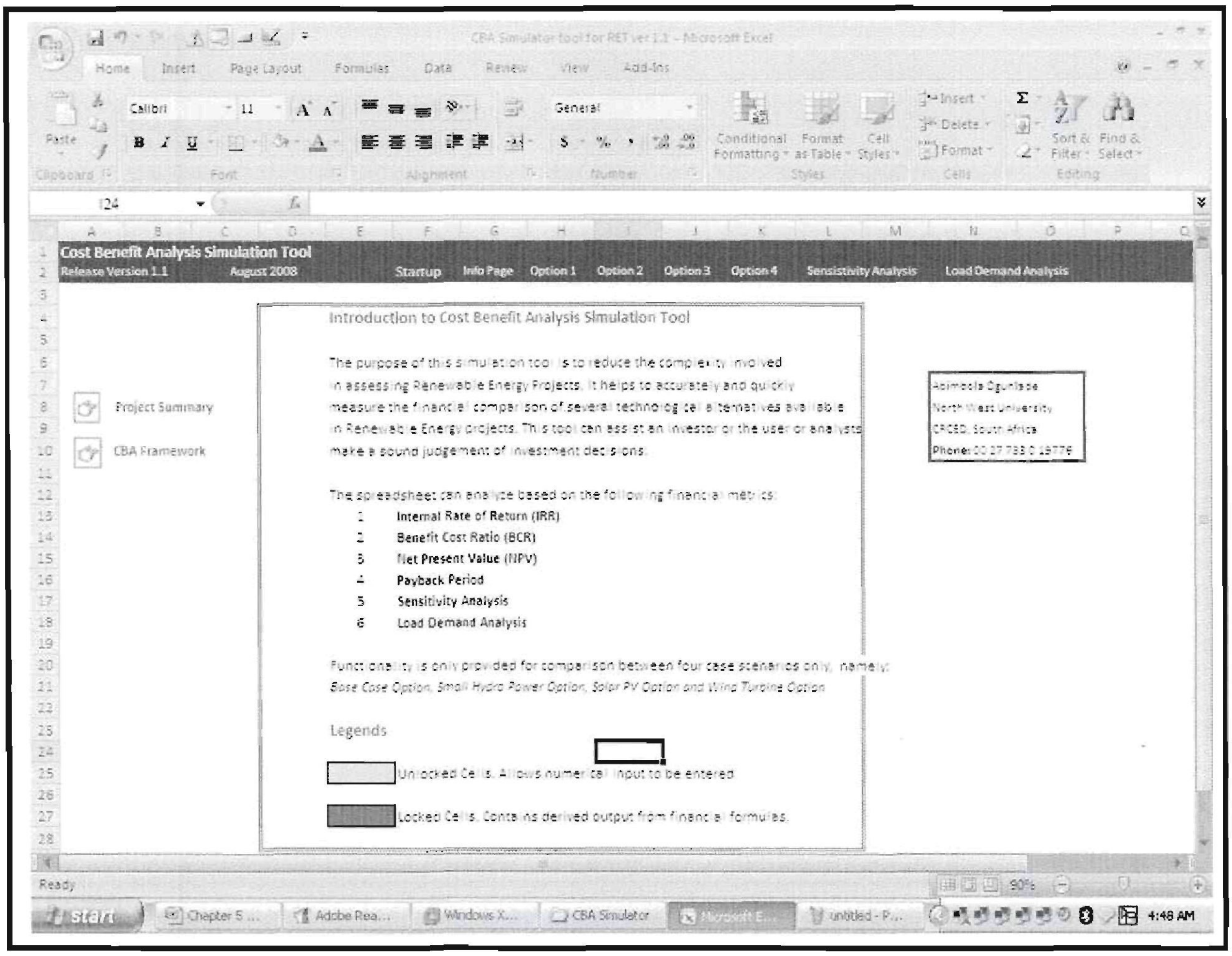

Figure 5.5: Introduction page of the CBA Simulation Tool for RET version 1.1

Step 3

Using the computer mouse, click on the "Info Page" to fill-in description and scope of the RE project under investigation. A worksheet similar to the one shown in Fig. 5.6 is displayed.

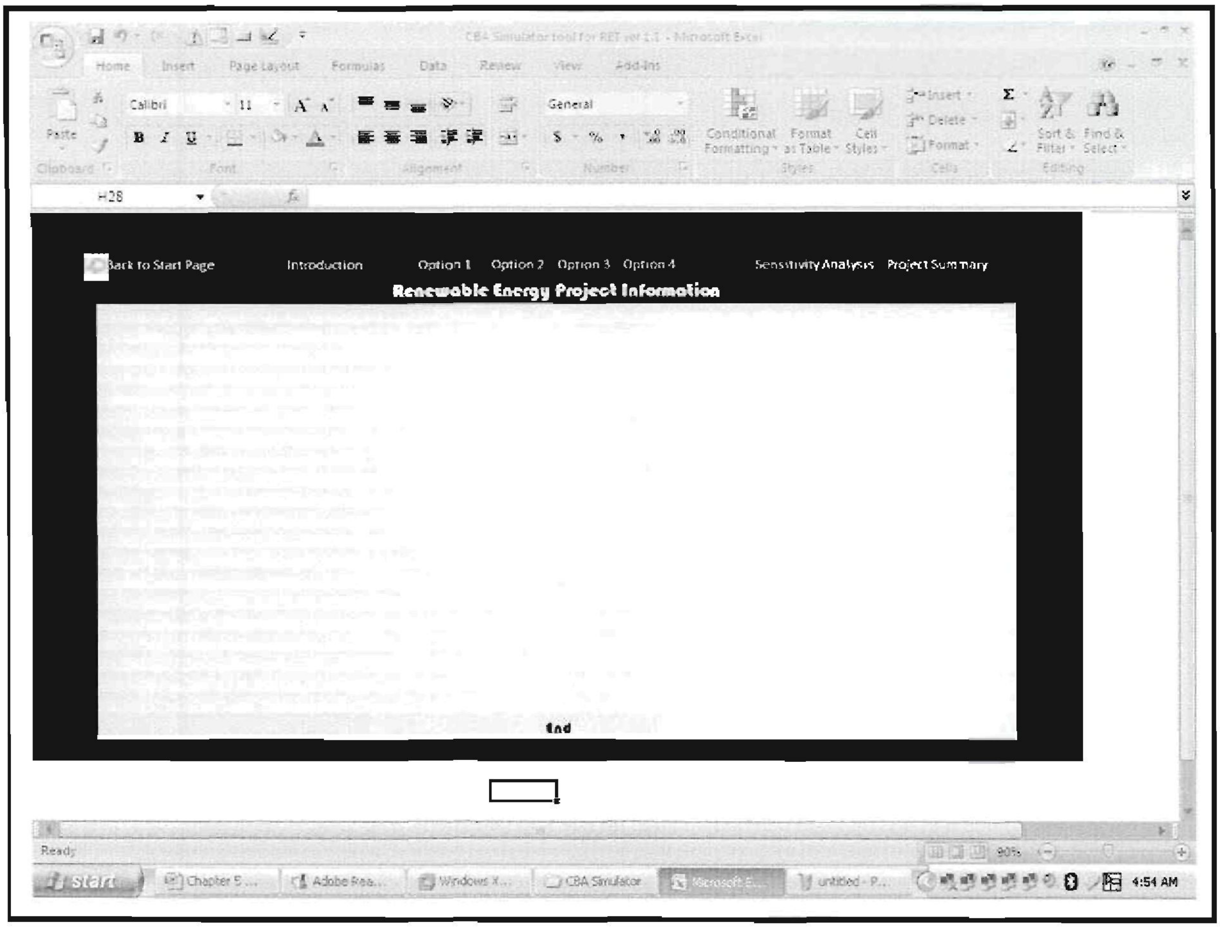

Figure 5.6: "Info Page" of the CBA Simulation Tool for RET version 1.1

Step 4

Using the computer mouse again, click on the hyperlink "Load Demand Analysis" in **step 3** to display a "Load Assessment for Power Energy" worksheet as captured in Fig. 5.7. The load demand analysis was designed to assist in determining the total power (in kW) requirement for the location under assessment.

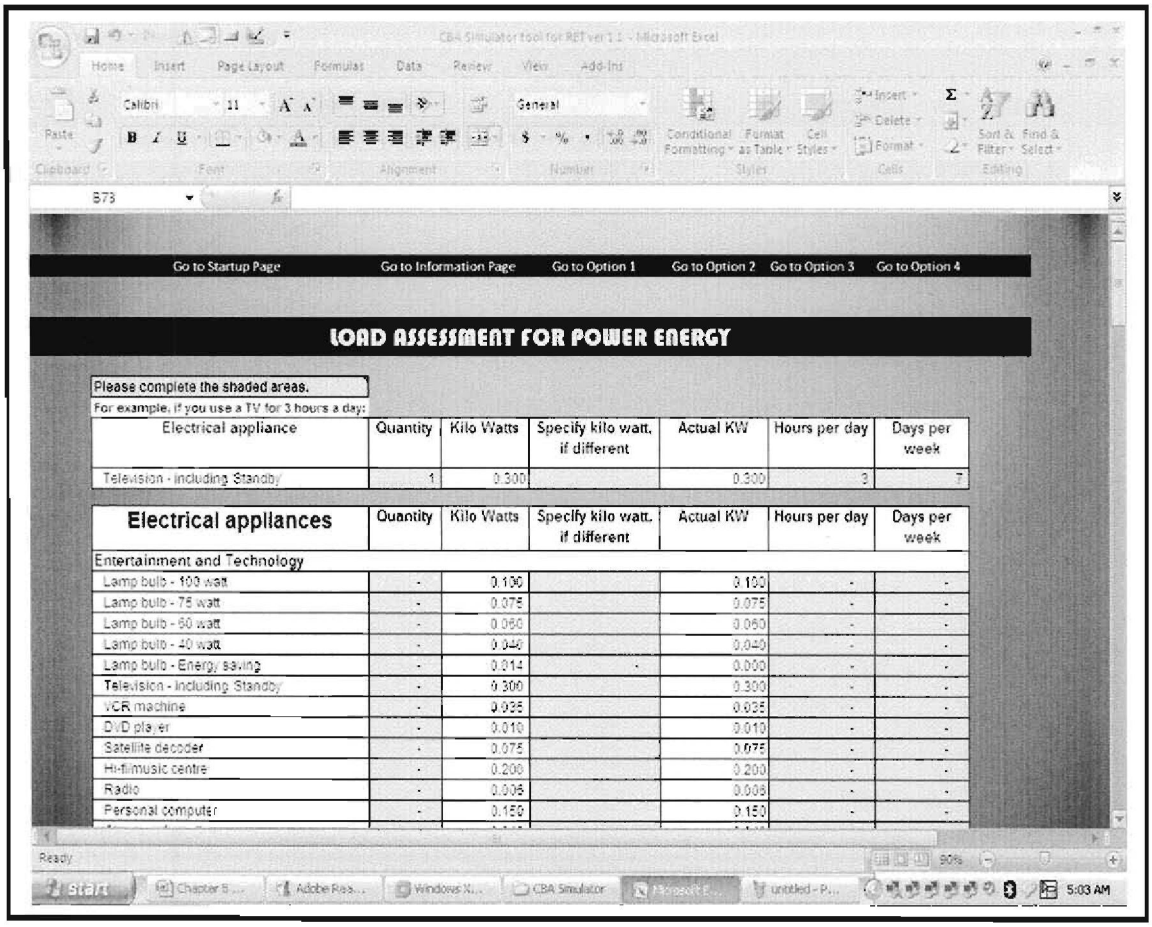

Figure 5.7: "Load Demand Analysis" of the CBA Simulation Tool for RET version 1.1

Step 5:

With the aid of the mouse pointer, click on the hyperlink "Option 1" in **step 4** to key in relevant cost and benefit parameters needed for the analysis. Fig. 5.8 displays snapshot of option 1 page from the CBA Simulation tool for RET version 1.1.

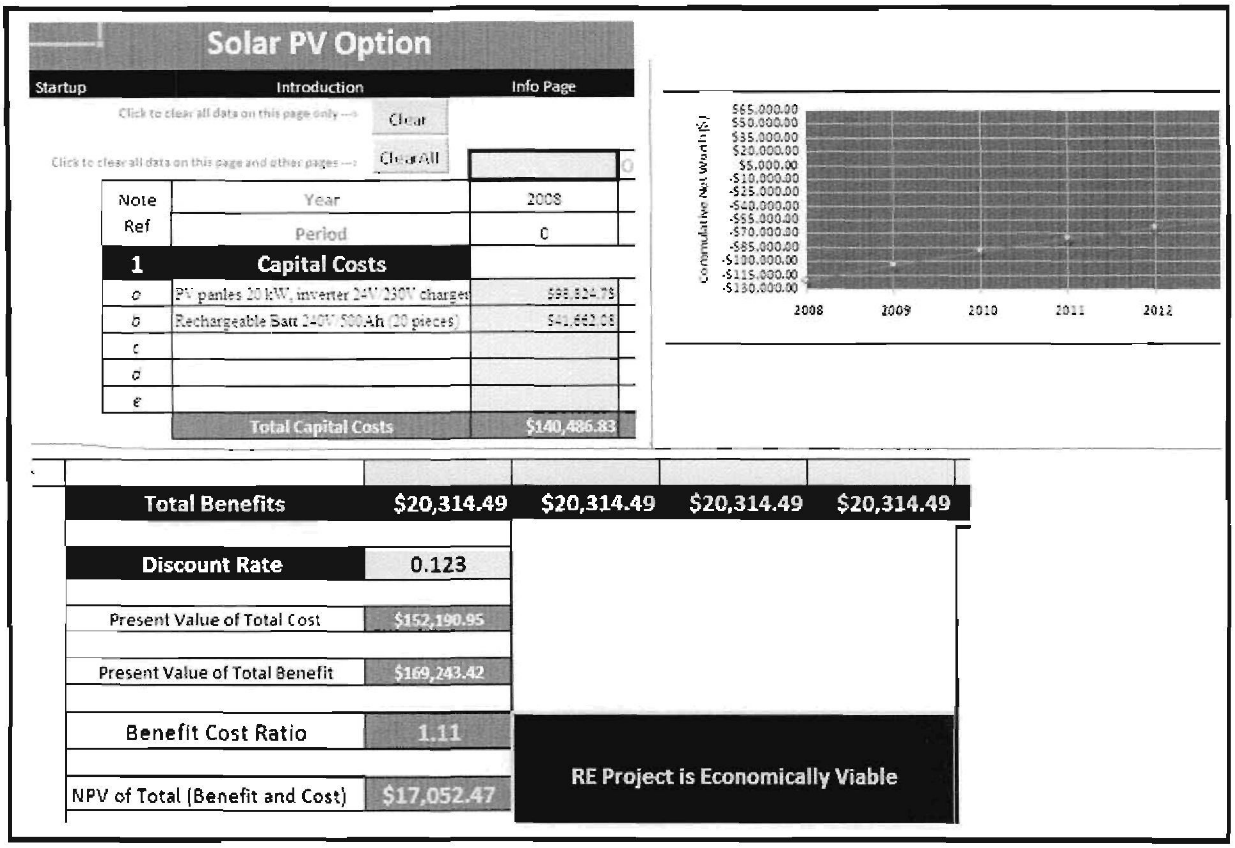

Figure 5.8: Different snapshots of "Option 1" page of the CBA Simulation Tool for RET version 1.1

Option 1, 2, 3, 4 have a similar outlook like Fig. 5.8 therefore, it will not be necessary to present their screenshots at this stage.

Step 6:

This step involves performing risk assessments by clicking on the hyperlink *"Sensitivity Analysis"* in **step 5**. A window similar to Fig. 5.9 should be displayed.

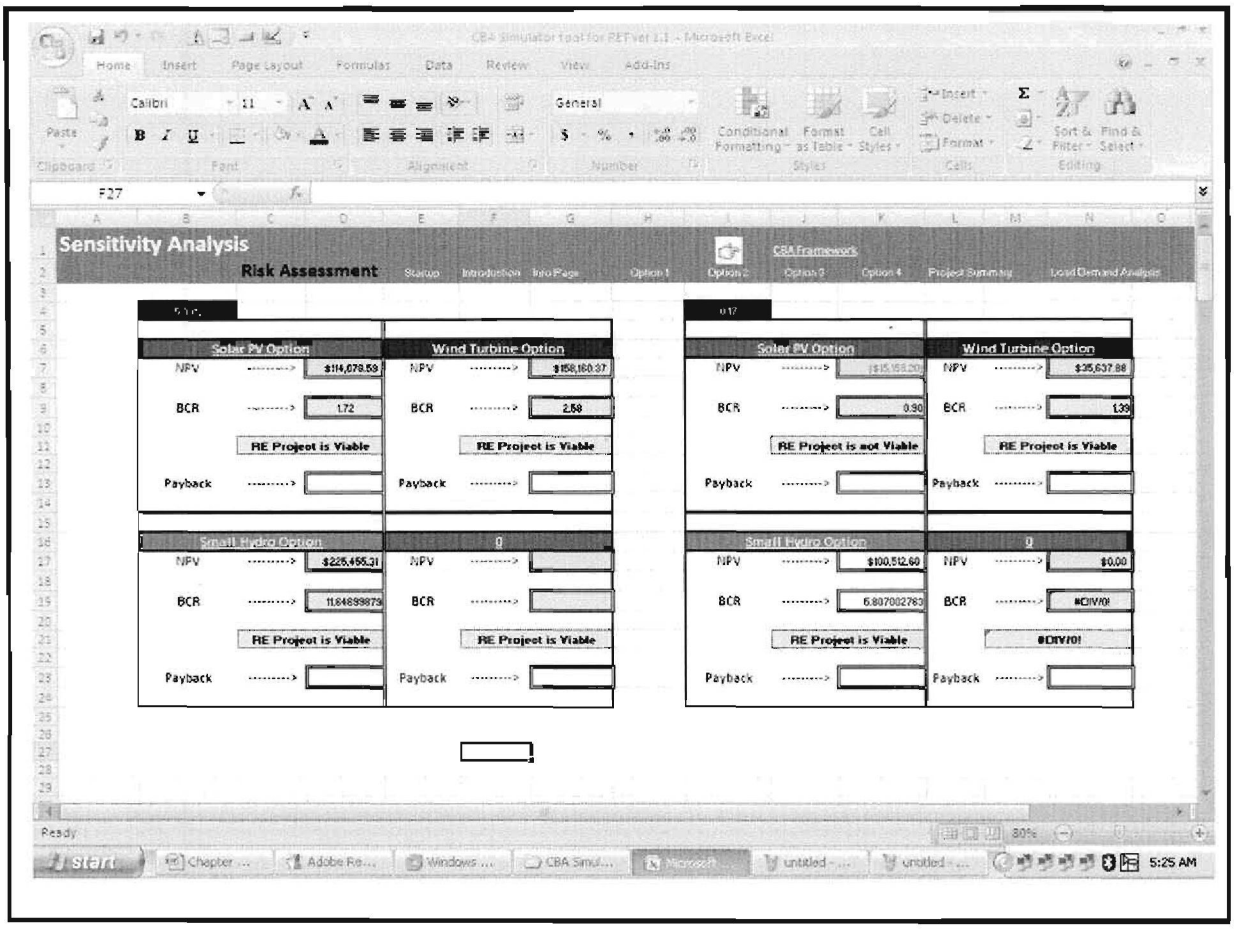

Figure 5.9: "Sensitivity Analysis" page of the CBA Simulation Tool for RET version 1.1

Test for sensitivity can be done with two discount rates that can be selected from the drop down lists of discount with black cells.

Step 7:

The last step involves displaying a summary of the CBA breakdown. Using the mouse pointer, click on *"Project Summary"* to give the CBA summary of all the RE options. The project summary can also display if the RE option is economically viable or not depending on the outcome of all the economic parameters of CBA. Fig. 5.10 captures the *"Project Summary"* page as produced by the CBA simulation tool for RET version 1.1.

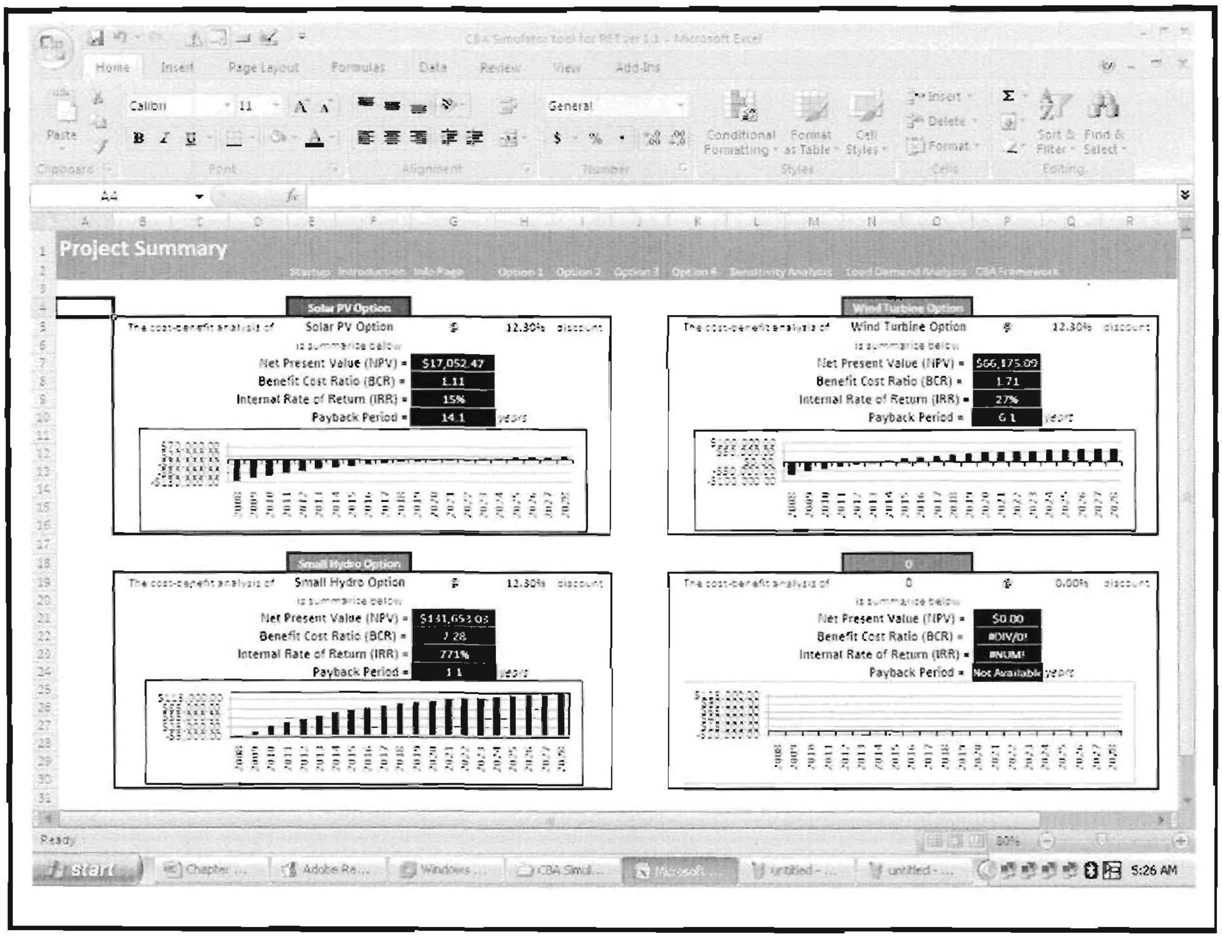

Figure 5.10: "Project Summary" page of the CBA Simulation Tool for RET version 1.1

5.7 Chapter Summary

By presenting the economic outcome of each available RE options expressed in monetary terms, the decision makers can judge the overall viability of each RE option using the three decision criteria which are built into the CBA framework.

The CBA analysis of Erinjiyan Ekiti has clearly revealed that all the three RE options (solar PV, wind turbine and small hydro power) will be economically viable if implemented. Further revelation on the CBA outcome has revealed that only solar PV option is marginally viable, thus turns negative upon an assumed increase in discount rate of only 17%. Likewise, opinion survey obtained from the rural respondents on factors and concerns they will consider when purchasing an RE system. About 88.1% of the respondents identified the quality of power generation as the major factor they will consider when purchasing an RE system. Similarly, 80.1% of the respondents emphasized maintenance as a major concern they might likely have, after an RE system has been purchased.

However, it is suggested that larger scope of intangible benefits together with users' opinion survey should form part of the criteria used to narrow down the most viable options in situations where multiple options seem economically viable.

Chapter 6

Conclusion and Recommendations

Chapter Five presented the findings of a CBA assessment conducted on a rural community in Nigeria using a proposed framework. This chapter concludes the overall research investigation. The contributions of the dissertation are indicated, recommendations and future research are identified.

6.0 Conclusion

This chapter concludes the overall research investigation. The contributions of the dissertation are indicated, recommendations and future research are identified.

This dissertation had three main objectives at its focus.

1. To propose a cost-benefit analysis framework for renewable energy towards rural community development in Nigeria as indicated in the 18-point recommendations of ECN (Ishmael, 2003: 53).
2. To formulate and develop a cost-benefit analysis tool, an automated decision making tool designed for decision-makers, which can analyze comparatively the costs and intangible benefits of renewable energy projects for rural application.
3. To establish cost-benefit components by determining the costs and monetary value of all the benefits required to implement renewable energy technologies in rural areas of Nigeria. Using a rural site as a case study, a comparative cost-benefit analysis was conducted to demonstrate the working methodology of the framework.

The cost-benefit analysis of three RE options (solar PV, wind turbine and small-hydro power) conducted on Erinjiyan Ekiti rural community in Nigeria revealed some remarkable results. Three decision criteria namely: Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR) were used to assess the economic viability of each RE options. Surprisingly, all the three RE options were found to be economically viable based on the three decision criteria. However, it is suggested that strict caution must be exercised in making a final decision. Results from the CBA assessment ranked Small-Hydro Power (SHP) option as the most viable option followed by the wind turbine option; however, this would be swiftly negated if the spiritual belief of the rural dwellers were taken into consideration. Furthermore, a sensitivity assessment of all the three RE options revealed that only solar PV option is marginally viable in Erinjiyan Ekiti, as it turns negative upon an assumed increase in discount rate of only 17%.

It is therefore apparent that small-hydro power is attractive for Erinjiyan Ekiti rural area, because there is a river that has exploitable features. For any other rural community area in Nigeria, there might not be such rivers, and wind profiles may also not be favorable. Solar devices can be installed anywhere as a result of abundant sunshine in the tropics. In spite of its high cost of implementation, solar option may thus end up being the most viable alternative for most rural application in Nigeria.

Evidently, the proposed CBA framework has clearly demonstrated its efficacy as an effective and efficient decision tool for assessing RE projects. It is therefore suggested that investors should exploit this framework, especially in situations where confronted by delicate RE investment decision making.

6.1 Recommendations

For future research activity and further improvement, the following suggestions were identified for recommendations:

1. Basic assumptions were made during the interpretation of respondents Willingness to Pay (WTP) for RE. Therefore, it is suggested that an open structured questionnaire be adopted to query respondents' willingness to pay for RE instead of the close ended question used in this dissertation, since a precise value which is very crucial in the result analysis ought to be reflected.

2. The CBA simulation tool for RETs can only assess four RE alternatives namely: base case, solar PV, wind turbine, and small-hydro power options. In which case, there might be a need to assess more than four RE alternatives. Consequently, the CBA simulation tool for RETs was designed as an open-source Microsoft Excel spreadsheet, for the benefit of future interested researchers.

Annexure A: Nigeria Political Map (2007)

Annexure B: A Description of Data Requirements

Variable	Description
Resource and Climate Data	
Hourly Average Global Horizontal Insolation (KWh/m^2)	Average solar insolation on a horizontal surface of a given location measured on an hourly basis.
Hourly / Monthly Wind Speed (m/s)	Site-specific wind speed measured as hub height of the wind turbine at the beginning of each hour or month.
Load Data	
Type of Appliance	The types of household appliances including CFL, fluorescent bulb, incandescent bulb, transistor radio, tape recorder, TV, VCR, electric heater, electric iron, electric fan, electric cooker, wash machine, refrigerator, air conditioner, electric pump, among others.
Number of Units	Number of units for each kind of appliance
Appliance Rated Power (W)	Rated power per unit of appliance Daily Operating Hours (hours)
Daily Operating Hours (hours)	Operating time per day by month for each unit of the appliance
System Configuration Data	
PV Array	
PV Array Angle (Degrees)	The angle of declination from horizontal of the PV array.
PV Array Area (m^2)	The surface area of the PV array.
PV Module Efficiency (%)	The fraction of solar energy that the PV array is capable of converting into direct-current electricity at PTC standard conditions.
Array Lifetime (years)	The expected useful lifetime of the PV array.
Wind Turbine	
Hub Height	Distance from the centre of the wind turbine rotor to the surface terrain.
Rotor Diameter (m)	The distance across the rotor.
Turbine Power Curve (kW)	The wind turbine's generated power at varying wind speeds (taking into account the incident energy lost from the turbine).
Wind Turbine Lifetime (Years)	The expected useful lifetime of the wind turbine.
Balance of System Components	

Size of Battery Bank (Ah)	The storage capacity of the battery bank.
Battery Lifetime (Year)	The expected useful life of the battery bank.
Size of Charge Controllers (W)	The size of charge controller used to prevent the battery from being overused.
Lifetime of Charge Controller (Year)	The expected useful life of the charge controller.
Size of DC/AC Inverters (W)	The size of inverter used to convert direct current (DC) to alternating current (AC).
Inverter Lifetime (Year)	The expected useful life of the inverter.
Cost Data	
PV System Costs ($)	The initial capital cost of the PV array plus system delivery cost, installation cost and warranty.
Wind System Costs ($)	The initial capital cost of the wind turbine plus system delivery cost, installation cost and warranty.
Small Scale Hydro Costs ($)	The capital cost of the Small Scale Hydro plus system delivery cost, installation cost and warranty.
PV Module Replacement Cost ($)	The cost of replacing a PV array over its lifetime.
Wind Turbine Replacement Cost ($)	The cost of replacing wind turbine over its lifetime.
Small Scale Hydro Replacement Cost ($)	The cost of replacing generator over its lifetime
Annual Operation & Maintenance (O&M) Costs ($)	Annual cost of removing dust and film from the PV array surface, of minor repairs and scheduled refurbishment of the wind turbine, of lubrication and bushing repairs for engine generator, and of electrical connection inspection and scheduled maintenance for BOS components.
Battery Costs ($)	Retail prices of batteries. A price matrix for locally available batteries is preferred.
Controller Costs ($)	Retail prices of charge controllers. A price matrix for locally available controllers is preferred.
Inverter Costs ($)	Retail prices of DC/AC inverters. A price matrix for locally available inverters is preferred.
Benefit Data	
Benefits (*in terms of cost of CO_2 emmission saved*)	Monetary sum of annual CO2 emission saved.
Total Willingness to Pay - TWTP ($)	This is the sum of the total mean willingness to pay for RETs in monetary terms.
Financial Data	

Discount Rate (%)	The interest rate used to determine the present worth of a future value.
Evaluation Period (Year)	The number of years for which a future value is discounted to its present value.
Currency Exchange Rate (=N=)	The conversion rate between foreign exchange and domestic currency.
Tariff (%)	A duty imposed on an imported part
Net Present Value (NPV)($)	The difference between the sum of the discounted cash flows which are expected from the investment and the amount which is initially invested.
Benefit-Cost Ratio (BCR)	The ratio of the total present value of benefits during the service life of the project to the total present value of the costs.
Internal Rate of Return ($) (IRR)	The discount rate that delivers a net present value of zero for a series of future cash flows.
Policy Data	
Land Use Charge ($)	A toll charge imposed by local authority upon the use of local lands for activities such as transporting fuels, RE projects setup.

Annexure C: Questionnaire Survey Template

Original Copy
Ver. 4.0

Questionnaire Survey

QUESTIONNAIRE SURVEY TEMPLATE FOR RURAL RENEWABLE ENERGY IMPLEMENTATION IN ERINJIYAN EKITI

Thank you for volunteering to participate in the questionnaire survey on rural renewable energy implementation for Erinjiyan Ekiti. Your participation will go a long way to determine individuals household details, energy pattern, and willingness to pay for renewable energy system. All information will be kept in strict confidence.

INSTRUCTIONS: *Kindly Mark* X *where applicable and ensure all questions are filled out.*

HOUSEHOLD PROFILE - Section 1

Part 1: Address of Respondent

Name of Settlement / Community:
Household Number / Community:
Village/Town:

Part 2: General information about the Household

1.1 Name of Respondent *(Enter Initials)*:
1.2 Sex of Respondent: Male ☐ Female ☐
1.3 Age of Respondent:
1.4 Highest Educational Level of Respondent:
- [1] Never attended school
- [2] Attended primary school
- [3] Attended junior middle school
- [4] Attended senior middle school
- [5] Attended vocational school
- [6] Attended college level or above

1.5 Occupation of Respondent:
- [1] Student
- [2] Farmer
- [3] Civil Servants
- [4] Self Employed
- [5] Trader
- [6] Unemployed
- [7] Others (Specify)

1.6 Respondent's Relationship to Head of the Household is:
- [1] Head of the Household
- [2] Wife or Husband of the Head
- [3] Daughter of the Head
- [4] Son of the Head
- [5] Daughter-in-law of the Head
- [6] Son-in-law of the Head

1.7 How many people are in the household? (Fill in according to age bracket.)

0 – 6 years: **Persons**
7 – 17 years: **Persons**
18 – 60 years: **Persons**
61 years & over: **Persons**
Total: **Persons**

1.8 Amount and Sources of Annual income of the family:

Agricultural: **Naira**
Non-agricultural: **Naira**
Total: **Naira**

1.9 Annual expenditure of the family:

1.9.1 Agricultural expenditure: **Naira**

1.9.2 Non-agricultural expenditure (Total): **Naira**

[1] Food: **Naira**

[2] Electric appliances: **Naira**

[3] Transportation Equipment and Maintenance: **Naira**

[4] Water: **Naira**

[5] Electricity: **Naira**

[6] Fuel: **Naira**

[7] Education and Entertainment: **Naira**

[8] Others (Specify): **Naira**

1.9.3 Total Annual Expenditure: **Naira**

INFORMATION ON HOUSEHOLD ENERGY USES - Section 2

2.1 Do you use electricity (yes or no)?

2.2 What is your source of electricity?

[1] Grid
[2] Own generation
[3] None (if none, goto 2 4)

2.3 How do you rate the quality of the electricity supply, if you use electricity?

[1] Satisfied
[2] Not satisfied due to frequent blackout and unstable electricity voltage
[3] I do not care

2.4 Which of these energy sources do you use presently?

[1] Electricity
[2] Kerosene
[3] Dry Cell Battery
[4] Candle
[5] Diesel or Petrol
[6] Other (specify)

2.5 How do you rate the quality of your energy supply?

[1] Satisfied
[2] Not satisfied due to scarcity of supply.
[3] Other (Specify)

2.6 What types of fuels do you use for cooking?

[1] Coal and/or Charcoal
[2] Straw and/or Dung (Biomass)
[3] Electricity
[4] Gas
[5] Firewood
[6] Kerosene

2.7 Please state your monthly energy consumption

Type	Amount per month	Total cost per month
Electricity	Kwh	₦
Coal or charcoal	Kg	₦
Gas	Litre	₦
Firewood	Kg	₦
Straw or dung	Kg	₦
Kerosene	Litre(s)	₦
Other (Fuel name:)	Kg	₦
Total		₦

2.8 How much electricity do you need in each month in the next five years?

Year	Monthly Amount
1	kWh
2	kWh
3	kWh
4	kWh
5	kWh

INFORMATION ON ALTERNATIVE FORM OF ENERGY (RENEWABLE ENERGY SOURCES) - Section 3

3.1 Are you familiar with any Renewable Energy Technologies (Yes or No)? **[If NO, go to 3.3]**
3.2 If yes, which of the Renewable Energy Technologies are you familiar with?
[1] Small Scale Hydro Energy
[2] Wind Energy
[3] Solar PV Energy
3.3 Which of these forms of renewable energy would you prefer?
[1] Small Scale Hydro Energy
[2] Wind Energy
[3] Solar PV Energy

WILLINGNESS TO PAY FOR RENEWABLE ENERGY SYSTEMS - SECTION 4

4.1 Would you be willing to pay more for electricity if more reliable service is guaranteed (yes or no)?
4.2 Type of energy system you would like to patronize in the near future:
[1] Wind turbine energy
[2] Solar PV system
[3] Small Hydro Power System
[4] Gasoline/Diesel Generator
[5] Not interested in any
4.3 How much are you willing to pay for a renewable energy system per month?
[1] Less than 3000 Naira
[2] 3001 - 5000 Naira
[3] 5001 - 10000 Naira
[4] 10001 - 15000 Naira
[5] 15001 - 20000 Naira
[6] More than 20000 Naira
4.4 How would you like to pay for the renewable energy system?
[1] Lump Sum
[2] Two Payments
[3] Three Payments
[4] Leasing (Pay a Monthly Fee)
4.5 Which factors would you rank first when purchasing a renewable energy system?
[1] Capital Cost
[2] Quality
[3] After-Sale Service
[4] Capacity
4.6 What are your biggest concerns of using a renewable energy system?
[1] Maintenance
[2] Spare Parts
[3] Repair and Services
[4] Environmental Effect

Name of Observer: .... Date of Interview: ....

THANK YOU for your time in filling this survey.

....

For official Use only

Form ID: ....

Annexure D: Summary of Questionnaire Results

	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.9.2.2	1.9.2.4	1.9.2.5	1.9.2.6
S/N	Names	Sex	Age	Educational Level	Occupation	Relationship to the Head	Household population	Annual Household Income	Annual Household expenditure	Electrical Appliance	Water	Electricity	Fuel
1	MR BUNMI AJAYI	Male	32	6	3	4	10	250000	210000	10000	2000	6000	10000
2	Mrs V. Ajayi	Female	45	2	5	2	8	150000	118000	5000	500	2500	0
3		Male	40	6	0	1	5	960000	508000	100000	0	12000	96000
4		Female	35	6	3	2	5	325000	12000	0	0	12000	0
5	Mr R.O Jegede	Male	39	6	3	1	10	1000000	900000	100000	10000	30000	30000
6	Mr Oladiran Akin	Male	44	6	3	4	8	3000000	2300000	200000	200000	300000	100000
7	Mrs I	Female	56	6	3	2	10	0	0	0	0	0	0
8	Chief S.O Ogundare	Male	60	5	3	1	7	980000	958000	15000	0	15000	120000
9	Chief JA Olawunmi	Male	61	6	3	1	6	330000	335000	0	0	15000	120000
10	Mr J.C Makinde	Male	60	2,3,5	2,4	1	10	0	60000	0	0	0	0
11	Mr Micheal Adebayo	Male	0	1	2	1	0	0	38650	0	0	0	0
12	Mrs Idowu Makinde	Female	0	1	6	1,2	0	0	24000	0	0	24000	0
13	Mr J.A Makinde	Male	50	2	2	1	0	80000	66000	0	0	24000	0
14	Mr Samson Olowokere	Male	55	1	2	1	0	3000	0	0	0	0	0
15	Mr James Oluwatayo	Male	39	6	3	1	0	0	144000	0	0	0	0
16	Mr A.O	Male	17	6	1	3	4	350000	130000	5000	2500	2500	10000
17	Mrs O.O Olaniyi	Female	48	6	3	2	4	500000	500000	5000	10000	5000	10000
18	Mr O.O Ogunlade	Male	58	6	3	1	5	1500000	1278000	100000	24000	12000	12000
19	Mr A.K Alabi	Male	9	2	1	4	6	350000	120000	5000	2500	2000	10000
20	Mr T.A Alabi	Male	8	2	1	4	6	350000	120000	5000	2500	2500	10000
21	Mr Ojo Akinyemi	Male	60	6	2	4	18	0	0	0	0	0	0
22	Mr Tade Olaiya	Male	38	5	3	6	14	420000	81000	0	0	14000	0
23	Mr Olu-Ojo Thomas	Male	52	2	4	1	12	360000	92000	30000	0	0	0
24	Mr Amusa Areola	Male	62	1	2	1	9	380000	340000	0	0	0	0
25	Mr G.O Olutade	Male	70	3	2	1	15	500000	486000	100000	35000	40000	36500
26	Mr J Oyedele	Male	68	5	2	1	10	1000000	230000	30000	0	0	0
27	Mr Ojo Temidayo	Male	52	5	4	4	13	1000000	915000	200000	80000	100000	75000
28	Mr Adebayo Ezekiel	Male	57	6	5	1	21	800000	720000	90000	60000	100000	80000
29	Mr L.E. Jimoh	Male	29	6	4	4	15	50000	150000	0	0	0	0
30	Chief Y.O Jimoh	Male	65	3	2	1	24	280000	190000	0	0	0	10000
31	Mr Ojo Joseph	Male	45	4	4	4	7	145000	130000	10000	0	0	0
32	Chief Adebisi Adedara	Male	85	2	2,5	1	17	600000	470000	100000	50000	20000	30000
33	Mr Fadipe Ade	Male	45	4	4	4	13	100200	940000	400000	100000	20000	10000
34	Mr Ojo Tope	Male	50	2	4	1	16	700000	380000	70000	20000	45000	25000
35	Mr Oni Gbenga	Male	48	4	4	4	14	920000	770000	120000	80000	120000	50000
36	Miss S.O	Female	13	4	1	3	4	350000	100000	5000	2500	2500	10000
37	Miss A.M	Female	15	3	1	3	6	350000	120000	15000	20000	10000	10000
38	Mr R.S Akintunde	Male	39	6	2	1	0	800000	638000	50000	6000	12000	30000
39	Mr Gbenga Oni	Male	49	6	3	1	5	450000	150000	40000	5000	40000	15000
40	Chief E.A Olawaye	Male	88	6	4	1	12	850000	450000	20000	0	30000	15000
41	Mr C.K Awoyelu	Male	67	6	3	1	10	1000000	500000	50000	100000	120000	30000
42	Mr G.O Oyedeji	Male	64	6	3	1	8	650000	600000	100000	60000	120000	200000

2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.7.1a	2.7.1b	2.7.2a	2.7.2b	2.7.3a	2.7.3b	2.7.4a
Do you use electricity	Your source of electricity	Quality of Electricity supply	Energy Usage Parttern	Quality of Energy Supply	Energy for Cooking?	Total Monthly Energy Consumption	Electricity (Quantity per Month) kWh	Electricity (Cost per month) =N=	Coal(Quantity per Month) kg	Coal(Cost per month) =N=	Gas(Quantity per Month) Litre	Gas(Cost per month) =N=	Firewood(Quantity per Month) Kg
yes	1	2	2 , 4	2	5	1600	30	500	0	0	0	0	1000
Yes	1	2	2,4	2	5,6	1400	20	350	0	0	0	0	750
yes	1	2	1	2	4	4000	250	1000	0	0	12.5	3000	0
yes	1	2	1,5	2	4	4000	250	1000	0	0	12.5	3000	0
yes	3	0	1,2,5	2	1,5,6	7100	0	3000	0	2000	0	0	0
yes	0	2	1,5	2	4,6	0	0	0	0	0	0	0	0
No	0	2	2	2	5	1600	0	0	0	0	0	0	0
yes	1,2	2	1,2,3,5	2	5,6	9000	25	1500	0	0	0	0	150
yes	1	2	1,2,3,5	2	5,6	7500	0	1500	0	0	0	0	500
yes	2	2	2	2	5	3000	0	1500	0	0	0	0	0
no	0	0	1	2	5	24000	0	24000	0	0	0	0	0
0	0	0	1	2	0	24000		24000	0	0	0	0	0
Yes	1	2	2	2	5	3000	0	0	0	0	0	0	500
Yes	1	2	2	2	5,6	3000	0	0	0	0	0	0	500
Yes	1	2	1,2,3,4	2	5,6	8500	250	1000	0	0	0	0	150
yes	3	2	1	2	4	9200	250	2500	0	0	50	5000	0
yes	1	2	1,4,5,6	2	4	1300	0	500	0	0	0	800	0
yes	1	2	1,3,4,5	2	3,4,6	5000	0	1000	0	2500	0	0	0
yes	3	0	1	2	6	3800	250	1000	0	0	0	0	0
yes	1	2	1	2	6	0	0	0	0	0	0	0	0
yes	2	2	1,2	2	5,6	30000	0	0	0	0	0	0	0
yes	2	2	2	2	5,8	6000	0	3200	0	0	0	0	0
yes	2	2	5	2	6	10000	0	3000	0	0	0	0	0
No	3	0	2	3	5	9500	0	0	0	0	0	0	0
yes	1	2	0	2	5,6	10000	0	0	0	0	0	0	0
yes	2	2	2	2	5	15500	0	2000	0	0	0	0	0
yes	2	2	5	2	5,8	13550	0	5000	0	0	0	0	0
yes	2	2	1	2	5,6	27000	0	4000	0	0	0	0	0
yes	2	2	5	2	1	10000	0	3000	0	0	0	0	0
yes	2	2	5	2	5	10000	0	4000	0	0	0	0	0
yes	2	2	5	2	5	7000	0	2000	0	0	0	0	0
yes	1	2	2	2	5	117000	50	6000	0	0	0	0	150
yes	1	2	6	2	5	105000	0	0	0	0	0	0	150
no	3	0	2	2	5,6	17,600	0	0	0	0	0	0	80
Yes	1	2	5	2	5,6	32,600	60	60000	0	0	0	0	130
yes	3	2	1	2	4	8550	250	2500	0	0	50	5000	0
yes	3	2	1	2	6	74500	0	50000	0	0	0	0	0
yes	1	2	2	2	5	4500	0	1000	0	500	0	0	0
yes	1	2	1,2,3,4	2	6	3800	0	0	0	0	0	0	0
yes	1,2	2	1,5	2	5,6	6700	0	0	0	0	0	0	0
yes	1,2	2	1,2,3,4,5	2	5,6	13200	0	0	0	0	0	0	0
yes	1	2	1,2,4,5	2	5,6	12,800	0	0	0	0	0	0	0

2.7.4b	2.7.5a	2.7.5b	2.7.6a	2.7.6b	2.7.7a	2.7.7b	2.8.1	2.8.2	2.8.3	2.8.4	2.8.8
Firewood(Cost per month) =N=	Straw(Quantity per Month)kg	Straw(Cost per month) =N=	Kerosene(Quantity per Month)Litres	Kerosene(Cost per month) =N=	Others(Quantity per Month)	Others(Cost per month) =N=	Energy Forecast Year 1(kWh)	Energy Forecast Year 2(kWh)	Energy Forecast Year 3(kWh)	Energy Forecast Year 4(kWh)	Energy Forecast year 5(kWh)
500	0	0	0	0	0	0	30	35	45	50	60
450	0	0	5	600	0	0	20	25	30	35	40
0	0	0	0	0	0	0	250	250	250	250	250
0	0	0	0	0	0	0	250	250	250	250	250
500	0	0	20	1600	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	20	1600	0	0	0	0	0	0	0
5000	0	0	30	2500	0	0	200	210	210	250	250
3000	0	0	30	3000	0	0	180	180	210	210	210
0	0	0	12	1500	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	150	160	180	190	195
6000	0	0	20	1500	0	0	50	50	60	75	75
0	0	0	10	700	0	0	250	250	250	250	250
0	0	0	0	0	0	0	250	250	250	250	250
0	0	0	20	1000	0	500	250	250	250	250	250
0	0	0	40	2800	0	0	250	250	250	250	250
0	0	0	0	0	0	0	0	0	0	0	0
10000	0	20000	0	0	0	0	0	0	0	0	0
0	0	0	40	2800	0	0	0	0	0	0	0
2200	0	0	0	1800	0	3000	0	0	0	0	0
5000	0	0	0	4500	0	0	0	0	0	0	0
0	0	0	0	6000	0	4000	0	0	0	0	0
10000	0	0	0	1000	0	2500	0	0	0	0	0
0	0	0	90	8550	0	0	0	0	0	0	0
10000	0	0	0	13000	0	0	0	0	0	0	0
0	0	0	0	0	0	7000	0	0	0	0	0
0	0	0	0	1500	0	4500	0	0	0	0	0
1500	0	0	0	1000	0	2500	0	0	0	0	0
105000	0	0	50	7000	0	0	0	0	0	0	0
105000	0	0	0	0	0	0	0	0	0	0	0
6400	0	0	160	11200	0	0	0	0	0	0	0
9100	0	0	100	14000	50	3500	0	0	0	0	0
0	0	0	15	1050	0	0	0	0	0	0	0
0	0	0	65	24500	0	0	0	0	0	0	0
500	0	0	0	2500	0	0	0	0	0	0	0
0	0	0	0	3800	0	0	0	0	0	0	0
2500	0	0	0	4200	0	0	0	0	0	0	0
10000	0	0	0	3200	0	0	250	250	320	350	400
10000	0	0	0	28000	0	0	0	0	0	0	0

3.1	3.2	3.3	4.1	4.2	4.3	4.4	4.5	4.6
Knowledge of RETs?	Familiar with which RET	chioce of RET	WTP RET?	Peference of RETs to buy?	How much WTP for RET	Method of payment for RET	Factors to consider before buying RET	Factors to consider before using RET
No		1	Yes	4	1	4	2	1
No		1	yes	4	1	4	2	1
yes	3	3	yes	2	2	4	3	3
yes	3	3	yes	2	2	4	2	3
No	0	1	yes	2,3	3	4	2	1
No	0	1	yes	3	2	4	2	3
yes	1	3	yes	2	2	3	3	1
yes	3	3	yes	2	4	4	1,2,3	1,2,3
yes	3	3	yes	2	3	4	1,2,3	1,2,3
0	0	0	yes	5	1	4	0	0
0	0	0	yes	0	1	4	0	0
0	0	0	0	0	0	0	0	0
No	0	3	Yes	2	1	4	1	1,2,3
no	0	3	yes	2	3	4	1,3	1,2,3
Yes	3	3	yes	2	1	4	1,3	1,3
yes	3	3	yes	2	3	4	2	1
yes	3	3	yes	2	1	4	1,2,3,4	1,2,3
yes	1,2,3	3	yes	2	2	4	2	1
No	0	3	yes	2	2	4	4	3
No	0	3	yes	2	2	4	4	3
No	0	3	yes	2	2	3	2	1
yes	3	3	yes	2	3	4	2	1
No	0	3	yes	2	2	4	2	1
No	0	3	yes	2	2	4	2	1
No	0	3	yes	2	2	3	2	1
No	0	3	yes	2	1	4	2	1
No	0	3	Yes	2	2	2	2	3
No	0	3	yes	2	1	2	2	1
No	0	3	yes	2	2	4	2	1
no	0	3	yes	2	3	4	2	1
No	0	3	yes	2	1	4	2	1
No	0	3	yes	2	1	4	2	1
yes	3	3	yes	2	1	4	2	1
No	0	3	yes	2	2	4	2	1
No	0	3	yes	2	1	4	2	1
Yes	3	3	yes	2	4	4	2	1
yes	3	3	yes	2	3	4	2	1
yes	3	3	yes	2	1	4	3	1
yes	3	2,3	yes	2	1	4	2	2,4
yes	1,2,3	1,3	yes	2	1	4	4	1,2,4
yes	2	2	yes	1	2	4	2	1
no	0	1	yes	3	1	4	2	4

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