ECONOMIC COST BENEFIT ANALYSIS OF AN OFF-GRID ELECTRICITY GENERATION PROJECT USING SUSTAINABLE AND RENEWABLE ENERGY TECHNOLOGY
CASE STUDY: A RURAL VILLAGE IN AFRICA

by

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Abstract

There are several rural areas in Africa that are off the grid and may never enjoy electricity due to several factors beyond their control. For such communities, it becomes important to consider alternative sources of electricity that is renewable and sustainable. This essay is based on a practical application of economic cost benefit analysis techniques to the installation of a sustainable renewable energy structure that will generate electricity for Samo. Samo is a rural area in Western Nigeria (a developing country in Africa). Samo is not connected to the national power grid and there is no prospect of such connection taking place in the next 50 years. A 1.3 KW photovoltaic structure with a project life of 28 years is proposed for the village. In this essay, we consider both the financial and economic benefit of implementing such a project, with the economic benefit far outweighing the financial benefit. The major difference between a solar energy project and the conventional means of electricity generation is the high initial investment costs associated with a solar structure. This is reflected in the sensitivity and risk analysis as we consider factors that can affect the financial cash flow, economic resource statement and externalities of the project.

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Finally, I will like to thank the people of Samo, Ogun State, Nigeria for giving me the opportunity to use their village for this analysis. I am hoping to get funding for this project and implement it for you guys free of charge. It will be nice for you to enjoy something that should be accessible to all people - electricity.

Abbreviations

NPV	Net Present Value
EV	Economic Value
FV	Financial Value
W	Watts
MW	Mega Watts
EXT	Externalities
MWhr	Mega Watts-Hour
KW	Kilo Watts
KWhr	Kilo Watts-Hour
GDP	Gross Domestic Product
GW	Giga Watts
PHCN	Power Holding Corporation of Nigeria
PV	PhotoVoltaic
CIDA	Canadian International Development Agency
UNDP	United Nations Development Programme
V	Voltage
IRR	Internal Rate of Return
Ah	Ampere-Hour
NGN	Nigerian Naira
EOCK	Economic Opportunity Cost of Capital
EOCL	Economic Opportunity Cost of Labour
CIF	Cost, Insurance, Freight

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Chapter 1

Introduction

1.1 Economic Cost Benefit Analysis

Given the current economic and financial climate, proper and quality evaluation of projects has become very important as big and small establishments keep looking for ways to drive down cost and improve cash flow. A quality investment appraisal has become very important as decisions are made regarding efficient allocation of resources within the country. An evaluation well carried out can help prevent bad projects and promote good projects. For government projects, this analysis helps prevent allocation of resources to projects that do not improve the economy of the country. As highlighted in Harbinger et al, "poorly prepared projects have 16 times as high a probability of failure within 5 yeas as compared to well prepared projects" (Jenkins, 1997). In addition to preventing bad projects from being implemented, a proper investment appraisal also helps to (Harberger *et al.*, 2009):

- show the financial profitability of the project,
- show the economic viability of the project,
- identify sources and magnitude of risks,

- identify project stakeholders, beneficiaries,
- identify the impact of the project on poverty alleviation goals,
- identify fiscal impacts.

An integral part of an integrated investment appraisal is the economic cost benefit analysis. For investors, a financial analysis is more important as it focuses on the financial profitability of the project hence either attracting or repelling investors. An economic analysis is different as it focuses on the impact of the project on the society. An economic analysis of a project asks the question: "how does this project affect the net wealth of the country"? For example if government invests $\$1,200$ into a project and the net present value (NPV) of all cash flows from the project is $500, then the project shrinks the economy. This is because the project uses up more resources than it produces in return. Such projects, from an economic analysis point of view should be avoided.

In economic cost benefit analysis it is important to differentiate between financial prices and economic prices. While financial prices are affected by tariffs, taxes, subsidies, economic pricing is influenced by how much the consumer is willing to pay for an additional unit of the product (or service). These market distortions, if expressed as a proportional distortion D gives a mathematical relationship between economic value and financial value:

$$(1 + D) = \frac{EconomicValue}{FinancialValue}$$

In addition to market distortions contributing to the difference between economic and financial values, it is also possible that financial costs used in financial evaluation may not be the true resource cost. For example, gas is sold to consumers in Nigeria at a financial price that is only a fraction of international opportunity cost. Three postulates -based on a number of fundamental concepts of applied welfare economics - underly the economic evaluation methodology (Harberger *et al.*, 2009):

1. The economic value of a good or service to the demander is measured by the competitive demand price for an incremental unit of the good or service;

2. The economic resource cost of a good or service is measured by the competitive supply price for an incremental unit of the good or service;

3. Costs and benefits are added up without regard to who the gainers and losers are.

Economic cost benefit analysis techniques has been used for various projects in both developed and developing countries. These projects range from a railway, roads, bridges, transportation and electricity generation. To the best of my knowledge very few economic cost benefit analysis techniques has been applied to electricity generation in a developing country via renewable and sustainable means. This is the focus of the essay as we consider a small village in Nigeria as we seek to find out the economic benefits of installing a solar structure to generate power for the entire village.

1.2 Electricity Generation in Nigeria

The world energy consumption is still dominated by petroleum products. Thus the cost and consumption pattern of petroleum are subject to international importation policies and pricing. Current dominant issues such as global warming, ozone layer depletion, acid rain, nuclear plant safety and disposal of radioactive waste products still remain big challenges for the safety of human life on earth. The use of hydrothermal electricity is still the privilege of only the main cities as the extension and subsequent maintenance of transmission lines over long distances and difficult terrains are expensive, particularly as the load becomes relatively small in rural areas.

In Africa, power is a major problem and a big challenge. Like in most African countries, the energy sector in Nigeria is characterized by an over exploitation of the forest resources (wood fuel), a total dependence on petroleum products, and the under exploitation of a potential renewable sources (Babasola and Egbunonu, 2009). The per capita energy consumption is very low, and this is of great concern as a country's level of energy consumption defines to a certain extend its level of development. For instance North American residents consume an average of 30 times more energy than African residents (Enda Tier-Monde)

The Nigeria Electricity supply is currently dominated by a state monopoly, and only 36% of the population have access to the national grid. Out of an installed capacity of around 5, 960 MW, the current generation is between 2, 500MW and 3, 500MW. Transmission and distribution of Grid connected electricity remains expensive across the country, particulary in rural areas due to load characteristics, bad roads, and land characteristics (geometry, access). Power Holding Corporation of Nigeria (PHCN) is currently saddled with the responsibility of providing all the power needed by the more than 120 million people of the country and so far has been doing a poor job regarding electricity generation. The important biomass potential of the country is over exploited. Although the supply of wood fuel has decreased due to increased access to petroleum products, the escalating cost and environmental implications of both wood fuel and petroleum energies are of great concern.

Nigeria per capita power generation relative to GDP in other countries is very low (Osunsanya, 2008). Even though the nation has for so long relied on hydro-thermal electricity generation and transmission as energy source, power supply has still been erratic and unreliable. The challenges in energy generation, transmission and distribution in Nigeria have been daunting despite huge monetary and material investments in the traditional energy sector.

This erratic nature of power supply in Nigeria has crippled many businesses causing commercial consumers to rely heavily on privately owned generating units (Diesel/ Petrol) as alternative to the irregular electrical power supplied by PHCN. Industrial consumers pay premium price (400% of grid price) to run the generating units, thus making cost very high. Residential consumers who can afford generating systems spend bulk of their income fueling and maintaining these units. The noise generated by such systems is alarming and the hazardous fumes emitted has resulted in loss of many innocent lives. Power is definitely a major factor that affects the socio-economic status of a Nation and has been a perennial problem in major parts of the African continent.

The current power demand in Nigeria is estimated to be about $10,000$MW with growth rate of about 8% annually while the installed generating capacity of PHCN is about $6,000$MW (currently generating between $2,500$MW and $3,500$MW). This shows that most of the industrial and residential power needs cannot be adequately provided by the National power grid and premium price would continue to be paid for electrical supply provided by current available alternative (Diesel/Petrol Generating sets).

The African continent is blessed with so much natural resources and an abundance of sources of sustainable and renewable energy. Unfortunately these resources have been left untapped and even as the developed countries are moving towards renewable energy, the continent is sitting still. In this essay, we conduct an economic cost benefit analysis of installing such electricity generating renewable and sustainable source of electrical power in a village that is not connected to the grid and lacks electricity.

1.3 Solar Energy Technology

Recently there has been a big movement towards having more electricity generated from sustainable and renewable means. On May 14, 2009 the Ontario Bill 150, Green

Energy and Green Economy Act, 2009 was passed into law. The purpose of the Ontario Green Energy Act is to make Ontario a global leader in the development of renewable energy, clean distributed energy and conservation - creating thousands of jobs, economic prosperity, energy security, and climate protection (Act, 2009). Prior to this, the Ontario government had the Standard Offer Program structure in place to encourage electricity generation via renewable and sustainable means. In the United States of America and in European Countries, there has been more programs and incentives put in place to encourage a shift towards a ”greener” culture. In addition to protecting the environment, using renewable sources to generate electricity has been found to be cheaper, cleaner, less noisy and above all sustainable. Different sources of renewable and sustainable energy exists including wind, solar, geothermal, fuel cells, etc. For the purpose of this essay, our focus will be on solar energy.

Solar energy, particularly the direct conversion of sun light into electricity by photovoltaic cells, has been used successfully for many years in space programmes where the cost is not a major factor provided the mission is successfully accomplished [Green and Wenham, 1995]. However, the large-scale use of photovoltaic (PV) modules for terrestrial applications is still hampered by the high cost of their unit energy as their efficiency still remains low (efficiency is defined as the percentage of solar radiation hitting a solar panel that is converted to electricity). For instance, the maximum recorded laboratory efficiency of a monocrystalline module cell is 24.7% while the typical module efficiency is between 12% and 15%. A silicon multi-crystalline module efficiency varies between 11% and 14%, with a maximum recorded laboratory efficiency of 19.8%, while the amorphous module efficiency lies between 5% and 7% for a maximum recorded efficiency of 12.7% (ACRE, 2004; Green, 2003; Deco, 2003). Solar power uses the energy from the sun to directly generate electricity. It is a free, abundant, renewable and clean energy source. The benefits of solar power are enormous. Some of the benefits includes but not limited to the following (Babasola and

Egbunonu, 2009):

- Provides constant, uninterrupted power supply
- Possible to use it without transmission lines and their associated problems
- Eradicates the need for generator and hence savings on diesel
- It's very quiet in contrast to the noisy generators currently in use.
- Little or no maintenance cost
- Could eliminate monthly payment of power bills (one time installation cost)
- Decreases the amount of local air pollution and carbon footprint
- No moving parts (i.e no parts that can be affected by friction, hence a need for a lot of maintenance and replacement)
- Safe

Solar energy is plentiful, essentially free and very environmentally friendly. It requires very little or no maintenance once the initial installation is completed. It can be used for heating water and air in homes or small buildings, and also for electricity generation using photovoltaic panels. Solar energy is measured in watts per square meter (W/m^2). On a clear day approximately $1000W/m^2$ of solar energy is available at the Earth's surface when facing the sun. The amount of available solar energy is also dependent upon the sun's height in the sky throughout the day.

The major downside of a solar system is the initial installation cost which can be very high. This initial cost discourages a lot of people from installing such structures in their homes/business. For homes and business with air conditioning units, this initial costs can be very high.

1.3.1 Electricity Generation

The main component of a solar structure is the solar panel (also known as Photovoltaic Cells). A solar panel (PV panel) is made of the natural element silicon, which becomes charged electrically when subjected to sun light. Solar panels are directed at solar south in the northern hemisphere and solar north in the southern hemisphere (these are slightly different from magnetic compass north-south directions) at an angle dictated by the geographic location and latitude of where they are to be installed. Typically, the angle of the solar array is set within a range of between site-latitude-plus 15 degrees and site-latitude-minus 15 degrees. This electrical charge is consolidated in the PV panel and directed to the output terminals to produce low voltage (direct current) - usually 6 to 24 volts. The most common output is intended for nominal 12 volts, with an effective output usually up to 17 volts (see Figure 1.1). The intensity of the Sun's radiation changes with the hour of the day, time of the year and weather conditions. To be able to make calculations in planning a system, the total amount of solar radiation energy is expressed in hours of full sunlight per mm^2, or Peak Sun Hours. This term, Peak Sun Hours, represents the average amount of sun available per day throughout the year.

The four primary components for producing electricity using solar power, which provides common 120 volt AC power for daily use are solar panels, charge controller, battery and inverter. Solar panels charge the battery, and the charge regulator insures proper charging of the battery. The battery provides DC voltage to the inverter, and the inverter converts the DC voltage to normal AC voltage. If 240 volts AC is needed, then either a transformer is added or two identical inverters are series-stacked to produce the 240 volts. In order to maximize the sun's energy year-round, PV systems are required to be positioned at an inclination, an angle equal to the area's latitude. Differing the orientation and/or inclination will further maximize energy production for the morning or afternoon, or for the changing seasons.

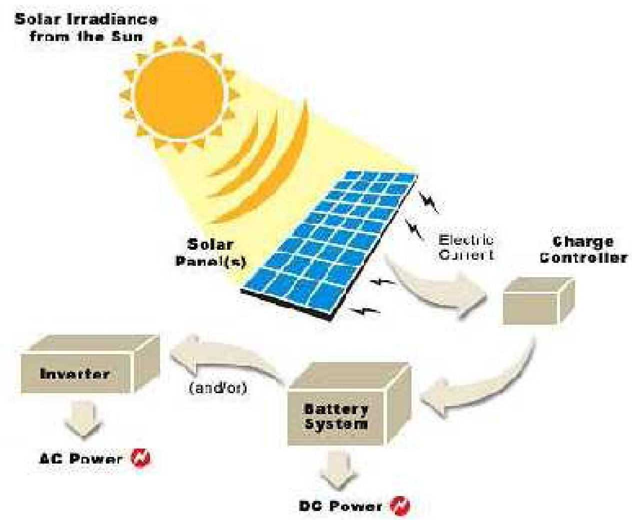


Figure 1.1: Solar energy for electricity generation

For this essay, we focus on solar energy as a source of renewable energy. There is a lot of solar radiation available in Nigeria. The only challenge with using solar panels in such region is the potential steady high temperatures obtainable in such regions. Unlike solar thermal devices, solar photovoltaic modules have a lower power output as their cells get hotter. In hot and dry climates, periods of bright sunshine, are usually also periods of high ambient temperatures, and therefore a reduced performance (efficiency) period for the PV module. For instance a silicon solar cell at 20^{o}C delivers about 20% more power than at 70^{o}C. PV modules are typically 20^{o}C warmer than the air temperature (Wolf, 1995; Hankins, 1995). The specific investment cost for solar PV grid connected system is around US \$10 million per MW as compared to US \$2 million for nuclear power, US \$0.5 million for thermal power, and US \$1.0 million for wind. The average cost of PV grid connected energy is around US Cent 30 per KWh (Diarra *et al.*, 2009).

1.4 Overview of Essay

This essay will be based on a practical application of economic cost benefit analysis techniques to the installation a sustainable renewable energy structure to generate electricity for a rural area in a developing country in Africa. So far such specific analysis has not been found in literature especially for the village under study. There are several rural areas in Africa that are off the grid and may never enjoy electricity due to various factors beyond their control. For such a rural area, this study will assess the economic benefit of generating electricity via a sustainable and renewable means. For this essay and for ease of obtaining data, we will consider **solar** energy.

A solar structure, involves utilizing an array of photovoltaic cells (in series or parallel) to capture sunlight and convert it into electricity. Using inverters, the electricity generated is converted into a mode that can easily be used in homes (William, 2004). An economic analysis of the project mentioned above is very important as it helps determine whether the project on a whole will increase the net wealth of the country and positively impact the society. This essay involves working closely with AEPAY Global Energy Corporation to collect the necessary data needed for the analysis, and using NETScreen for some of the engineering design and specifications.

The contribution of this original work is manifold. First, it helps to highlight if there is an economic benefit of installing the aforementioned structure in a developing country using the project village as a case study. Secondly, we hope to actually source for funds with this study in order to implement the project for the village under study. Thirdly, we hope that by carrying out this study and implementing, it will serve as a motivation for other communities, government, organizations to want to do more for the African continent with respect to renewable energy. Finally, we hope to put a smile on the faces of the villagers by implementing the project (there is already a lot of excitement in the village especially when they heard about the study).

This essay is structured as follows. In Chapter 2, a detailed description of the project and the village under study is given with feasibility and engineering studies for the project. In Chapter 3, a financial analysis of the project is presented. In Chapter 4, an economic appraisal of the project is done and presented. Chapter 5 consists of the stakeholder impact analysis while Chapter 6 is the sensitivity and risk analysis. Finally I draw my conclusions in Chapter 7.

Chapter 2

Project Description and PV Sizing

2.1 Photovoltaic Electricity Generation

A nation's electricity consumption goes a long to show how much development is taking place in that country. In most cases, access to reliable energy is a major factor in encouraging or discouraging new business and hence industrialization. As global demand for electricity increases, the demand for solar electric power systems is also on the increase (RETScreen, 2001-2004). One of the greatest drivers of the worldwide solar power industry today is the need for reliable and low cost electricity power in isolated areas of the world. It is estimated that there will be a significant growth in demand for such systems to meet the basic electrical needs of 2 billion people without access to conventional electricity grids (RETScreen, 2001-2004).

2.1.1 Solar Structure Composition

The basic component of the solar system for generating electricity are the photovoltaic cells. The term photovoltaic is derived from the Greek language "photo" meaning light, and "voltaic", voltage which assists the flow of electricity. The PV cell effect was discovered in the 1950s at Bell Laboratories(William, 2004). Other components of a solar system -depending on the application- can include batteries, inverters, controllers, tracking device, rectifiers, generators, etc. For the purpose of this project, the complete solar system for generating electricity consists of the following components:

- **Photovoltaic (PV) Modules**: PV modules convert the energy from the sun into electrical energy that can be used to power homes, electrical appliances, etc. PV modules consists of PV cells made using crystalline silicon wafers or advanced thin film technology (see Figure 2.1) . Since the primary application of PV involves battery charging, most modules are made to deliver direct current (DC). A typical crystalline silicon module consists of a series circuit of 36 cells, encapsulated in a glass and plastic package for protection from the environment. This package is framed and provided with an electrical connection enclosure, or junction box. Typical conversion (solar energy to electrical energy) efficiencies for common crystalline silicon modules are in the 11 to 15% range(RETScreen, 2001-2004).

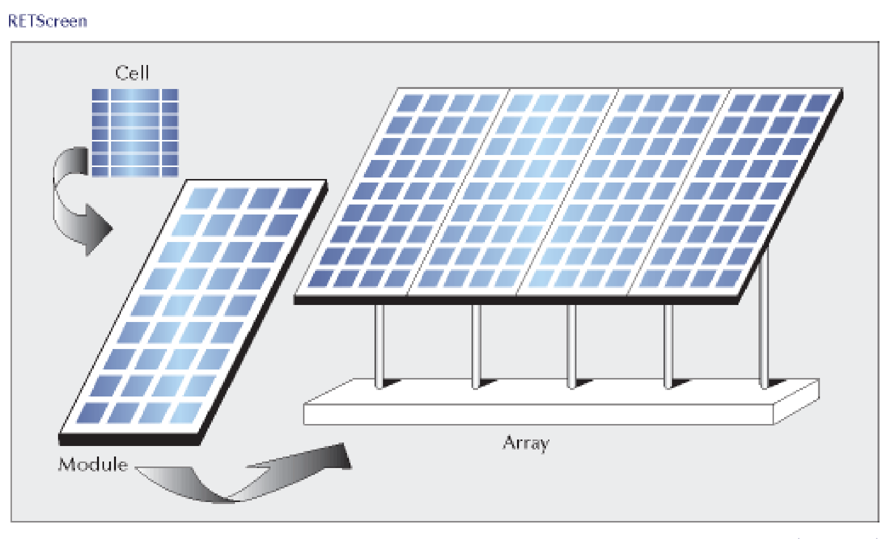


Figure 2.1: Photovoltaic Cells

For the purpose of this project, our PV modules will have cells made from mono/poly crystalline silicon wafers. PV modules are rated on the basis of the power delivered under Standard Testing Conditions (STC) of 1 kW/m^2 of sunlight and a PV cell temperature of 25 degrees Celsius (^oC). Their output measured under STC is expressed in terms of peak Watt or W_p nominal capacity.

- **Battery** : The second most important component of the Solar System structure -especially in an off-grid scenario- are the batteries. Since the sun is not available all day long, it becomes pertinent to make sure that the structure can provide energy when the sun is not shining, hence the need for an energy storage device. The most common battery types are lead-calcium and lead-antimony. Nickel-cadmium can be used , especially when the battery is exposed to a wide variety of temperature. The amount of battery capacity that can be discharged without damaging the battery depends on the battery type. Lead-calcium batteries are suitable only in shallow cycle applications where less than 20% discharge occurs each cycle. Nickel-cadmium batteries and some lead-antimony batteries can be used in deep cycle applications where the depth of discharge can exceed 80% (RETScreen, 2001-2004). The capacity of the battery is expressed in Ampere-hours (Ah). In order to calculate the amount of energy a battery can store (in Watt-hours (Wh)). For example, a 40 Ah, 24 V battery will store $40 \times 24 = 960$ Wh of electricity under nominal conditions.

- **Inverters**: Most home electrical appliances (and utility grids) require alternating current (AC). Since the output from the PV modules and/or battery is Direct Current (DC), there is a need to convert the direct current to alternating current. This is the function of inverters.

- **Controllers**: These regulate the charge and discharge cycles of the battery

- **Maximum Power Point Tracking**: Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of.

- **Structure**: Required to mount or install the PV modules and other components.

- **Power Cable**: This delivers the electricity from a central system to the various homes and business facilities.

2.1.2 Photovoltaic Applications

There are various application of a PV system. For electricity generation, such applications can either be "on-grid" or "off-grid".

In on-grid systems, the solar system feeds electrical energy directly into the electric utility grid. This includes central on-grids and distributed on-grids. In central on-grids, all the electrical power from the solar system is sent directly to the grid. In distributed on-grid, some of the electrical energy is used for the load (in the house or facility) with excess energy from the system sent directly to the grid. On-grid systems are most common in Canada especially with the incentive of government paying for electricity supplied to the grid. In on grid situations, the solar system is connected to the grid and during down times (when there is no sun), electricity is supplied to the load (in the house or facility) from the grid. This is very relevant in developed areas with good grid connections, where the solar system is an alternate source of electrical energy. For very reliable grid systems, the need for back-up batteries is not really much and one can afford not to include batteries in the system.

Off grid application is most relevant in areas that are isolated from the electric grid. In these type of applications, incorporating batteries in the solar structure becomes very important as the PV is frequently used to charge the batteries thus providing the user with electricity on demand. Off-grid applications are very competitive against electric grid extension, primary (disposable) batteries, or diesel, gasoline and thermoelectric generators. The cost of grid extension in the US, estimated by the Utility Photovoltaic Group (UPVG) ranges from US $20,000 to US $80,000 per mile. Thus, PV competes particularly well against grid extension for small loads, far from the utility grid (RETScreen, 2001-2004). The main advantage of a solar structure when compare to all these is the low operation, maintenance and replacement costs.

For this project, the village is isolated from electrical grid hence an off grid application is more relevant (see Figure 2.2) . The electricity is conveyed to the village via an underground cable. Each house will be equipped with a miniature circuit breaker to avoid overloading the system.

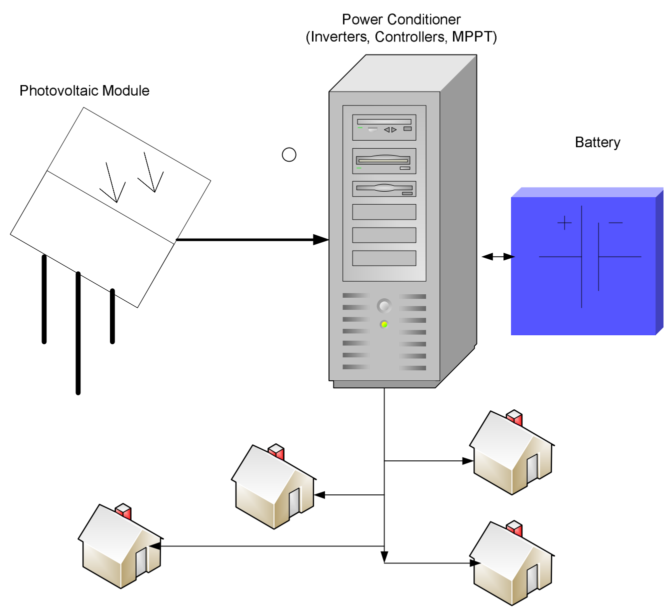


Figure 2.2: Schematic Diagram of Solar Electrical Energy Distribution in Village

2.2 Engineering

2.2.1 Project Site Description

Our case study is a village in Nigeria called **Samo**. Samo consists of four household of the Yoruba people of Nigeria. The project site is located at latitude 7.0^oN and longitude $3.5^o E$ and the nearest location for weather data (needed to size our solar structure) is Ijebu Igbo in Ogun State. Located in Ogun State, Nigeria, Samo is located along the Sagamu-Abeokuta expressway (beside a new police college and opposite a Radio Station (Paramount FM)). It is surrounded very closely by three other villages: Kuluku, Basala and Akete all located in Ogun State. The three villages have 8, 7 and 9 households, respectively. Only one man in the entire four villages has (and can afford) a generator set to charge phones, light 2 bulbs and watch a television set. The central location of Samo makes it attractive especially as a pioneering project site for such systems. Samo has been in existence for a long time and has no access to electrical power. Mr Samuel Sorinola is the leader of this community.

The solar structure for the Samo community can be considered as a central "off-grid" system that will supply electricity to the four households. In this essay the focus will be on the economic cost benefit analysis of installing a centralized photo-voltaic (PV) power plant for this village that is far from an electricity grid. Funding for actual implementation of the project will be sourced from Canadian International Development Agency (CIDA), United Nations Development Programme (UNDP) and other bodies that can be part of this pioneering effort. The project team will consists of Engineers and Technicians from AEPAY Global Energy Corporation, a renewable energy company based in Canada and with a branch in Nigeria. For actual installations, and commissioning, we will involve the National Electricity Provider to get permission and also involve them in monitoring the project. We now design the PV system for this village (Figure 2.3, Figure 2.4,Figure 2.5).

Figure 2.3: Picture of Samo Village in Ogun State

Figure 2.4: Samo

Figure 2.5: Samo

Current Electrical Need	Power (W)	Quantity	Total Power (W)
Electric Bulbs	60	5	300
Television	100	1	100
Fans	13	2	26
Radio	10	2	20
TOTAL	....	....	446

Table 2.1: Total Current Capacity

Current Electrical Need	Power (W)	Quantity	Total Power (W)
Electric Bulbs	13	5	65
Television	100	1	100
Fans	13	2	26
Radio	10	2	20
TOTAL	.....	.....	211

Table 2.2: Total Proposed Capacity

2.2.2 PV Sizing

The first step in sizing the PV modules is to determine the power needs of Samo village. In order to do this, we have to determine the power needs of each of the four households. The base case for the project is the existence of no electricity. This means that the project represents a 100% change from the base (without electricity) case. Table 2.1 shows the current capacity for each household in the village.

Since we are incorporating energy efficiency with energy generation for this project, the proposed load for each household in the village is also calculated and presented in Table 2.2 (where the 60 W electrical bulbs are replaced by a more efficient 13 W bulbs.

This brings the total power need for each household to 211 W (or 0.211 KW) and the entire village power need to 0.844 KW. For this project, we will assume the total load requirement (capacity) for Samo to be 1.3 KW. This is calculated by multiplying

Load	Total Power (KW)	Daily Hourly Use (hr)	Energy Use (KWhr)
Bulb	0.065	10	0.65
TV	0.100	10	1.0
Fan	0.026	10	0.26
Radio	0.02	15	0.3
TOTAL	0.211	....	2.21

Table 2.3: Total Proposed Daily Energy Usage

the actual need by 1.5. i.e.

$$\text{Total Load Sizing} = \text{Actual Load Requirement} \times 1.5 \tag{2.1}$$

$$\text{Total Load Sizing} = 0.844 \text{ KW} \times 1.5 \tag{2.2}$$

$$\text{Total Load Sizing} = 1.266 \text{ KW}$$

$$\text{Total Load Sizing} \simeq 1.3 \text{ KW}$$

Finally we need to understand how much energy (in KWhr) that each household consumes in a day in order to calculate the total amount of electrical energy that the village will consume. We design the system with the proposed case in mind but with an eye on the current load. It is very important to implement the energy efficiency measures so as to reduce the overall costs of our system. Table 2.3 shows the computation for the total daily energy needs in a households (and in the village) in KWhr

Therefore we have the energy of each household as 2.21 KWhr per day or 15.47 KWhr per week. This gives us a total of 8.84 KWhr per day or 61.88 KWhr per week energy needs for the entire village (since we have 4 households in the village).

The final engineering analysis is done using the RETScreen software (Figure 2.6). The RETScreen Clean Energy Project Analysis Software is a unique decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, is used to evaluate energy production and savings, costs, emission reductions, financial viability and risk for various types of renewable-energy and energy-efficient technologies (RETs). The software is available in multiple languages and includes a worldwide hydrology and climate databases which is very important for this project.

2.2.3 Summary

From the analysis and design, we have that the total power capacity of the centralised PV module -based on the total load in the village - is 1.30 KW. This PV system for Samo consists of a solar array of 9 modules of 165 W capacity each. We select a Polycrystalline Silicon (Poly-Si) as the cell type for our PV module with an efficiency of 13.1%. The mono-Si is more expensive than the poly-Si PV cells but with greater efficiency. Right now, we are assuming that the modules will be supplied by BP Solar (the other alternative is ARISE Technologies in Waterloo, Canada). The sub-arrays will be fixed a 45^o tilt angle.

The battery bank will consists of cells connected in series to provide 48 V nominal storage voltage. The total capacity of the battery bank is 1,155 Ah. The battery bank is designed to supply 55 KWh of energy with 3 days of autonomy. The days of autonomy is the number of days that the system, starting from a state of full charge, would be able to meet the load using the batteries only.

The system uses an inverter with a capacity of 0.9 KW. We use 0.9 KW since it is the expected peak load for the village. The peak load is the maximum power that is required assuming all the appliances in the village are on at the same time. This can be upgraded if needed. The electricity will be conveyed to the village via an underground cable and each house equipped with a circuit breaker to avoid system overload.

The village has never had electricity and with the small population and low load

Component	Inverter
Capacity	0.9 KW
Efficiency	90%

Table 2.4: Inverter Details

Component	Battery
Days of Autonomy	3 days
Voltage	48 V
Efficiency	80%
Maximum depth of discharge	80%
Charge controller efficiency	95%
Capacity	$1,155$ Ah
Battery Power	55 KWh

Table 2.5: Battery Details

demand, there is a high possibility that they may never get one. Comparing it with the base case of an electric generator, it is seen that the proposed case of a PV structure is better. Apart from the financial benefits, the source is clean, sustainable and renewable. Tables 2.4, 2.5, 2.6 gives a summary of the engineering components of our proposed PV structure (calculated using RETScreen 4.1).

Component	**Photovoltaic**
Type	mono-Si
Power Capacity	1.49 KW
Manufacturer	BP Solar
Model	Poly-Si-BP 3165
Number of units	9
Efficiency	13.1%
Nominal operating cell temperature	45^oC
Temperature coefficient	0.40%
Solar collector area	11.3 m^2
Control method	Maximum power point tracker
Miscellaneous	2.0%
Capacity factor	18.9%
Electricity delivered to load	2.15 MWh
Solar tracking mode	Fixed
Slope	45.0

Table 2.6: Photovoltaic Details

Natural Resources Canada | Ressources naturelles Canada | Canada

RETScreen® International

www.retscreen.net

Clean Energy Project Analysis Software

Project information

See project database

Project name	Samo Community - 1.3 kW - Off-grid
Project location	Nigeria
Prepared for	MA Essay
Prepared by	Patrick Egbunonu
Project type	Power
Technology	Photovoltaic
Grid type	Off-grid
Analysis type	Method 2
Heating value reference	Lower heating value (LHV)
Show settings	☐

Site reference conditions

Select climate data location

Climate data location	Ijebu Igbo
Show data	☑

	Unit	Climate data location	Project location
Latitude	°N	7.0	33.3
Longitude	°E	4.0	4.0
Elevation	m	104	104
Heating design temperature	°C	21.4	
Cooling design temperature	°C	29.8	
Earth temperature amplitude	°C	7.3	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		26.0	68.6%	5.32	99.9	2.7	27.6	0	496
February		26.4	72.7%	5.48	99.8	2.9	28.1	0	458
March		26.2	81.5%	5.37	99.8	2.7	27.7	0	502
April		26.3	83.4%	5.21	99.8	2.4	27.6	0	488
May		26.2	84.3%	4.79	99.9	2.1	27.4	0	501
June		25.4	85.3%	4.15	100.1	2.3	26.3	0	461
July		24.5	84.8%	3.88	100.2	2.5	25.1	0	449
August		24.2	84.6%	4.04	100.2	2.6	24.9	0	440
September		24.6	85.8%	3.96	100.1	2.4	25.3	0	437
October		24.9	85.9%	4.44	100.0	2.1	25.8	0	462
November		25.2	83.0%	4.95	99.9	2.1	26.3	0	456
December		25.5	74.7%	5.21	99.9	2.4	26.5	0	480
Annual		25.4	81.3%	4.73	100.0	2.4	26.5	0	5,630
Measured at	m					10.0	0.0		

NASA UNEP GEF reeep

Complete Energy Model sheet

RETScreen4 2009-05-25 | © Minister of Natural Resources Canada 1997-2009. | NRCan/CanmetENERGY

Samo Community - 1.3 kW - Off-grid
Nigeria

02/08/2009
RETScreen4-1

Figure 2.6: Start Page for Engineering Modeling using RETScreen

Chapter 3

Financial Analysis

3.1 Introduction

Electricity is a big challenge for many communities in Africa especially those who are isolated from the national electricity grid. For most of these communities, the government expects them to be responsible for any grid extension and provision of transformers for the generation of electricity. Because of the high cost of such projects most communities with financial capabilities opt for generators as means to generate electricity. These have their own challenges. Apart from the noise, and environmental pollution that comes with the use of generators, the high cost of diesel is also a major challenge. Currently, in Nigeria diesel is sold at $NGN5.98$ per liter where the current foreign market exchange rate is $NGN149$ per $1US$. All financial prices are given in the local currency (Nigerian Naira [NGN]). In this section we first start by stating the total initial investment cost for the project. Financing for the project will include debt financing and equity. It is projected that 57% of the total initial investment cost will be debt financed at an annual real interest rate of 7.00%.

Category	**Total Amount**
Feasibility Studies	128,140.00
Development	476,800.00
Materials and Procurement	5,622,515.00
Engineering	1,260,540.00
Total	**7,487,995.00**

Table 3.1: Summary of Initial Investment Costs (NGN in 2009 prices)

3.2 Cost Estimates

The project life of the solar structure is 28 years. The four parts of the project includes detailed feasibility, development, materials and procurement, actual engineering. A summary initial investment costs is given in Table 3.1. A more detailed break down of feasibility, development, materials and engineering costs is given in Table 3.2, Table 3.3, Table 3.4, and Table 3.5 respectively. From these tables we see that the total initial investment cost of the project is NGN7,487,995.00 in 2009 prices (or USD $50,255).

3.2.1 Operating and Maintenance Costs

The great thing about using renewable energy to generate electricity is the low maintenance costs. This is largely due to the absence of large moving parts. With the project is estimated at about NGN 7,450 annually for maintenance and other expenses. Also, we assume that the battery needs to be replaced every 8 years. All future costs are adjusted for inflation. The recent June 2009 Nigerian inflation rate of 11% is used for all such adjustments. The United States inflation rate is taken assumed to be 3% for all relevant calculations. The total operational and maintenance real costs for the 28 year life of the project is NGN 3,520,870.00

Category	Amount
Skilled Labour Wages	32,780.00
Unskilled Labour Wages	65,560.00
Travel and Accommodation	29,800.00
Total	NGN 128,140.00

Table 3.2: Feasibility Costs (NGN in 2009 prices)

Category	Amount
Skilled Labour Wages	81,950.00
Unskilled Labour Wages	98,340.00
Legal and Accountant	81,950.00
Travel and Accommodation	74,500.00
Cost of Land	74,500.00
License Fees, Permits and Approvals	65,560.00
Total	476,800.00

Table 3.3: Development Costs (NGN in 2009 prices)

Category	Amount
PV Panels	1,147,300.00
Transmission Cable	298,000.00
Efficiency Measures	149,000.00
Battery	1,132,400.00
Inverter	521,500.00
Support Structure	283,100.00
Installation	59,600.00
Taxes and Duties at Port of Entry	1,154,750.00
Taxes on Equipment	529,695.00
Transport to Samo	223,500.00
Unskilled Labour (Security)	49,170.00
Travel and Accommodation	74,500.00
Total	5,622,515.00

Table 3.4: Material Costs (NGN in 2009 prices)

Category	Amount
Skilled Labour Wages	163,900.00
Skilled Labour Wages	163,900.00
Unskilled Labour Wages	327,800.00
Electrical Equipment and Materials	74,500.00
Travel and Accommodation	521,500.00
Taxes on Equipment	8,940.00
Total	1,260,540.00

Table 3.5: Engineering Costs (NGN in 2009 prices)

3.3 Financial Evaluation

Using integrated investment appraisal framework, we start with the financial evaluation of the project. We do this by assessing the incremental import of the project in which the "with" and "without" project scenarios must be identified. Under the "without" project scenario, the solar structure will not be installed and the village will be left without electricity for a long period of time. In the "with" project scenario, the solar project - which did not exist initially- is implemented. All the new assets are considered as investments. In this section, we assess whether the implementation of the project is viable from the investor point of view. We also identify key variables that affect the feasibility of this project.

3.3.1 Project Parameters and Assumptions

The financial model for the solar project has been developed, based on the following calculations and/or assumptions:

- The total initial investment cost inclusive of the VAT is estimated at NGN $7,487,995.00$ (or USD $\$50,255.00$) in 2009 prices.
- Land is given to the project as a subsidy by the village. This land is returned to the village at the end of the project
- There is no residual value for all the assets at the end of the project.
- The project cost is to be financed by 43% equity and 57% loan from a bank.
- The loan will be disbursed immediately with repayment of principal and interest spread over 14. The loan is to be repaid in 14 equal installments.
- The interest rate to be charged by the bank (a fixed rate) is based on an underlying real interest rate assumed to be 7% per annum. After accounting for the

expected inflation rate in Nigeria, the resulting nominal interest rate is 18.77% per annum.

- The minimum real rate of return required by the private investor is 10%.
- The inflation rate is expected to be 11% per annum in Nigeria and 3% per annum in USA.
- The real exchange rate as of July 2009 is 149 NGN/US$.
- The Value Added Tax rate in Nigeria is 5%.
- Personal income earned is taxed at 10%.
- The income earned by the private investor is subject to Corporate Income Taxation at a rate of 30%.
- Total annual power generated for Samo village is 4.84 MWhr per annum.
- Assets are depreciated over a 15 year period for tax purposes.

3.3.2 Financial Income and Cashflow

The financial model is constructed with the assumption that the electricity generated will be sold to the villagers at the same rate as the national rate- NGN 5.98. We assume that the income from the village is the only source of annual revenue for the village in the financial computations. Furthermore, we assume that this tariff is subject to an annual increase of 1% real due to the excess demand for electricity. For simplicity, we assume further that there is no difference between revenue and cash inflow nor between expenditure and cash outflow in the model. Based on the aforementioned assumptions and parameters, the financial cash flow statement from the point of view of total investment is built. This analysis will be of great interest to AEPAY GLOBAL ENERGY CORPORATION, as they consider investing in the actual implementation of the project. It will will also be of great interest to banks, and development organizations that will be approached to finance this project. The Table in Figure 3.1 shows the cash flow (in nominal prices) for the entire 28 year duration of the project. Meanwhile, the Table in Figure 3.2 shows the cash flow in real prices together with some ratios calculated to help the lender evaluate the ability of the project to meet it's debt obligations. The first ratio is the Annual Debt Service Coverage Ratio (ADSCR). The ADSCR is the ratio of the annual net cash flow of the project before financing, over the annual debt repayment (interest and principal) for the same period. The second ratio- Loan Life Cover Ratio (LLCR)- is the present value of the net cash flow before financing during the loan repayment period divided by the present value of the remaining debt obligations, using the real interest rate on the loan as a discount rate.

The financial cash flow analysis from the banker's perspective is not encouraging because the annual debt service coverage ratios are less than 1. The minimum value is -3.42 and the maximum is 0.07. The negative value means that in that year, there is a negative net cash flow. Also, the loan life cover ratios are also less than 1 with some negative ratios. The minimum value is -1.82 and the maximum is 0.07. These numbers implies that the project might not be able to meet the financial obligations to the lender.

The Equity Owner cash flow summary can also be found on the Table in Figure 3.2 just below the banker's summaries. It enables us to address the question of whether the flow of financial benefits over the lifetime of the proposed project is big enough to pay off the capital and operating expenditures incurred, and also earn a required rate of return on equity. For this to be possible, the present value of the discounted net financial benefits over the life of the project should not be less than zero. That is, the owner of the project (private investor) would receive a real rate of return on the investment at least equal to 10% real.

Year--->	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
INFLOWS																													
Tarriff Revenue	0	32	36	40	45	51	57	64	71	80	90	101	113	127	142	159	178	200	224	251	282	316	354	397	445	499	559	627	703
Land (subsidy)	75																												
Grant																													
Liquidation (Land)																													1388
Total Inflows	**75**	**32**	**36**	**40**	**45**	**51**	**57**	**64**	**71**	**80**	**90**	**101**	**113**	**127**	**142**	**159**	**178**	**200**	**224**	**251**	**282**	**316**	**354**	**397**	**445**	**499**	**559**	**627**	**2091**
OUTFLOWS																													
CAPITAL EXPENDITURES																													
Feasibility Studies																													
Skilled Labour Wag	33																												
Unskilled Labour W	66																												
Travel and Accomo	30																												
Development																													
Skilled Labour	82																												
Unskilled Labour	98																												
Legal/Acc.	82																												
Travel/Accomodati	75																												
Cost of Land	75																												
Licence, Permit, Ap	66																												
Materials																													
PV Panels	1147																												
Transmission Cable	298																												
Efficiency Measure	149																												
Battery	1132							2357							4894							10161							
Inverter	522																												
Support Structure	283																												
Installation	60																												
Taxes and Duties at	1155																												
Taxes on Equipmer	530																												
Transport to Samo	224																												
Unskilled Labour (S	49																												
Travel and Accomo	75																												
Engineering																													
Skilled Labor 1	164																												
Skilled Labor 2	164																												
Unskilled Labor	328																												
Electrical Equipmer	75																												
Travel and Accomo	522																												
Taxes on Equipmer	9																												
OPERATING EXPENSES																													
Miscellaneous		8	9	10	11	13	14	15	17	19	21	23	26	29	32	36	40	44	49	54	60	67	74	82	91	101	112	125	138
Principal + Interest Payment		1086	1032	979	925	872	819	765	712	658	605	552	498	445	391	338	0	0	0	0	0	0	0	0	0	0	0	0	0
Corporate Tax Payments		0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	42	47	53	59	66	0	84	94	106	119	134	151	586
Total Outflows	**7488**	**1094**	**1041**	**989**	**937**	**885**	**833**	**3138**	**729**	**677**	**626**	**575**	**524**	**474**	**5318**	**395**	**81**	**91**	**101**	**113**	**127**	**10228**	**158**	**177**	**197**	**221**	**246**	**275**	**724**
Net Cash Flow	-7413	-1062	-1005	-949	-892	-834	-776	-3074	-658	-597	-536	-474	-411	-347	-5176	-236	97	109	123	138	155	-9912	196	220	248	278	313	352	1367

Figure 3.1: Financial Cash Flow Statement (Nominal Prices)(thousand NGN)

The results of the financial analysis from the owner's perspective shown on the Table in Figure 3.2 depicts a negative Net Present Value (NPV) of NGN 7.62 million accruing to the private investor, using 10% real return rate on equity as the discount rate. This implies that the private investor will not be able to earn 10% real return on his investment after deducting the operating costs from revenue. The Internal Rate of Return (IRR) on the project is negative. The Internal Rate of Return (IRR) is the discount rate of the project that will make the net present value of all net financial

Year--->	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
INFLOWS																											
Tarriff Revenue	0	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Land (subsidy)	75																										
Grant																											
Liquidation (Land)																											
Total Inflows	**75**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**	**29**
OUTFLOWS																											
CAPITAL EXPENDITURES																											
Feasibility Studies																											
Skilled Labour Wages	33																										
Unskilled Labour Wages	66																										
Travel and Accomodation	30																										
Development																											
Skilled Labour	82																										
Unskilled Labour	98																										
Legal/Acc.	82																										
Travel/Accomodation	75																										
Cost of Land	75																										
Licence, Permit, Approval	66																										
Materials																											
PV Panels	1147																										
Transmission Cable	298																										
Efficiency Measures	149																										
Battery	1132							1132							1132							1132					
Inverter	522																										
Support Structure	283																										
Installation	60																										
Taxes and Duties at Port	1155																										
Taxes on Equipment	530																										
Transport to Samo	224																										
Unskilled Labour (Security)	49																										
Travel and Accomodation	75																										
Engineering																											
Skilled Labor 1	164																										
Skilled Labor 2	164																										
Unskilled Labor	328																										
Electrical Equipment	75																										
Travel and Accomodation	522																										
Taxes on Equipment	9																										
OPERATING EXPENDITURES																											
Miscellaneous		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Corporate Tax Payments		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	6	6	6	0	6	6	6	6	6
Total Outflows	**7488**	**7**	**7**	**7**	**7**	**7**	**7**	**1140**	**7**	**7**	**7**	**7**	**7**	**7**	**1140**	**8**	**14**	**14**	**14**	**14**	**14**	**1140**	**14**	**14**	**14**	**14**	**14**
Net Cash Flow before Financing	-7413	21	21	21	21	21	21	-1111	21	21	21	21	21	21	-1111	21	15	15	15	15	15	-1111	15	15	15	15	15
Discounted PV of Net Cash Flow		-788	-890	-1003	-1127	-1263	-1413	-1578	-513	-588	-671	-762	-861	-971	-1092	21											
Discounted PV of Loan Repayment		4001	3759	3515	3269	3020	2768	2513	2254	1991	1724	1451	1174	891	601	304											
ADSCR		**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**-2.40**	**0.05**	**0.05**	**0.05**	**0.06**	**0.06**	**0.06**	**-3.42**	**0.07**											
LLCR		**-0.20**	**-0.24**	**-0.29**	**-0.34**	**-0.42**	**-0.51**	**-0.63**	**-0.23**	**-0.30**	**-0.39**	**-0.52**	**-0.73**	**-1.09**	**-1.82**	**0.07**											
Annual Loan Disbursement	4268	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
Annual Loan Repayments	0	583	563	543	524	504	484	464	444	424	404	384	364	344	324	304	0	0	0	0	0	0	0	0	0	0	0
Net Cash flow after Financing	-3145	-562	-542	-522	-502	-482	-462	-1575	-422	-402	-383	-363	-343	-323	-1435	-283	15	15	15	15	15	-1111	15	15	15	15	15
NPV	**-7621**																										

Figure 3.2: Financial Cash Flow Statement (Real Prices) (thousand NGN)

cash flows to be zero. Mathematically, IRR can be calculated using the formula:

$$NPV = \sum_{n=0}^{N} \frac{A_n}{(1 + IRR)^n} \tag{3.1}$$

Where n is the year under consideration and N is the life of the project. A is the amount of net financial cash inflow after financing in year n. A higher IRR usually increases the probability of undertaking the project. Based on these two investment criteria, the private investor will not be encouraged to undertake the project nor would the lender be likely to finance the project.

3.4 Summary

The financial analysis of the PV project in Samo done so far shows that the deterministic case is not a financially viable project. One way to make it more viable is to consider an increase in the tariff expected from the consumers. In carrying out an integrated investment appraisal, we mentioned earlier that the financial analysis is the first stage to know if the private investor or/and the lender stands to benefit from the project. In this case, the benefits for these first two groups are not really there. The next question we now ask is what about the society, what about the country? Does the project benefit them? This leads us to the economic analysis which will be discussed in the next chapter.

Chapter 4

Economic Analysis

4.1 Introduction

The financial analysis of a project is very important as it either encourages or discourages investors from embarking on a project. An economic analysis is very different. An economic analysis of a project is concerned whether the project increases the net wealth of a country or well being of all residents of society as a whole or not. It evaluates the impacts of the project on the entire society. In order to achieve this, we calculate the present value of the economic benefits of the project and determine whether the project contributes to the country's wealth and the economic welfare of its households. To achieve this purpose, an economic resource statement needs to be built. This statement translates all the financial receipts and expenditures (financial transactions) into economic benefits and costs in order to reflect their true value to the society.

The economic resource statement is directly linked to the financial cash flow statement of the project. The economic analysis is structured to be in full consistency with the financial analysis. To guarantee such a consistent transformation from the financial appraisal into economic analysis, the economic model is essentially based on the project's financial values and parameters. These financial values are converted into their respective economic values by making some adjustments due to a variety of distortions in the market. In general, the economic values of all tradable goods are estimated at the C.I.F prices of the imported goods net distortions such as import duties, taxes and subsidies but should include the foreign exchange premium due to the presence of various tax distortions in the markets for tradable goods and services in the economy. The relationship between the financial and economic value of a particular good or service is defined as a Commodity Specific Conversion Factor (CSCF) and is calculated as the economic value over the financial price. Once the conversion factors are computed, they are multiplied by the respective financial values in order to obtain the corresponding economic values.

4.2 Economic Parameters and Assumptions

Aside from the financial prices estimated in the financial model (as discussed in the previous Chapters), the following economic assumptions and parameters are necessary for the economic analysis.

- The Economic Opportunity Cost of Capital (EOCK) for Nigeria is estimated to be 11% real.
- The Foreign Exchange Premium (FEP) on tradable goods is estimated to be 7.5%.
- The Shadow Price of Non-Tradable Outlays (SPNTO) is estimated 1% higher than its market price.
- All initial investment capital items are not subject to any import duty or VAT. These capital items include the materials purchased and imported for the project.

Item	**Conversion Factor**
Land (subsidy)	0.00
Liquidation value of land	1.00
Economic Opportunity Cost of Labor (Skilled)	0.90
Economic Opportunity Cost of Labor (Unskilled)	0.60
Equipment	0.975
Cost of Land	1.00
License, Permits, Approvals	1.00
Travel and Accommodation	0.85
Transport	0.85

Table 4.1: Conversion Factors for Economic Analysis

- Operation and maintenance materials are not subject to import duty and VAT.

The willingness of the consumers to pay for the electricity-via solar energy- is calculated by comparing it to the alternative source of electricity which will be a generator. The total annual costs of using a 1.2KW generator for the entire village is NGN $793,276.00$. This includes annual cost of diesel and maintenance costs. This is used to approximate the willingness of the customers to pay for electricity. It is estimated that this amount is NGN163.90/KWh in 2009 prices. This means that electricity consumers in Samo, Nigeria willingness to pay for electricity is almost 27 times more than the current electricity tariff. This value is multiplied by the annual electricity generated by the proposed project to estimate the annual economic benefits received by households in Samo throughout the life of the project.

4.3 Economic Feasibility of Project

The main aim of the economic analysis is to determine if the project is economically beneficial to the society. As initially stated, in order to carry out the analysis, we need to analyze the economic resource flow statement. The resource statement is presented on the table in Figure 5.1.

Year--->	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
INFLOWS																													
Economic Benefits	0	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793	793
Land (subsidy)	0																												
Grant																													
Liquidation (Land)																													75
Total Inflows	**0**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**793**	**868**
OUTFLOWS																													
CAPITAL EXPENDITURES																													
Feasibility Studies																													
Skilled Labour Wag	30																												
Unskilled Labour W	39																												
Travel and Accomo	25																												
Development																													
Skilled Labour	74																												
Unskilled Labour	59																												
Legal/Acc.	74																												
Travel/Accomodati	63																												
Cost of Land	75																												
Licence, Permit, Ap	66																												
Materials																													
PV Panels	1119																												
Transmission Cable	291																												
Efficiency Measure	145																												
Battery	1104							1104							1104							1104							
Inverter	508																												
Support Structure	276																												
Installation	58																												
Taxes and Duties a	0																												
Taxes on Equipmen	0																												
Transport to Samo	190																												
Unskilled Labour (S	30																												
Travel and Accomo	63																												
Engineering																													
Skilled Labor 1	148																												
Skilled Labor 2	98																												
Unskilled Labor	197																												
Electrical Equipmen	73																												
Travel and Accomo	443																												
Taxes on Equipmen	0																												
OPERATING EXPENSES																													
Miscellaneous		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Principal + Interest Payment		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
Corporate Tax Payments		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
Total Outflows	**5246**	**7**	**7**	**7**	**7**	**7**	**7**	**1112**	**7**	**7**	**7**	**7**	**7**	**7**	**1112**	**7**	**7**	**7**	**7**	**7**	**7**	**1112**	**7**	**7**	**7**	**7**	**7**	**7**	**7**
Net Cash Flow	-5246	786	786	786	786	786	786	-318	786	786	786	786	786	786	-318	786	786	786	786	786	786	-318	786	786	786	786	786	786	861

ENPV@EOCK: 11% Real	606
EIRR Real	12.6%
EBCR	1.09

Figure 4.1: Economic Resource Flow Statement (real) prices (thousand NGN)

The net economic benefits anticipated over the life of the solar power project yields a positive net present value (NPV) of 0.61 million Naira using as a discount rate the economic opportunity cost of capital in Nigeria (11% real). This represents the incremental contribution of the solar power energy project to the well being of residents in Nigeria. The projected economic internal rate of return if the project is implemented is about 13% real. This is an indication that this project is expected to generate a higher rate of return on capital compared to other investments in the country.

4.4 Summary

An integral part of an integrated investment appraisal is the economic cost benefit analysis. For investors, a financial analysis is more important as it focuses on the financial profitability of the project hence either attracting or repelling investors. An economic analysis is different as it focuses on the impact of the project on the society. An economic analysis of a project asks the question: "how does this project affect the net wealth of the country"?

For the solar power project, even though the financial evaluation is not encouraging -for investors and lenders-, the economic cost benefit analysis shows that the project has a positive impact on the net wealth of the country.

Chapter 5

Stakeholder Impacts

5.1 Introduction

The main purpose of the stakeholder analysis is to identify the extra-economic impacts that the implementation of the solar project has on different stakeholders in the society. In addition, quantification of these impacts is an important part of the stakeholder analysis in order to find out by how much each stakeholder would gain or lose as a result of the project implementation. In order to undertake this analysis, the projected information from the financial and economic appraisals is used. The relationship between the financial, economic and stakeholder impacts of the ith input can be given as:

$$\text{Economic Vaule}_i = \text{Financial Value}_i + \sum_j \text{Stakeholder Impacts} \tag{5.1}$$

Taken over all variables i and time periods and using a common discount rate, we can re-write the equation above as:

$$\begin{aligned} \text{NPV Economic} &= \text{NPV Financial} + \sum \text{PV Stakeholder Impacts} && (5.2) \\ NPV_{eco}^{ECO} &= NPV_{eco}^{Fin} + \sum PV_{eco}^{EXT} && (5.3) \end{aligned}$$

where all discounting is at the economic cost of capital real discount rate and stakeholder impacts is also known as externalities. In the process, the stakeholder analysis is composed of six distinct steps (Harberger *et al.*, 2009):

1. Identify the externalities
2. Measure the net impact of the externalities in each market as the real economic vales of resource flows less the real financial values of resource flows
3. Measure the values of the various externalities throughout the life of the project and calculate their present values by using the economic discount rate
4. Allocate the externalities across the various stakeholders of the project
5. Summarize the distribution of the project's externalities and net benefits according to the key stakeholders in society
6. Reconcile the economic and financial resource flow statements with the distributional impacts.

5.2 Identification of Externalities

For the purpose of this project, we identify the following stakeholders:

- Government
- Households
- Labour

Using the discount rate of 11% real (EOCK), we calculate the sum of externalities using the equation below:

$$\sum PV_{eco}^{EXT} = NPV_{eco}^{ECO} - NPV_{eco}^{Fin} \tag{5.4}$$

where NPV_{eco}^{ECO} is the present value of the net economic benefits, NPV_{eco}^{Fin} is the present value of the net financial cash flow, and $\sum PV_{eco}^{EXT}$ is the sum of the present value of all the externalities generated by the project. This shows that the economic benefits obtained from project implementation can be distributed between the government, household and labour. For the purpose of this project, we carry out the stakeholder analysis by:

- Firstly, the stakeholder impacts of the project are identified item-by-item, by subtracting the financial cash flow statement from the economic statement of benefits and costs.
- Secondly, the present value of each line item's flow of externalities is calculated, using as discount rate the economic cost of capital in Nigeria.
- Finally, the present value of the externalities is allocated to the affected groups in the economy- government, household, labor.

The Stakeholder Analysis statement is presented in the Table in Figure 5.1

5.3 Summary

Referring to the table in Figure 5.1, one can see that the present value of the net financial cash flow from the implementation of this project using a discount rate of 11% real is -NGN8.2 million. Similarly, the economic impact of the project is measured by the net economic resource flow which is positive and amounts to NGN0.61 million. The difference between the financial NPV and the economic NPV of the solar project, both discounted at the economic cost of capital of 11% real, measures the present value of all externalities created by the project which amounts to NGN8.8 million.

	(A) Financial PV@11%	(B) Economic PV@11%	(C)=(B)-(A) Externalities PV@11%	(D) Government	(E) Household	(F) Labour
INFLOWS						
Economic Benefits	248,791.93	6,823,460.16	6,574,668.23		6,574,668.23	
Land (subsidy)	74,700.00		-74,700.00		-74,700.00	
Grant						
Liquidation (Land)	4,020.47	4,020.47	0.00		0.00	
Total Inflows	**327,512.41**	**6,827,480.63**	**6,499,968.23**	**0.00**	**6,499,968.23**	**0.00**
OUTFLOWS						
CAPITAL EXPENDITURES						
Feasibility Studies						
Skilled Labour Wages	32,780.00	29,502.00	-3,278.00			-3,278.00
Unskilled Labour Wages	65,560.00	39,336.00	-26,224.00			-26,224.00
Travel and Accomodation	29,800.00	25,330.00	-4,470.00			-4,470.00
Development						
Skilled Labour	81,950.00	73,755.00	-8,195.00			-8,195.00
Unskilled Labour	98,340.00	59,004.00	-39,336.00			-39,336.00
Legal/Acc.	81,950.00	73,755.00	-8,195.00			-8,195.00
Travel/Accomodation	74,500.00	63,325.00	-11,175.00			-11,175.00
Cost of Land	74,500.00	74,500.00	0.00		0.00	
Licence, Permit, Approval	65,560.00	65,560.00	0.00	0.00		
Materials						
PV Panels	1,147,300.00	1,118,617.50	-28,682.50		-28,682.50	
Transmission Cable	298,000.00	290,550.00	-7,450.00		-7,450.00	
Efficiency Measures	149,000.00	145,275.00	-3,725.00		-3,725.00	
Battery	2,067,077.86	2,015,400.91	-51,676.95		-51,676.95	
Inverter	521,500.00	508,462.50	-13,037.50		-13,037.50	
Support Structure	283,100.00	276,022.50	-7,077.50		-7,077.50	
Installation	59,600.00	58,110.00	-1,490.00		-1,490.00	
Taxes and Duties at Port	1,154,750.00	0.00	-1,154,750.00	-1,154,750.00		
Taxes on Equipment	529,695.00	0.00	-529,695.00	-529,695.00		
Transport to Samo	223,500.00	189,975.00	-33,525.00	-33,525.00		
Unskilled Labour (Security)	49,170.00	29,502.00	-19,668.00			-19,668.00
Travel and Accomodation	74,500.00	63,325.00	-11,175.00			-11,175.00
Engineering						
Skilled Labor 1	163,900.00	147,510.00	-16,390.00			-16,390.00
Skilled Labor 2	163,900.00	98,340.00	-65,560.00			-65,560.00
Unskilled Labor	327,800.00	196,680.00	-131,120.00			-131,120.00
Electrical Equipment	74,500.00	72,637.50	-1,862.50		-1,862.50	
Travel and Accomodation	521,500.00	443,275.00	-78,225.00			-78,225.00
Taxes on Equipment	8,940.00	0.00	-8,940.00		-8,940.00	
OPERATING EXPENSES						
Miscellaneous	64,082.08	64,082.08	0.00			0.00
Corporate Tax Payments	9,672.11	0.00	-9,672.11	-9,672.11		
Total Outflows	**8,496,427.05**	**6,221,831.99**	**-2,274,595.06**	**-1,727,642.11**	**-123,941.95**	**-423,011.00**
Net Cash Flow	-8,168,914.64	605,648.64	8,774,563.28	1,727,642.11	6,623,910.17	423,011.00

Figure 5.1: Stakeholder Analysis of The Solar Project, 2009 (real) prices (NGN)

Finally, by distributing the externalities, we can see that the net cash flow for government externalities, household externalities, labour externalities is positive with values NGN1, 7 million , NGN6, 6 million,NGN4.2 million respectively. Most of the benefits are accrued to the household meaning that the households stands to gain most from an economic perspective if the project is implemented.

Chapter 6

Sensitivity and Risk Analysis

6.1 Sensitivity Analysis

In the sensitivity analysis, we test how sensitive the output in the model is to change in value of one input variable at a time. This test enables us to test which variables are important as a source of risk. For inputs, we consider cost overrun and inflation as the input variables. The output that we want to see what factors affect them most are: For the purpose of the risk analysis, we consider the following outputs:

- Financial Net Present Value
- Economic Net Present Value
- Present Value of Externalities
- Present Value of Government Externalities
- Present Value of Household Externalities
- Present Value of Labour Externalities

The results of the sensitivity analysis-done using Microsoft Excel- is presented in Figure 6.1 (for cost overrun) and Figure 6.2 (for inflation). From the tables, we see that cost overrun has a greater impact on the output. This means that these output are more sensitive to costs than they are to inflation. A possible explanation is that a major component of the overall costs over the life of the project is initial investment costs. A possible way of greater influencing these parameters is to look for possible ways to reduce the initial investment costs.

The challenge with this sensitivity analysis is two fold. The first is that we do not have the probability distribution of the output parameters. Secondly we are not able to simultaneously consider the impact of the two input parameters - cost overrun and inflation- on the output parameters. This leads us to risk analysis which solves these two problems.

	FNVP	ENVP	PV EXTERNALTIES	PV HOUSEHOLDS BENEFITS	PV GOVERNMENT BENEFITS	PV LABOUR
	-7777.42	605.6486	8774.563282	6623.910172	1727.642111	423.011
10%	-8582.93	-10.1264	9000.064028	6635.410366	1899.341562	465.3121
5%	-8180.18	297.7611	8887.30006	6629.660269	1813.478241	444.16155
0%	**-7777.42**	**605.6486**	**8774.563282**	**6623.910172**	**1727.642111**	**423.011**
-5%	-7374.67	913.5361	8661.826505	6618.160074	1641.805981	401.86045
-10%	-6971.91	1221.424	8549.089728	6612.409977	1555.969851	380.7099

Figure 6.1: Sensitivity Analysis (Cost Overun) (thosands NGN)

	FNVP	ENVP	PV EXTERNALTIES	PV HOUSEHOLDS BENEFITS	PV GOVERNMENT BENEFITS	PV LABOUR
	-7777.42	605.6486	8774.563282	6623.910172	1727.642111	423.011
17%	-7777.42	605.6486	8774.563282	6623.910172	1727.642111	423.011
14%	-7777.42	605.6486	8774.563282	6623.910172	1727.642111	423.011
11%	-7777.42	605.6486	8774.563282	6623.910172	1727.642111	423.011
8%	-7777.42	605.6486	8774.563282	6623.910172	1727.642111	423.011
5%	-7777.42	605.6486	8774.563282	6623.910172	1727.642111	423.011
3%	-7777.42	605.6486	8774.563282	6623.910172	1727.642111	423.011

Figure 6.2: Sensitivity Analysis (Inflation) (thousands NGN)

6.2 Risk Analysis

The main disadvantage of the sensitivity analysis discussed so far is its deterministic nature. The implicit assumption being made is that the probability of having values for the project's input and output variables is 1. Inadvertently, this implies that the estimated project financial and economic NPVs have probabilities of 1. Since the project cash flow and economic resources analysis is spread over 28 years, this assumption is not realistic. It becomes ineluctable to account for the possible variations and uncertainties in these values over the project life.

For the purpose of identifying, analyzing and interpreting the variability of the financial and economic outcomes of the project, it is important to include a risk analysis. We assume that the risk variables are cost overrun and inflation. The difference this time is that we include the probability distributions associated with these risk variables to account for uncertainties in their values (see Figure 6.3).

For the risk analysis, we make use of the crystal ball software which utilizes Monte Carlo simulations. It does this by running about 2000 multiple simulations of the financial and economic analysis by selecting randomly the variables that affect the performance of the project in accordance with specified probability distributions. This enables us to estimate the expected value of the projects' outcomes as well as the probability distribution of the possible outcomes. For the purpose of the risk analysis, we consider the following outputs:

- Financial Net Present Value
- Economic Net Present Value
- Present Value of Externalities
    1. Present Value of Government Externalities
    2. Present Value of Household Externalities

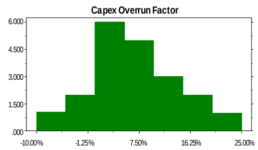
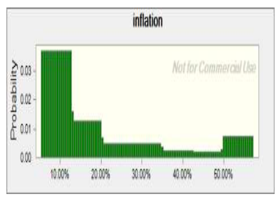
Variable	Distribution Type		Range and Parameters	Mean Value
Investment Cost Overrun Factor (%)	Step Distribution	 	Min Max Likelihood -10% to -5% 0.05 -5% to 0% 0.10 0% to 5% 0.30 5% to 10% 0.25 10% to 15% 0.15 15% to 20% 0.10 20% to 25% 0.05	Assumption: 0% Expected Mean: 6.7%
Inflation (%)	Step Distribution	 	Min Max Likelihood 5% 13% 52% 13% 20% 18% 20% 28% 7% 28% 35% 7% 35% 42% 3% 42% 50% 3% 50% 57% 10%	Assumption: 0% Expected Mean: 19%

Figure 6.3: Risk Analysis Input Variables

3. Present Value of Labour Externalities

A risk analysis is very different from a sensitivity analysis. A sensitivity analysis allows only one or two project parameters to be changed simultaneously to test their impact on project outcomes. Risk analysis on the other hand enables multiple parametric modeling and testing of impact on project outputs. Also, sensitivity analysis does not enable variation in the tested parameter from one period to another; unlike risk analysis which enables such variations in the tested parameter. Sensitivity analysis does not consider the impact of the correlation between the tested parameter and other project parameters whereas the risk analysis incorporates such correlation conditions into the model. A major difference is that the sensitivity analysis does not allocate probability distribution to the output parameters while with the risk analysis we do have a probability distribution to the outcomes. This enables us to know how likely it is for a particular outcome to occur in the project. This information can be very important in key project decisions.

6.2.1 Risk Analysis Results

For our analysis, we consider the impact of cost overrun and inflation on the financial net present value, economic net present value and the present value of the externalities. Figure 6.4 gives the probability distribution of for the financial net present value, economic net present value and the present value of the externalities outcomes based on the inputs explained earlier.

The financial net present value distribution has a negative mean value of NGN $8,397$ thousand, and a standard deviation of NGN 607 thousand. The minimum financial net present value is -NGN $9,999$ thousand and the maximum is -NGN $6,927$ thousand. This tells us that the probability of having a positive financial net present value is 0.

The economic net present value distribution has a mean value of NGN 172 thousand, and a standard deviation of NGN 230 thousand. The minimum economic net present value is -NGN 930 thousand and the maximum is NGN $1,221$ thousand.

The present value of externalities distribution has a mean value of NGN $8,915$ thousand, and a standard deviation of NGN 169 thousand. The minimum present value of externalities is NGN $8,523$ thousand and the maximum is NGN $9,327$ thousand.

We further analyze the different externalities. Figure **??** gives the probability distribution for the present value of the government externalities, present value of household externalities and the present value of labour externalities outcomes based on the inputs explained earlier. The present value of government externalities distribution has a mean value of NGN $1,848$ thousand, and a standard deviation of NGN

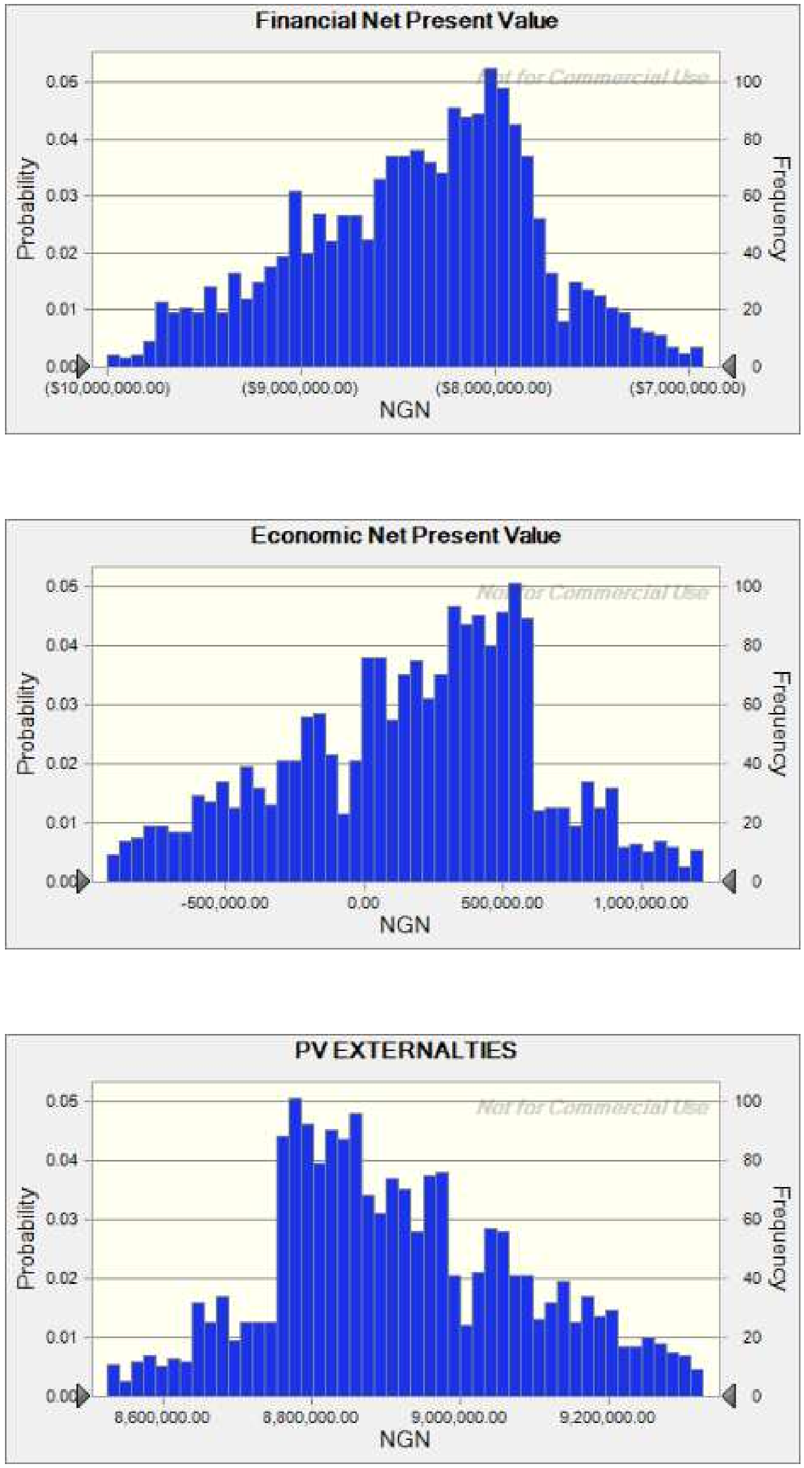


Figure 6.4: Forecasts Probability Distribution

126 thousand . The minimum present value of government externalities is NGN 1, 556 thousand and the maximum is NGN 2, 156 thousand.

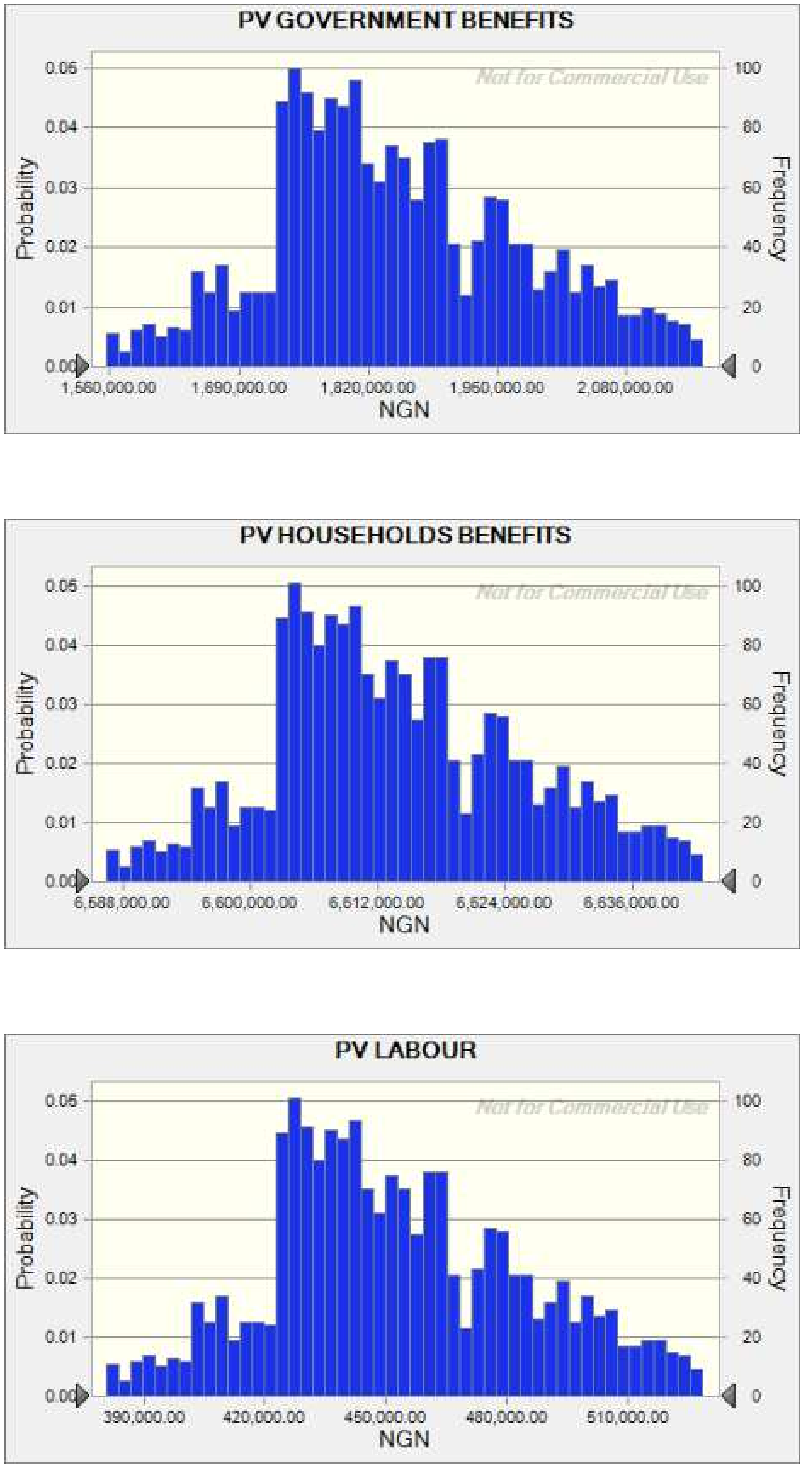


Figure 6.5: Externalities Probability Distribution

The present value of household externalities distribution has a mean value of NGN 6,614 thousand, and a standard deviation of NGN 12 thousand. The minimum present value of household externalities is NGN $6,586$ thousand and the maximum is NGN $6,643$ thousand.

The present value of labour externalities distribution has a mean value of NGN 453 thousand, and a standard deviation of NGN 31 thousand. The minimum present value of labour externalities is NGN 381 thousand and the maximum is NGN 529 thousand.

6.3 Summary

The results from the sensitivity and risk analysis of the solar project complement each other. The risk analysis gives a more detailed information with a probability distribution. The simulation results tells us that the cost over run has the greater impact on the project both from a financial and economic overview. As mentioned earlier, a possible reason for this is that a greater portion of the overall costs for the project are initial investment costs.

Chapter 7

Conclusions

There are several rural areas in Africa that are off the grid and may never enjoy electricity due to several factors beyond their control. For such communities, it becomes important to consider alternative sources of electricity that is renewable and sustainable. This essay is based on a practical application of economic cost benefit analysis techniques to the installation of a sustainable renewable energy structure that will generate electricity for Samo, a village in Nigeria.

For renewable energy, we considered solar energy as a source of electricity. The solar structure for the Samo community can be considered as a central "off-grid" system that will supply electricity to the community. For the project, a 1.3KW solar structure is considered with the balance of systems included and a project life of 28 years. The total initial investment costs of the project is estimated as NGN7, 487, 995.00 (or USD \$50, 255) in 2009 prices with 57% of this costs sourced through debt financing.

The financial feasibility of the Solar project was evaluated from the lender's point of view and the private investor's point of view. It was shown that the project is not able to service debt under the term specified and provides a negative NPV to the investor. This further led to an economic evaluation to see what benefits the project provides to the well being of the Nigerian population and the community as a whole.

The net economic benefits anticipated over the life of the solar power project yield a positive net present value (NPV) of 0.61 million Naira using as a discount rate the economic opportunity cost of capital in Nigeria (11% real). This represents the contribution of this solar power energy project to the welfare and the expansion of the wealth of Nigeria. Expressed differently, the projected economic internal rate of return if the project is implemented is 13% real. This is an indication that investment in this project is expected to generate a higher rate of return on capital as compared to other investments in the country.

A stakeholder impact analysis showed that the residents in the community stands to benefit most if the project is implemented. Finally, a sensitivity and risk analysis was carried out and showed that the investment cost has the greatest impact on the entire project. Nevertheless, the economic results still show that the project is viable from the country's viewpoint.

Sustainable, renewable energy is gaining more grounds in North America and the case for implementation of such project in Africa is very cogent. With an abundance of natural resources and the problem caused by pollution, it can be seen that the economic benefit of such a project is substantial and the adventure should be pursued.

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