THESIS TITLE

RENEWABLE ENERGY BASED POWER DISTRIBUTION (USING HOMER SOFTWARE)

by

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Department of Electrical and Electronic Engineering

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RENEWABLE ENERGY BASED POWER DISTRIBUTION (USING HOMER SOFTWARE)

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Declaration

We hereby declare that this thesis is the result of our original work carried out at the Islamic University of Technology Dhaka-Bangladesh under the supervision of Prof. Dr. Md. Ashraful Hoque (Head of the department of Electrical and Electronic Engineering Department) and Mr. Mehedi Hasan Galib (lecturer, Electrical and Electronic Engineering Department). This thesis has never been submitted in part or in whole for a degree at any institution.

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CONTENTS

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Abstract

With a national electrification rate of an estimated 40 per cent and with certain rural areas having an electrification rate as low as 6 per cent, the time is ripe in The Gambia for the Rural Electrification with Renewable Energy (RE) Nationally Appropriate Mitigation Action (NAMA). A number of building blocks have already been put in place in the country. The 2013 Renewable Energy Act provides the framework for both on and off-grid renewable energy tariffs and net metering, as well as establishing a national RE Fund. There has been development of pilot renewable energy projects as well as diesel powered multi-function platforms, which provide energy access for economic activities in rural areas.

These objectives will be accomplished through a number of activities, divided into Phase 1 and Phase 2. Phase 1 activities will include the establishment of two types of ventures which will connect unelectrified rural communities: RE Community Energy Centers (RE-CEC) and RE Micro-Grids (RE-MGs). Phase 2 ventures will comprise RE systems which will displace thermal generation at existing regional grids (referred to as RE Displacement Systems—RE-DIS) and RE independent power producers (RE-IPPs).

Both RE-CECs and RE-MGs will have as a core design component a rural productivity zone (RPZ), where community members will be provided energy access which can be used to start up small businesses; these businesses may include setting up a shed where people pay to use industrial equipment or providing irrigation via a water pump. The RPZ will also provide energy to a limited number of public buildings. The key difference between the RE-CEC and the RE-MG ventures is the manner of distribution of electricity to households: RE-CECs provide electricity through rechargeable batteries, while RE-MGs provide individual household connections. Approximately 50 households will receive electricity access from each of the eight proposed RE-CEC ventures and the eight RE-MG ventures. The business model applied for both venture types will be a public-private partnership (PPP), in which a public entity owns the RE system but a private sector company manages and maintains the system. In addition to the implementation of the ventures, ongoing capacity-building at all levels will occur. Regulations and policies will be updated, training sessions will be held and awareness will be raised.

Phase 2 will shift activities to a larger scale private sector model. Ventures will include six RE-DIS, of various capacities, and a seven megawatt RE-IPP.

The activities of the NAMA will be paid for via both international and national finance. At the national level, finance will come from the national budget, cost reduction measures and consumer payment schemes. Finance will be provided to through mechanisms such as direct investment grants, the RE Fund and a loan facility. The NAMA will be governed by a multi-stakeholder approval committee and coordinated by the Coordinating Authority. Technical advice will be provided by an expert group and a trustee will manage financial flows.

Part 1: The Gambia

1 CHAPTER 1: Introduction

The Gambia is the smallest country in continental Africa, with a total land area of about 11,295 km2 (CIA, 2014). It is located in West Africa and is bordered by Senegal on three sides, with the Atlantic Ocean coastline on its western edge. The country's population, according to the preliminary results of the 2013 Population and Housing Census, is 1,882,450. Around 60 per cent of the population lives in urban or semi-urban areas. The country experienced a high annual population growth rate of 3.3 per cent between 2003 and 2013[1], and the consequent increase in domestic demand has been exerting enormous pressure on the country's natural resources, which in turn is having an impact on environmental, social and economic conditions (Gambia Bureau of Statistics, 2013).

1.1 Overview of energy situation of the Gambia

The main source of energy in The Gambia is wood fuel and other biomass fuels), followed in decreasing order by petroleum products, electricity and a small fraction of renewable energy, as seen in Figure 4. The biggest consumers of energy in The Gambia are households and the transport sector, with a steady and consistent increase during the past decade in the consumption of petroleum products. Wood fuel consumption is increasing due to increasing energy demand from households for cooking and household-related needs. The dependence on wood fuel means that users are subject to the associated health hazards (such as indoor air pollution) and spend excessive time, effort and money collecting or buying wood fuel. The Government, however, is committed to providing safer energy services (clean cooking fuel and electricity) at affordable prices (IRENA, 2013).

As a part of its Program for Accelerated Growth and Employment (PAGE), which was designed to foster cross-sectorial socio-economic development, the Government intends to increase electricity generation, enhance access to electricity and improve operational efficiency by focusing on the following four objectives (Ministry of Finance and Economic Affairs, 2012):

a. providing reasonable incentives and facilitation to promote private sector investment in electricity-generation projects;

b. promoting efficient technologies in utility companies to increase their operational efficiency

c. undertaking the replacement and upgrading of ageing transmission and distribution systems; and

d. promoting the use of renewable energy technologies (such as wind, solar and biomass), with emphasis on rural areas (MOFEA, 2011).

The current level of electrification in The Gambia is insufficient and the Government lacks the resources to improve the situation, given the huge demand. In 2011, The Gambia had an overall electrification rate of approximately 35 per cent, with very high regional variations (from 6 per cent in the North Bank region to 93 per cent in the Banjul region). These electrification rates indicate average electricity access of only 12 per cent2 in the rural and semi-urban regions.

1.2 Renewable Energy

The Gambia offers an abundance of natural resources to meet its energy needs. In light of the NAMA, the renewable energy discussed here will focus on electricity, not thermal energy. In 2005-2006, solar and wind measurements were taken as part of a study for the Renewable Energy Master Plan (Lahmeyer International, 2006). Solar radiation measurements were taken at eight stations and the study concluded that there is high solar radiation in all regions of The Gambia. The average solar radiation is 4.4-6.7 kWh/ m2/day. Even in the rainy season when radiation is at its lowest level, the amount of radiation is high enough to power solar energy projects.

1.3 Some renewable Energy in The Gambia

1.3.1Solar energy

The location of The Gambia gives rise to an appreciable amount of solar energy radiation with a fair distribution. Radiation levels vary across the country with 3.5 kWh/m2 per day in the coastal latitude to 7 kwh/m2 per day in the far north, giving an annual average solar intensity estimated to be 1934.5 kW/m2.4.Solar energy usage has not gained much popularity in The Gambia. Its usage is limited to pilot and demonstration projects. Solar thermal energy has found various applications, including solar cooking, heating and drying applications. The ECN has developed solar water heaters, solar dryers, and solar cookers. Solar energy applications serve various energy needs among the rural 23 dwellers as they are usually deprived of grid supply. Solar PV technologies are growing, though awareness is relatively low. PV installations are commonly found in street lighting. They find use in rural electrification projects as well as low and medium level uses such as solar pumps. PV cells have been installed to serve needs of rural clinics and schools. Solar energy initiatives are on the rise with various Research and Development projects. Many industries has developed solar water heaters as well as solar cookers. National Centre for Energy Research and Development Nsukka has also developed chick brooders. There are demonstration projects for solar stills. An estimate 264 kWp of module installation was recorded in 1999 with an estimate of 1.74 MWp for Solar energy in The Gambia has got more to offer. Solar energy is basically driven by the unavailability of grid supply. Its growth is hindered various inherent challenges. High cost of system components is a major discouragement. Furthermore, the present level awareness has not matched up as to initiate a transition, so the majority would rather stick to traditional sources. Standards and regulatory policies to support solar energy integration remain largely inadequate coupled with security challenges associated 24 with standalone installations as well as the current low level of technical expertise in these technologies.

1.3.2 Wind Energy

The Gambia experiences strong winds from April to October arising from the seasonal rain-bearing westerly winds and strong North-East trade winds from November to March. The southern regions experience winds ranging from 1.4 to 3 m/s while speeds could reach 4-5.12m/s in the extreme North. Studies indicate potential of up to 6 MWh/y in Foni, 41 MW/yr in upper river region. Wind data in The Gambia is collected from stations, mainly airports and urban centers, using various instruments. Generally, the southern parts of the country experience relatively weak wind speeds as compared to the Northern parts, except for the coastal regions and offshore.51 The mountainous regions in the North, however, receive the strongest winds, consequently; major initiatives are found in the North. Wind speeds could vary drastically from one region to another within the country, a result of variations in topography. There is need to explore wind energy resources which is one of lowest prices renewable technologies available. Wind energy could serve as viable option for rural dwellers. They could also be combined with other sources to form a hybrid system. Wind farm could be adopted for off-grid/grid connected generation. Similar challenges to solar energy face wind energy in The Gambia. First is the high cost of wind energy equipment, although it is hope that this would fade out with time. The Gambia lacks particular policies needed to see to the growth of wind energy. Current level of technical expertise in these technologies is still low slowing down development. Furthermore, research and development in wind energy needed to be improved upon as well as data sources. An increase in awareness level would, however, be needed to create the needed spark for growth.

1.3.3 Hydro Energy

Organization pour la Mise en Valeur du FleuveGambie (OMVG), which includes Guinea, Senegal, Guinea-Bissau, and The Gambia, also seeks expressions of interest from consultants by August 4 to provide technical assistance for implementation of its hydropower-based energy project. OMVG recruited technical-legal and environmental management consultants last year to advance development of the energy project, which includes Sambangalou on the Gambia River catchment in Senegal, the transmission lines, and the 240-MW Kaleta project in Guinea on the Konkoure River. According to Hydro world news services, OMVG courted private sector partners in 2009 to develop the hydro projects and grid interconnection. The energy project is funded by eight international lending organizations. The propose works will be located 930 km upstream from the mouth of the Gambia River and about 25km south of Kédougou. The dam will be located in Senegal, and part of the 185 km2 reservoir will be in Guinea. The countries involved namely Senegal, Guinea, Guinea-Bissau and the Gambia will enjoy low-cost, renewable energy. This project originally formed part of a larger OMVG project which entailed an interconnecting power grid with the Kaleta Dam in Guinea. The availability of low-cost electricity will lead to increased regional power trade and enable regional integration. The additional electricity made available through this project will also increase the region's energy security. The site of Sambangalou Dam is located in Senegal 930km upstream from the mouth of the Gambia River and about 25km south of Kédougou. It consists of a well-established dam site with a capacity of 128 MW and a potential for 400 GWh, with irrigation and flood control prospects. This site was chosen given the power deficit in the region and the high dependence on imported oil and use of environmentally damaging hydrocarbon power generation.

1.3.4 Biomass

Biomass resources are vast in The Gambia. They include; fuel wood, agricultural waste and crop residue, saw dust and wood shavings, animal and poultry waste, and industrial/municipal wastes. Biomass consumption is huge in The Gambia, making up to 37% of total energy demand. Combustion of fuel wood is popular leading to an increasing rate of deforestation. This serves rural dwellers for off-grid heating needs. Annual consumption of fuel wood is about 43.4 $\times$109 out of 14 million tons/year of biomass energy resources. Biomass resources in the country follow the vegetation pattern. Woody biomass is abundant in the southern rainforest region while crop residues are mainly found in the Guinea savannah of the North bank region. Biomass could lend itself in solid or converted liquid/gaseous forms for consumption. However, solid consumption is common in highly inefficient combustion.

2 CHAPTER 2: Aims and Objectives

2.1 Rationale of the Study

Power shortages in most African countries have been a key constraint to its economic growth. The Gambia has a total installed electricity production capacity of 85 MW, but the country's effective functioning productive capacity is, at present, only 65 MW (PURA, 2012). This shortfall has been caused by various factors including among others; the reliance on aged facilities and equipment, the effects of harsh climatic conditions, and the lack of long term maintenance.

"Energy related threats such as the lack of sustainable secure and affordable energy supplies, together with the environmental damage incurred in producing, transporting and consuming energy, have been the main drive to the need for renewable energy development. With a world's population of 6 billion people heading to 11billion, rising fuel costs, climate change concerns and the growing demand for electricity, renewable energy is fast becoming an increasingly valuable solution for the global energy problem.

The quest for energy has created greenhouse gases (GHG) emission problems which have contributed greatly to global warming. Emissions of GHG such as carbon dioxide, methane, and others, have increased dramatically in the last century through fossil fuel burning and land use changes. Human activity has pushed atmospheric concentrations of carbon dioxide, the chief greenhouse gas, to more than 30% above pre-industrial levels, 370 parts per million today compared to about 280 in 1750 (CDIAC 2001).

2.2 Aims and Objectives of the Research

This research work attempts to evaluate the potential of wind and solar energy of our respective countries (The Gambia, Yemen and Bangladesh). It tries to establish the state of the art of electricity generation, transmission and distribution in these countries, the problems it faces and the inability to meet the current energy demand for these countries. In addition, the research seeks to examine and assess the renewable energy sector and the possibility to revitalize the energy sector in these countries in an environmentally friendly way. The research further examines the legal framework of The Gambia and other government initiatives in as much as energy and electricity is concerned. It also considers the potential role of renewable energy, especially wind and solar, in improving the performance of the energy and electricity sector in The Gambia.

2.3 Thesis Outline.

Going backwards, this thesis begins with an introductory chapter that presents the Republic of the Gambia and its energy situation. It also introduces renewable energy and gives an overview of the renewable energy resources in the Gambia.
This current chapter (chapter 2) provides substantial information on the perspectives, motives and objectives underlying this dissertation. The chapter ends with this outline. In the third chapter entitled “Methodology”, the methodology used in this thesis is outlined and justified. It introduces the software tool (Homer pro) used in this research to analyze the wind and solar potentials for the Gambia.
The fourth chapter provides the center point of this research. It begins with an introduction of the various study areas used, followed by the five step procedures used in the analysis. It further describes the technical specifications of the wind turbine and characteristic values used in the analysis for the wind resource followed by results and discussions for each of the locations analyzed. The remainder of the chapter looks at the solar resource, giving the technical specifications for the solar module and characteristic values used to analyze the solar resource. The chapter ends with a general discussion for the solar resource.

2.4 WHAT IS RENEWABLE ENERGY

Renewable energy is sustainable energy that comes from the natural environment. Certain sources of energy are “renewable” as they are maintained or replaced by nature. Renewable energy is obtained from sources that are essentially inexhaustible, unlike fossil fuels, of which there is a finite supply and cannot be replenished. Renewable sources of energy include solar, wind, water, biomass, wood, waste, geothermal, wind, photo voltaic, and solar thermal energy. Non renewable energy sources include coal, oil and natural gas. Renewable energy is energy which is self-replenishing. Many people would say that it is also sustainable energy, which implies that in accordance with many definitions of sustainability it should be self-replenishing within a generation, so that the present generation does not rob energy resources from future generations.

Renewable energy takes many forms but starts out being either stored in the earth's crust and deep magma, or nuclear; the vast majority of which is from the sun. Geothermal energy is not totally renewable, because when we use geothermal energy it is removed from the earth's crust. However, the proportion we could conceivably use is so tiny that it would take billions of years for man to use up all the earth's geothermal energy. Therefore, geothermal energy is classed as renewable.

Burning wood is thought of as renewable, but it is only really renewed once the forest it was cut from has grown again. As long as the woodland is replanted though, most people would consider burning it to be renewable since it will re-grow in temperate regions within a generation. In contrast, burning fossil fuel is clearly not renewable because it takes millions of years for new coal, oil, or natural gas to form. That's a lot longer than one generation.

There is an interesting form of renewable energy which often renews itself in a year or less, and if it isn't used it simply is wasted: That is biogas, which is made from the anaerobic digestion process, which uses ancient microorganisms which have existed since there has been life on earth, to make it.

Renewable (sustainable) biogas energy works like this. A crop, or better still an organic waste left over from the growth of a crop (for example supermarket food waste), is fermented in a biogas digester, a gas (biogas) bubbles off, and that gas is used instead of natural gas. This is a fabulous renewable energy, because it burns clean - which would certainly doesn't. It can be used for anything natural gas can be used for, including as CNG (compressed natural gas) for vehicle fuel. It is also quickly replenished (much more quickly than wood) by using the material remaining afterwards as a fertilizer, to grow the next year's crop.

2.5 WHY IS RENEWABLE ENERGY NEEDED (ADVANTAGES)

Renewable energy is important because of the benefits it provides. The key benefits are:

2.5.1 Environmental Benefits

Renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies for our children's. Renewable energy will not run out. Ever. Other sources of energy are finite and will someday be depleted.

2.5.2 Jobs and the Economy

Most renewable energy investments are spent on materials and workmanship to build and maintain the facilities, rather than on costly energy imports. Renewable energy investments are usually spent within the United States, frequently in the same state, and often in the same town. This means your energy dollars stay home to create jobs and fuel local economies, rather than going overseas.

2.5.3 Renewable Energy Is Economically Sound

By recent Greenpeace estimates, the world could save around $180 billion a year by switching 70% of the planet's electricity production to renewable options. While this alone is an excellent economic argument in favor of renewable energy, the truth is that the sheer savings involved aren't the only economic factors that support the use of renewable energy as a positive way forward. Some local markets are already starting to gain access to renewable energy options in their local power grid that have them saving more money than with traditional fossil fuel sources.
When other economic indicators like employment are considered, the use of renewable energy becomes even more attractive. In Germany, nearly one quarter of national energy demand is met by renewable resources. This has led to an increase in employment within the energy sector by nearly 380,000 new jobs. It's reasonable to conclude that this trend will be continuing into the future as renewable energy investment continues to rise around the world.

2.5.4 Renewable Energy Is Generally Better for the Environment

In 2014, carbon dioxide accounted for just over 80% of the greenhouse gases emitted into the atmosphere. Fossil fuels are also responsible for a significant amount of land, water, and air pollution beyond their CO2 production. For example, coal mining brings solid wastes to the surface that would normally remain underground and the areas around a mine can remain barren for generations if due to the lack of proper topsoil. The burning of coal for energy also produces many different types of particulate matter that pollute the air. The finest of these particles can be inhaled deeply and cause various respiratory health problems in people living around the power plant. These pollutants make their way into the water cycle and fall the ground as acid rain, which can destroy land and pollute large bodies of water.

Renewable energy sources are not without their environmental impacts. Wind turbines can impact migrating bird species and dams can severely disrupt the ecology of surrounding areas. There is also an argument that renewable energy options are not as efficient as fossil fuels; however this is purely an economic argument. When one factors in the various non-financial costs of fossil fuel use such as pollution, climate change, and the impact on biodiversity, renewable energy is actually far more efficient than fossil fuels.

2.5.5 Renewable Energy Makes Sense

There are a lot of good reasons to move toward the use of renewable energy both now and in the future. However, the most powerful of these arguments is simply that at some point you will no longer have the option. Whether it's you specifically or your grandchildren, fossil fuels will be left behind at some point. The question now is whether society wants to transition away from fossil fuels on its own terms or be forced into it by desperate necessity sometime down the line.

2.6 OBSTACLES FACE IN GENERATION OF RENEWABLE ENERGY

Despite the benefits, obstacles continue to stand in the way of renewable energy consumption and technologies. Renewable energy accounts for only 23% of the world’s electricity generation. This is according to the latest figures from the National Renewable Lab. One would be forgiven for thinking that this is a rather low figure since the development of renewable energy technology has been growing significantly and their costs are on the decrease.

So what is holding the industry back?

A lack of reliable energy storage technologies: Technologies are still in the early stages of research and development. Although a great deal of money is being ploughed into their development, utilities will not rush in until the technology has proven its reliability. Where storage solutions are available, for example hydroelectric pumped storage, it is normally not located close to the renewable source which makes the supply less controllable than fossil fuel supplies.
Outdated business models: There are utilities which continue to receive rewards for the construction and maintenance of fossil fuel plants.

High initial capital costs: Although the costs of renewable energy technology are coming down, it's the initial implementation costs that can be rather high. Transmission systems must be adjusted in order to handle renewable energy integration and a huge investment is required to construct power lines across jurisdictions.

Balance of system costs: These can add up as they include the cost of the inverter and electrical system, mechanical racking, installation, and permitting. However, large installations could work out cheaper than smaller installations.

Perceived technology performance uncertainty:
There are numerous startup companies in the renewable energy sector. This can be very confusing for the utility and they may opt for the cheapest option. Often, it doesn't pay to go cheap and utilities may end up being disappointed by poor performance levels. This may lead utilities to believe that all renewable technology is of poor quality.

Lack of appropriate transmission infrastructure to support these projects:
There is a need for new transmission corridors to serve remote sites, as well as extensive environmental impact assessments which can take years to complete.

Ideal locations for renewable energy development: Sometimes these may be too far from demand centers and existing distribution networks. To extend the transmission network, may cost a great deal of money.

Use of dated technology: Old models do not adequately consider input from renewable resources, preventing grid companies from including them in to the supply mix. The smart grid will also assist in the integration and management of renewable energy. It is therefore essential that the right technology exists to support the introduction and maintenance of renewable.

WHAT WOULD INSTIGATE RENEWABLES' GROWTH?

- Negative preconceptions about renewable energy and technologies will need to be changed.
- Increasing renewable energy requirements.
- Dropping the "rate of return" as a basis for utility profit.
- Rewards for utilities that switch to renewable energy.
- An increase in research funds for energy storage solutions.
- Upgrading of transmission infrastructure and technologies to support renewable energy integration.
- An increase in the number of micro grids, this would solve the transmission infrastructure issue.
- Institutional funds ploughed in to renewable.

Despite the long list of negatives, renewable energy will continue to grow for the simple reason that our fossil fuels are dwindling. We cannot ignore the fact that renewable provide us with a sustainable energy source. Today, renewable energy is at a technological advantage, the technology simply needs a chance to develop further and compete with existing energy sources. Regulators and utility companies must recognize the need for energy models to adapt, with smarter logic and comprehensive scenario planning. In addition, they have to develop comprehensive policies which will create a fair playing field for all energy technologies, only then can the role and potential of renewable energy and its technologies be fully realized.
Energy ~ Renewable Energy

WHAT ARE EXAMPLES OF RENEWABLE ENERGY

The most common types of renewable energy include:
•solar energy (produced by the sun and captured in solar panel systems)
•wind energy (produced by the wind and captured through wind turbines)
•geothermal heat (derived from heat in the earth's core and captured through

geothermal power pumps that drill holes into rocks to capture steam)
•rain or snow (which can flow into streams and be captured and turned into hydroelectric power.

2.7 WHAT IS POWER DISTRBUTION

Electric power distribution is the final stage in the delivery of electric power, it carries electricity from the transmission system to individual consumers. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 kV and 35 kV with the use of transformers. Primary distribution lines carry this medium voltage power to distribution transformers located near the customer's premises. Distribution transformers again lower the voltage to the utilization voltage of household appliances and typically feed several customers through secondary distribution lines at this voltage. Commercial and residential customers are connected to the secondary distribution lines through service drops. Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the sub transmission level. Can also be put in this way.
Power distribution is a process which is used to move electricity from locations where it is generated to people who need it. Distribution takes place through a system known as the electrical grid or simply “grid,” which is designed to keep power constantly on call so that it can meet demand. Managing the electrical grid is an extremely challenging and demanding task, and in several nations, concerns were raised in the early 21st century that existing power distribution infrastructure might not be up to changing demand.
The process of power distribution starts at the facility where electricity is generated. A number of techniques can be used for electrical generation, most of which revolve around spinning a turbine, whether with wind, water, or steam. Once the power is generated, it moves to a transformer substation where the voltage is “stepped up” to travel across high voltage transmission lines. These lines connect with other substations which step down the voltage to make it safe for household and industrial use, with power lines running from these substations to various consumers.

2.8 WHY IS POWER DISTRIBUTION NEEDED

Switchgear: A Necessity for Power Distribution

Electricity is an important part of our life. However, when it comes to electricity distribution, it needs to be done in a safe and secure manner. It entails several handling hazards, which, when not done safely, can easily turn into a deadly trap. There are times when accidents and mishaps happen due to the lack of safety at different power distribution units. Therefore, to maintain the security levels at all distribution units and sub stations, it is critical to install safety devices and mechanisms. While there are many mechanisms that help in safeguarding electrical connections at residential and industrial areas, switchgear is one of the most popular ones due to its various functions and features. Analyzing switchgears from the perspective of commercial, industrial, and institutional MV (medium voltage) distribution system, its functions are as follows:

Switchgears provide sufficient segmentation of the MV system to reduce the extent of circuit outages during electrical work on cables and power stations.

This device helps in the distribution and carriage of load and overloads during maintenance and service of different electrical connectors.

It helps in clearing and identifying different types of faults and connection failures, helping minimize the damage.

3 CHAPTER 3: SOFTWARE INTRODUCTION

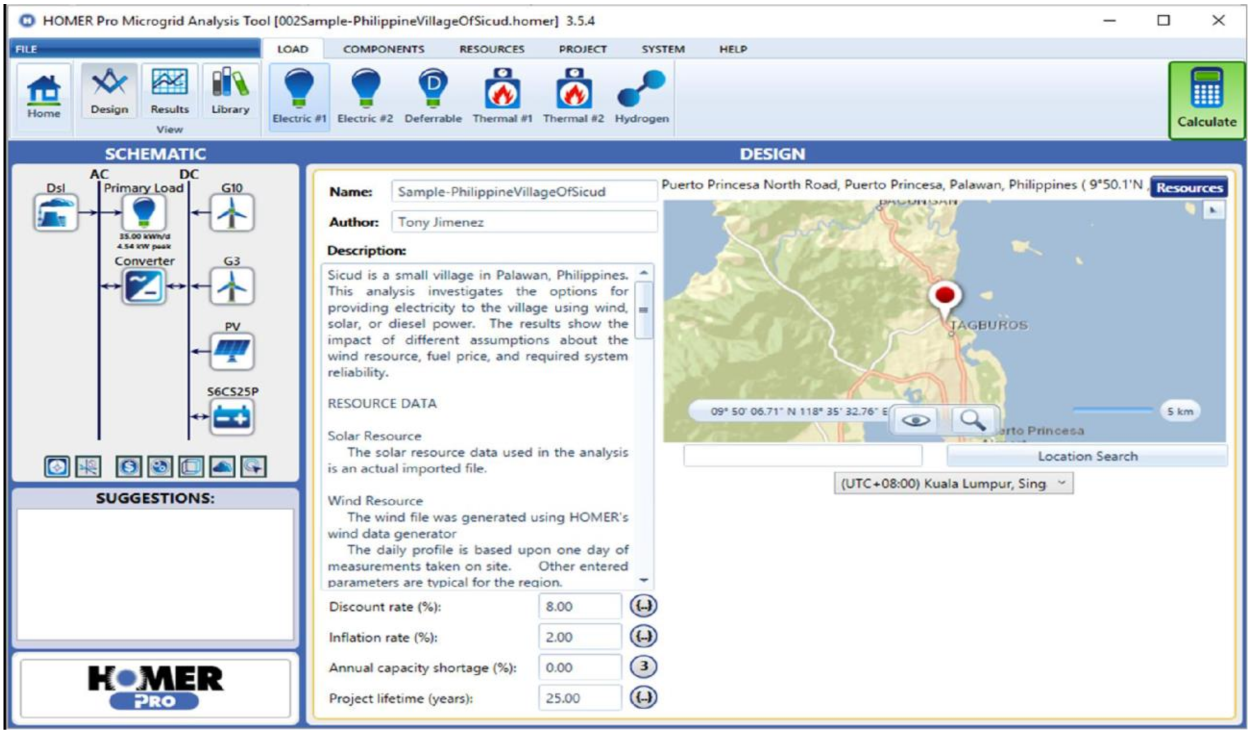
3.1 Homer Pro

The Homer Pro Clean Energy Project Analysis Software is an innovative energy awareness, decision support and capacity building tool. The HOMER Pro micro grid software by HOMER Energy is the global standard for optimizing micro grid design in all sectors, from village power and island utilities to grid connected campuses and military bases wind power potential has never been considered as an alternative source of energy in some countries. For that reason, many researches took place to utilize renewable energy especially wind energy in a full-fledged manner. In their research, calculations of the mean wind power density from a hypothetical aero generator or water pumping system and the mean wind power from circular areas were also made. In the Western regions of the Gambia, a very fruitful result would be achieved if windmills were installed for producing wind energy for drinking water, irrigation and electricity for small households, they concluded. For the realization of this research work, relevant information in the international scientific arena was collected, through diverse studies of literature from textbooks/literature, international scientific journals, internet websites, reports by governmental agencies and NGO's. Substantial knowledge was gathered and a review of what other scientists have written on issues concurring with the research topic was made. Major literature reviews were conducted to assemble information in the following areas. The first was related to a description of the state and situation of energy generation and consumption in the Gambia. The second was aimed at presenting the rationale, objectives and outline of the workflow in this research. The third area was used to give a detailed description of the tool used in the technical analysis to assess the potential of RE generation in the Gambia.

HOMER being one of the most used. By using such tools, the optimum configuration can be found by comparing the performance and energy production cost of different configurations. HOMER was originally developed at the National Renewable Energy Laboratory (NREL), United States. A commercial version has been developed, upgraded and distributed by HOMER Energy, LCC and is used by the authors as teaching aid for our renewable energy course. It can be used to design, analyze and model micro-power and hybrid power system's configurations with various energy resources for economics and sizing to determine the optimal combination of them to meet the load demand and the user requirements. It shows the calculation result of the number of cases of different renewable energy sources under weather conditions, load demands, capacity ranges, fuel costs, and carbon emission constraints to select the optimum system. HOMER software package can facilitate the design and analysis of hybrid power systems for both stand-alone and grid-connected applications. Input information to be provided to HOMER includes: electrical loads (one year of load data), renewable resources, component technical details and costs, constraints, controls, type of dispatch strategy, etc. It designs an optimal power system to serve the desired loads, performing several simulations to ensure best possible matching between supply and demand in order to design the optimum

System. It uses life cycle cost to rank order these systems, while can simulate the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system.

HOMER performs the energy balance calculations, system cost calculations for each of the considered system configuration, listing all of the possible system sizes, sorted by Net Present Cost (NPC). HOMER includes several energy component models, and evaluates suitable options considering cost and availability of energy resources. Grid connection is also considered in HOMER design procedure. It requires initial information including energy resources, economical and technical constraints, energy storage requirements and system control strategies. Inputs like component type, capital, replacement, operation and maintenance costs, efficiency, operational life, etc. are also required.



3.2 Applications of Homer Software in Grid Connected

3.2.1 SOLAR CONNECTED TO GRID

The variable power flow due to the fluctuation of solar irradiance, temperature and choice of power semiconductor devices are some of the parameters that affect the power quality of photovoltaic systems. Good power quality translates into obtaining a sinusoidal voltage and current output from a photovoltaic system in order to avoid harmonics, inter harmonics and eventually voltage distortion. With high connection densities of photo voltaic in the distribution grid, low irradiance can lead to undesirable variations of power and supply quality (voltage and current) at the connection point which might even exceed acceptable limits that are set out by the respective grid codes. Aspects related to the quality of electricity as generated from the inverter, which is the element in a PV system responsible for converting the DC power to AC, are also important. The circuit topology of the inverter can determine the behavior and the power characteristics, during input and output changes. In addition, large quantities of photovoltaic inverters can give rise to power quality problems on networks, even when inverters comply with standards. Such behavior, characterized by low power quality, is often troublesome because it prevents reliable equipment operation and causes failure of sensitive electronic devices. The figure shows two stage conversion processes. The PV array generates the DC output which is stored in a battery. The output DC is converted to AC with the help of the inverter circuitry arrangement. The boost converter is employed here to covert variable DC to fix DC, which gives a constant output irrespective of change in input.

Conversion Stages

1) Photovoltaic DC to chopper
2) Chopper to battery
3) Battery to AC conversion
4) Converted AC to load

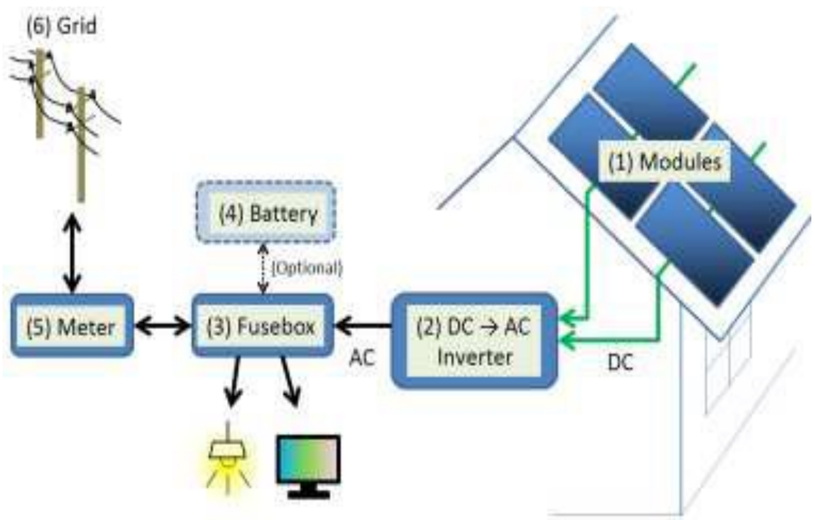
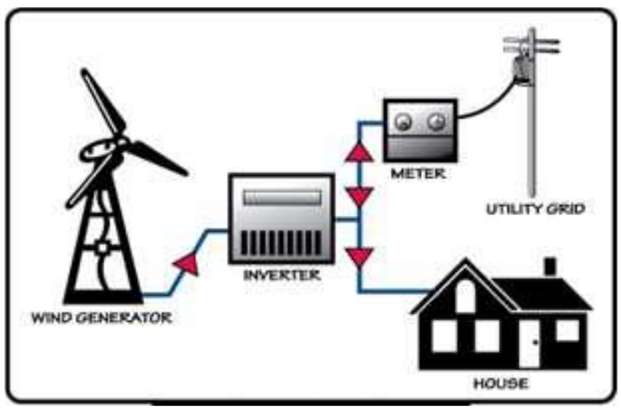


Fig. 1: Grid connected solar system 1

3.2.2 WIND SYSTEM CONNECTED TO GRID

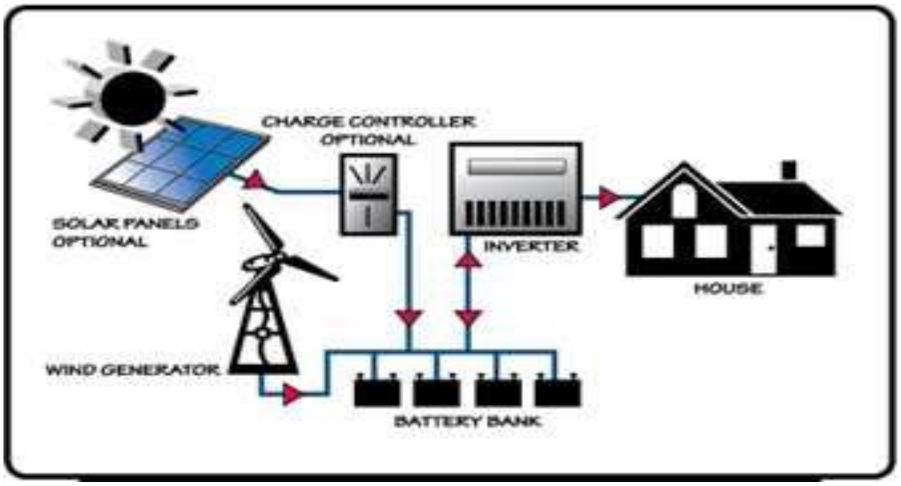
The wind turbines generate power by rotating a permanent magnet generator which generates three phase AC at the frequency of the turbine's rotation. The AC power from the generator is not only the wrong voltage to be connected to the local power grid, but also, as the wind speed changes so do the rotational speed of the turbine, and therefore the frequency of the power generated. The power from the generator therefore needs to be converted to DC and then fed into a special electronic device called an inverter, to ensure that it is always at the correct frequency and voltage to the local grid.

The power generated will be first used by your own property, thereby saving you the maximum amount possible on your electricity bill. Any excess energy your wind turbine generates, e.g. on windy days or at night, is “spilled” to the power grid and your electricity supplier pays you for it. In order to charge your electricity supplier for any energy that you export to the grid, you need to have a new bi-directional electricity meter installed which will work both when you buy (import) and sell (export) electricity. Depending upon your local requirements, there may be additional meters needed to record energy generation to enable a claim for a Government subsidy.

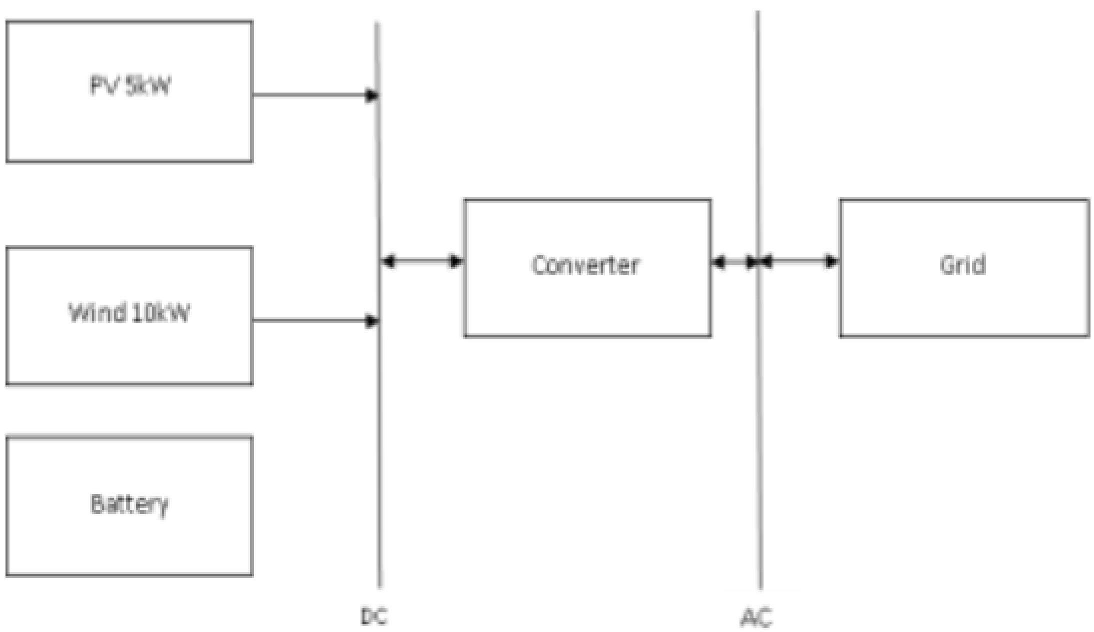


3.2.3 SOLAR AND WIND SYSTEM CONNECTED TO GRID

Combining Wind Turbine and Solar Panels into a hybrid system offers several advantages. In many places, wind speeds are low in the summer when the sun is plentiful. The wind is strong in the winter when less sunlight is available. Because the peak operating times for wind and solar systems occur at different times of the day and year, hybrid systems are better balanced and more likely to produce power when you need it. Wind power can be an excellent complement to a solar power system. When the sun isn’t shining, the wind is usually blowing. Wind power is especially helpful in the winter to capture both the ferocious and gentle mountain winds during the times of least sunlight and highest power use. In some locations wind is not suitable as the ONLY source of power—it simply fills in the gaps left by solar power quite nicely.



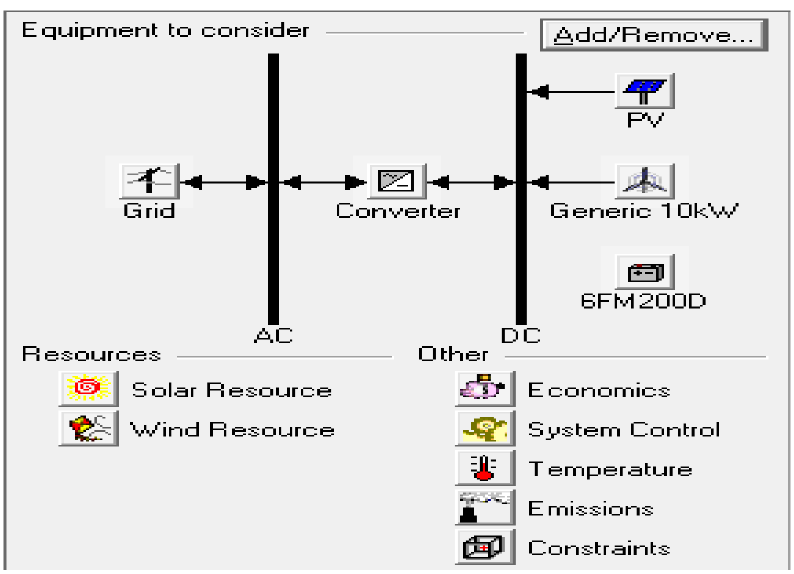
BLOCK DIAGRAM OF PROPOSED SYSTEM



The proposed block diagram represents the 15kW grid connected solar and wind system. A 5kW solar panel is integrated to 10kWwind energy through a DC bus bar. A battery system is provided in additional to store the excess energy which can be used when there is a need. A suitable converter is used for conversion of DC source into AC before connecting to the grid through the AC bus bar.

3.2.4 SIMULATION SOFTWARE

HOMER is a micro power optimization model which simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations. HOMER simulates the operation of a system by making energy balance calculations in each time step of the year. HOMER performs these energy balance calculations for each system configuration that needs to be considered. It then determines whether a configuration is feasible, i.e., whether it can meet the electricity demand under the specified conditions and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest. After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by net present cost (sometimes called life cycle cost), that can be used to compare system design options. When you define sensitivity variables as inputs, HOMER repeats the optimization process for each sensitivity variable that you specify. For example, if you define wind speed as a sensitivity variable, HOMER will simulate system configurations for the range of wind speeds that you specify.



4 CHAPTER 4: Technical analysis

4.1 Case study 1: The Gambia

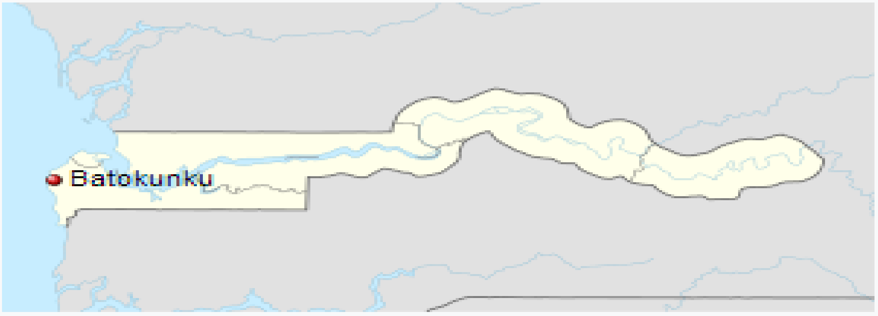
4.1.1 Introduction

For a comprehensive analysis of the renewable energy resource potential of The Gambia, two major sources of renewable energy were considered. These were wind and solar.
Due in a large part to time constraint and the scope of a master thesis, other sources of renewable energy such as biomass, combine heat and power, nuclear and geothermal heat was not considered. Hydro was not considered based on the fact that it has already been developed in the Gambia and is the main source of electricity generation. The location for this research was carefully selected.

4.1.2 Location of the project Batokunku

Batokunku (also spelled as Batukunku) is a village located in Kombo South, one of the nine districts of The Gambia's Western Division. In January 2009, the village became notable as the location of the first wind turbine erected in West Africa. The 150 kilowatt turbine, a second-hand machine originally built by the Danish wind energy manufacturer Bonus, currently provides electrical power for the entire village.[1] The windmill is currently serviced/maintained by Global Energy (generator service) based in the nearby village of Tujereng in collaboration with Windstrom SH from Germany

Batokunku	
Village	



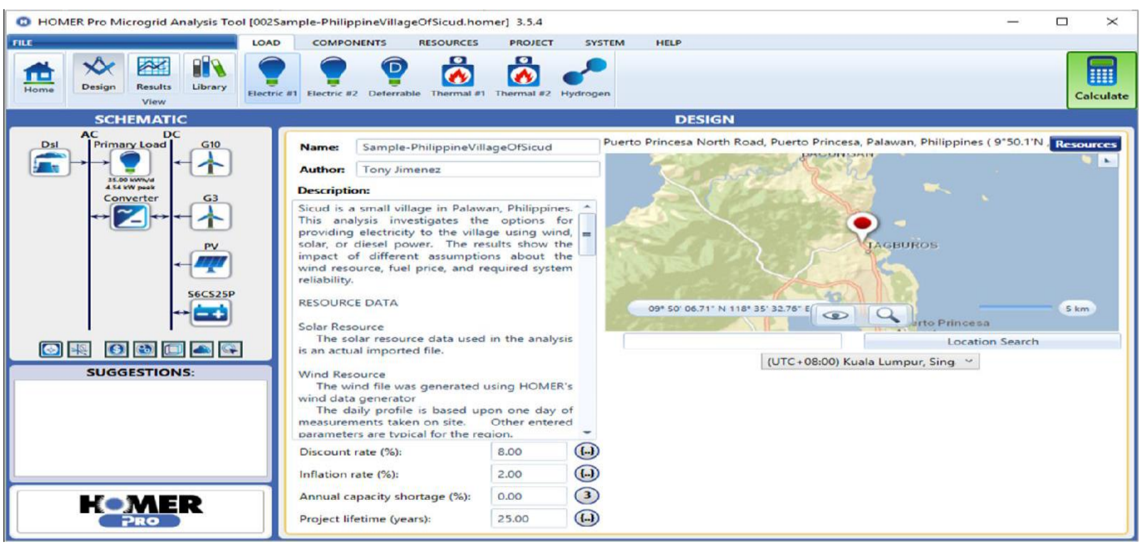
Location of Batokunku in The Gambia

Coordinates: 13°19′24″N 16°48′3″W

Country	The Gambia

The following step was use for the Analysis:

1. As part of the Homer Pro Clean Energy Project Analysis software, the Start worksheet was used to enter general information about the project, as well as site reference conditions regarding climate. It was also used to select standard settings used to perform the analysis.



2. After all the general information for the analysis were entered, the energy model worksheet was used to evaluate various types of energy efficiency measures projects. This was then used to investigate the viability of energy efficiency in the locations selected for wind and solar. This could also be used for improvements in a wide range of residential, commercial, institutional buildings, and industrial

facilities, from single-family homes and apartment complexes, to office buildings, hospitals, large pulp and paper mills.

Results and Discussion

Monthly assessment results

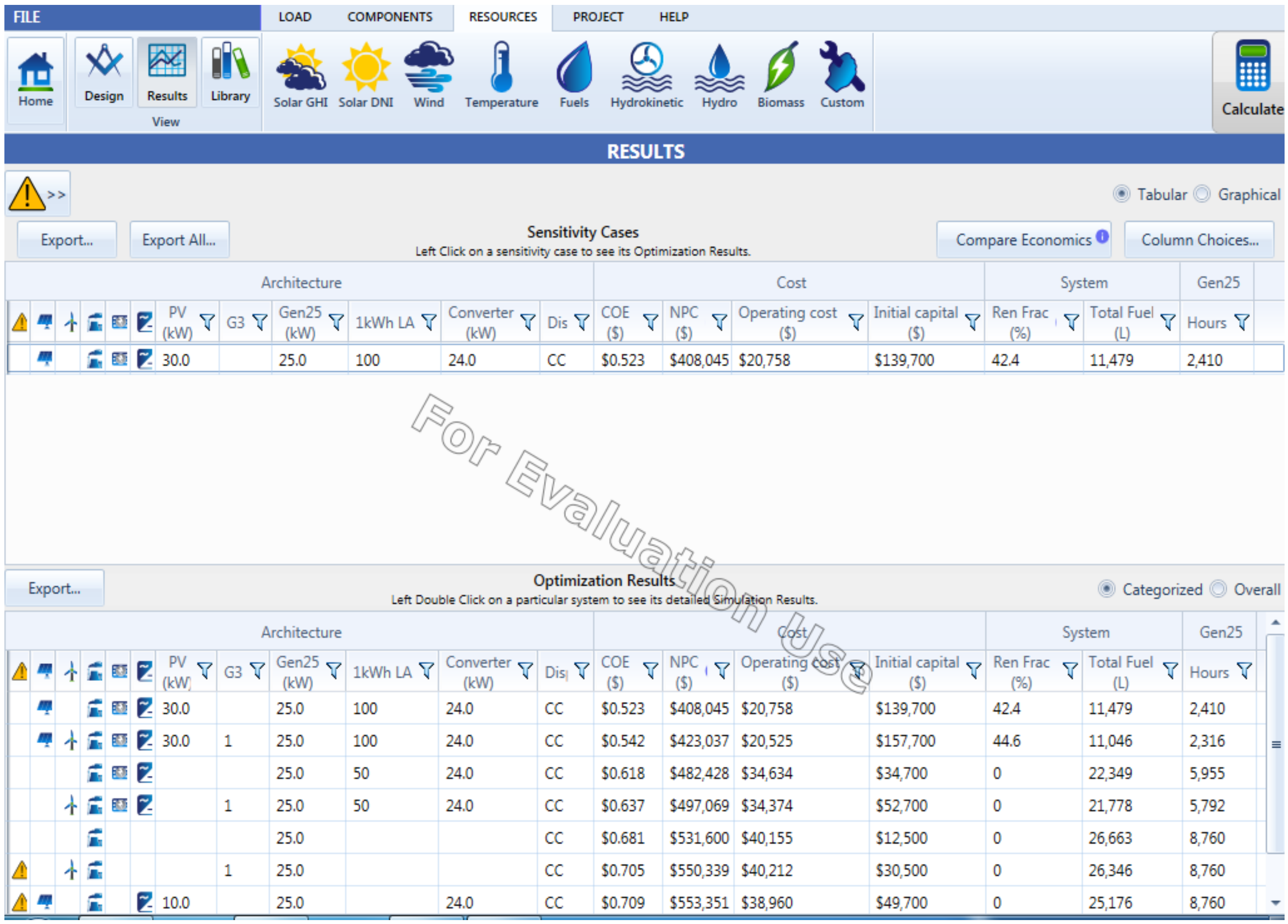
Months	Batokunku wind speed (ms)
January	5.750
February	5.590
March	5.440
April	5.620
May	5.380
June	4.560
July	4.250
August	3.970
September	3.540
October	3.280
November	4.090
December	5.040
Annual	4.709

Following the above results, it is obvious that Batokunku has a moderate prospect for electricity generating capacity from wind. Comparatively though, it is the best location for wind energy in The Gambia. Peak months could be noted in January when the winds are strongest whereas in the month of October, the winds are low and therefore would not be capable of generation.

Monthly assessment results (Solar)

Months	Daily solar radiation -horizontal kWh/m²/d
January	4.784
February	5.362
March	6.000
April	6.145
May	6.086
June	5.229
July	4.654
August	4.465
September	4.786
October	5.090
November	4.800
December	4.794
Annual	5.183

4.1.3 Simulation Results



Sensitivity Cases

PV (kW)	G3	Gen25 (kW)	1kWh LA	Converter (kW)	Dis	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Total Fuel (L)	Gen25 Hours
30.0		25.0	100	24.0	CC	$0.523	$408,045	$20,758	$139,700	42.4	11,479	2,410

Optimization Results

PV (kW)	G3	Gen25 (kW)	1kWh LA	Converter (kW)	Dis	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Total Fuel (L)	Gen25 Hours
30.0		25.0	100	24.0	CC	$0.523	$408,045	$20,758	$139,700	42.4	11,479	2,410
30.0	1	25.0	100	24.0	CC	$0.542	$423,037	$20,525	$157,700	44.6	11,046	2,316
		25.0	50	24.0	CC	$0.618	$482,428	$34,634	$34,700	0	22,349	5,955
	1	25.0	50	24.0	CC	$0.637	$497,069	$34,374	$52,700	0	21,778	5,792
		25.0			CC	$0.681	$531,600	$40,155	$12,500	0	26,663	8,760
	1	25.0			CC	$0.705	$550,339	$40,212	$30,500	0	26,346	8,760
10.0		25.0		24.0	CC	$0.709	$553,351	$38,960	$49,700	0	25,176	8,760

Our goal was to keep the Cost of Energy as low as possible (Less than 1). In this project our **COE= 0.494** which is very good because <<1, and the Net Present Cost NPC is **$636, 073,** So the project is feasible. The COE is simply the average cost per kWh of electricity. NPC: Represent the life-cycle cost of the system. This single value includes all costs and revenues that occur within the project lifetime.

4.1.4 Conclusion and Perspective

The present work is to make a design study of a wind farm in the village of Batokunku the kombo south district of the Gambia. For this, a study of the site said energy potential was performed with the software Homer Pro. The study of the

deliverability of the site, the installation of wind turbines on the site and study of the noise impact has been made with the Homer Pro software. This study allowed us to give the following conclusions:
- The annual average rate increased to 50 m height is 4.01 m / s. it is 4. 89 m / s for 70 m high, 5.09 m / s for 100 m high, 5.28 m / s for 139 m high and 5.32 m / s for 150mhigh.
- The directions where the winds are most dominant is recorded in sectors 13 °19.7’ N, 16 °47.8’W.
To refine this work, there should be a comprehensive environmental study showing clearly:
- The study of the visually impacted area (ZVI)
- The study of the impact on birds
- The study of SHADOW (duration flicker shadows)
It would also make a soil survey to facilitate the achievement of Foundations different wind turbines to be installed at the site, a study of injection to the existing network and make a detailed economic study.

4.2 Part 2: Case study of Yemen (Amran)

ʿAmrān (Arabic: عمرانis a small city in western central (Yemen. It is the capital of the 'Amran Governorate, and was formerly in the Sana'a Governorate. It is located 52.9 kilometers (32.9 mi) by road northwest of the Yemeni capital of Sana'a.[1] According to the 2004 census it had a population of 76,863, and an estimated population of 90,792 in 2012.

4.2.1 History

The founding of the town dates back to the era of the South Arabian Himyarite Kingdom. At the time of the Sabaean kingdom, the town blossomed into a fortress. A series of bronze plaques from that time were found in the town in the mid-nineteenth century and are now in the British Museum. In particular, in the seventh century it was the great city of valour during the clashes against the Sabeans, a plurality of regionally based tribes. Remains of carved stones that belonged to former temples and palaces bear witness today of past glory. A large stone inscription is found in the western city gate (Bab al-Kabir). The oldsouq is noted for its stone columns. Amran is completely surrounded by walls which date to 1720. The surrounding landscape is dominated by terraced landscapes with stone walls to counteract erosion of fertile arable land.

Location in Yemen

Coordinates: 15°40′N 43°57′E

Country	Yemen
Governorate	'Amran Governorate
District	Amran District
Occupation	Houthis (Ansar Allah)
Population (2012)	
• **Total**	90,792
Time zone	Yemen Standard Time (UTC+3)

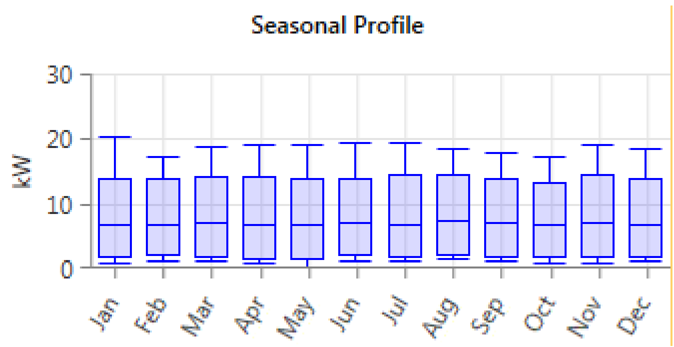
Homer software has been used to find out the best energy efficient renewable based hybrid system options to power a unit of 50 homes and supply water via a water pump. Input information to be provided to HOMER includes: electrical load (primary energy demand), renewable resources (solar radiation, wind speed data), component technical details, cost, constraints and controls etc. The software designs an optimal configuration to serve the desired electric loads.

To design the optimum system HOMER performs thousands of hourly simulations. HOMER also performs sensitivity analysis to see the impact of solar insulation, PV investment cost, wind speed and diesel fuel price on the COE.

Homer can't Module transient changes which are smaller than 1 hour. Economic analysis is very important before installing the system to generate power. HOMER makes this economic analysis and ranks the systems according to their net present cost.

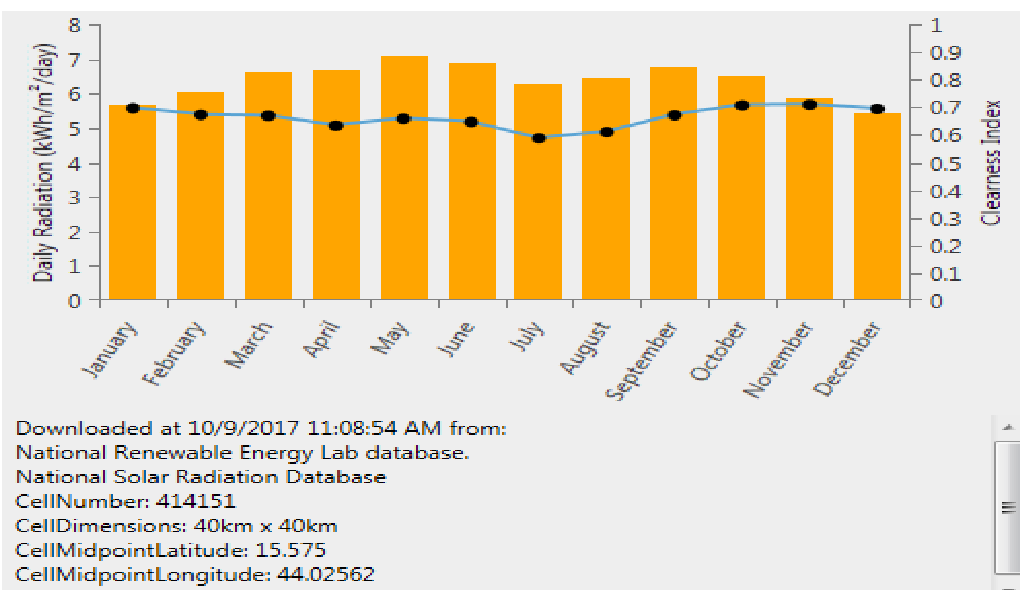
4.2.2 Load

In this study, a unit of 50 households has been considered. This load is based on 3 energy efficient lamps (compact fluorescent bulb, 15 W each), 1 fan (ceiling fan, 40 W), and 1 television (TV, 40 W) for each family and 2 energy efficient lamps (15 W each), 1 fan (40 W).



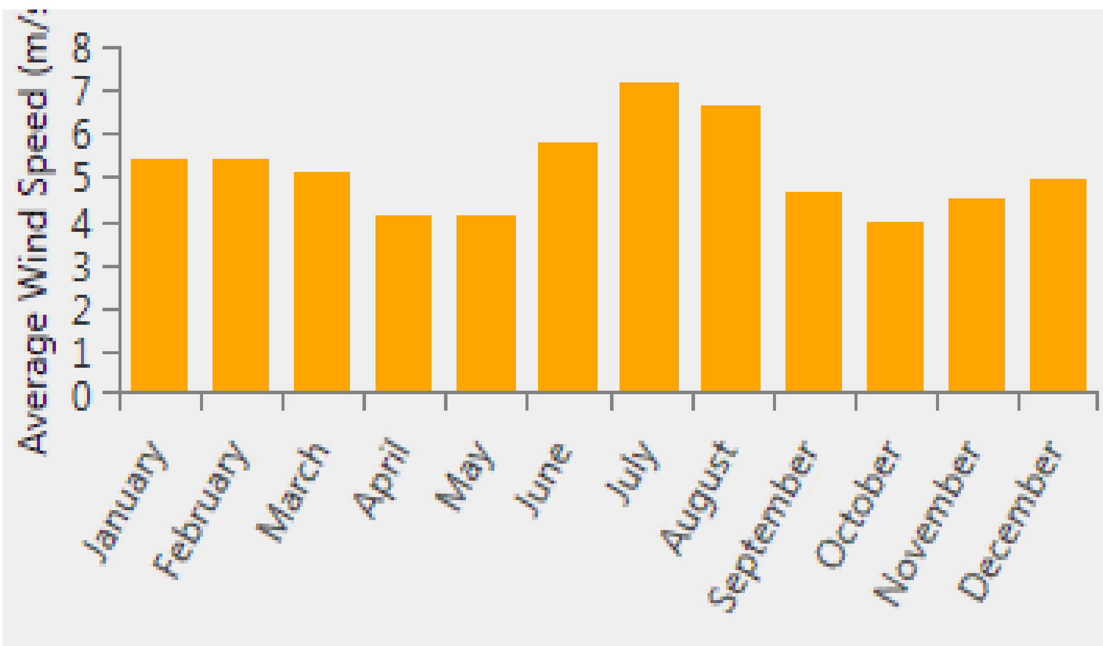
4.2.3 Solar Energy

As hourly data is not available therefore monthly averaged global radiation data has been taken
from NASA (National Aeronautics and Space Administration).

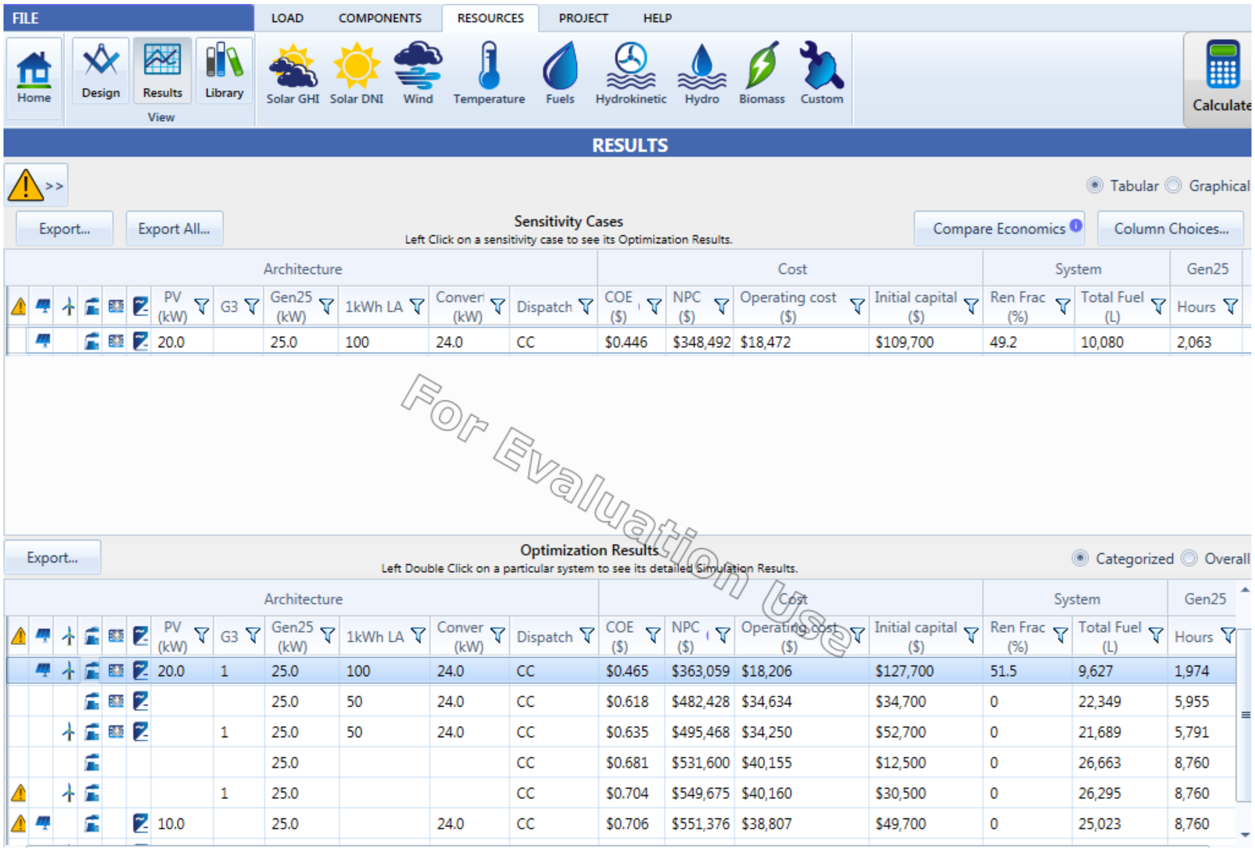


4.2.4 Wind Energy

When hourly data is not available, hourly data can be generated synthetically from the monthly averages. HOMER’s synthetic wind speed data generator is a little more different to use than the solar data because it requires four parameters.
The Weibull value: k value is a measure of distribution of wind speed over the year. In this study, the value of k is taken as 2. The autocorrelation factor: This factor measures the randomness of the wind. Higher values indicate that the wind speed in 1 h tends to depend strongly on the wind speed in the previous hour. Lower values mean that the wind speed tends to fluctuate in a more random fashion from hour to hour. The autocorrelation factor value is taken as 0.78. The diurnal pattern strength: It is the measure of how strongly the wind speed depends on the time of the day. In this study, 0.30 is used. The hour of peak wind speed: It is simply the time of day tends to be windiest on a average throughout the year. In this study, 8 is used as the hour of peak wind speed.



4.2.5 Results and discussion



Sensitivity Cases

Architecture						Cost				System		Gen25
PV (kW)	G3	Gen25 (kW)	1kWh LA	Conver (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Total Fuel (L)	Hours
20.0		25.0	100	24.0	CC	$0.446	$348,492	$18,472	$109,700	49.2	10,080	2,063

Optimization Results

Architecture						Cost				System		Gen25
PV (kW)	G3	Gen25 (kW)	1kWh LA	Conver (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Total Fuel (L)	Hours
20.0	1	25.0	100	24.0	CC	$0.465	$363,059	$18,206	$127,700	51.5	9,627	1,974
		25.0	50	24.0	CC	$0.618	$482,428	$34,634	$34,700	0	22,349	5,955
	1	25.0	50	24.0	CC	$0.635	$495,468	$34,250	$52,700	0	21,689	5,791
		25.0			CC	$0.681	$531,600	$40,155	$12,500	0	26,663	8,760
	1	25.0			CC	$0.704	$549,675	$40,160	$30,500	0	26,295	8,760
10.0		25.0		24.0	CC	$0.706	$551,376	$38,807	$49,700	0	25,023	8,760

In this software the optimized results are presented categorically for a particular set of sensitivity parameters like solar radiation, wind speed, diesel price, maximum annual capacity shortage and renewable fraction. HOMER performs thousands of hourly simulations over and over in order to design the optimum hybrid system.
Simulations have been conducted considering different values for solar radiation, wind speed, minimum renewable fraction, and diesel price providing more flexibility in the experiment. The optimization results for specific wind speed **5.15m/s**, solar irradiation **6.36kWh/m.sq**. It is seen that a PV, wind turbine, diesel generator and battery hybrid system is economically more feasible with a minimum **COE $0.446 KWh** and a **NPC $348,492**.

4.2.6 Conclusion

Data of most kinds are scarce for Yemen where even reliable GDP estimates have been difficult to ascertain. This study includes several statistical facts that we cite with as much diligence about their validity as possible given the lack of data about the country. All statistics cited should therefore be used cautiously. As the results shown of the case study of Amran town the feasible implementation of a hybrid system, we can duplicate the concept to the rural regions which represent the majority of the Yemen landscape and avoid other humanitarian crises also it would refresh the overall economy.

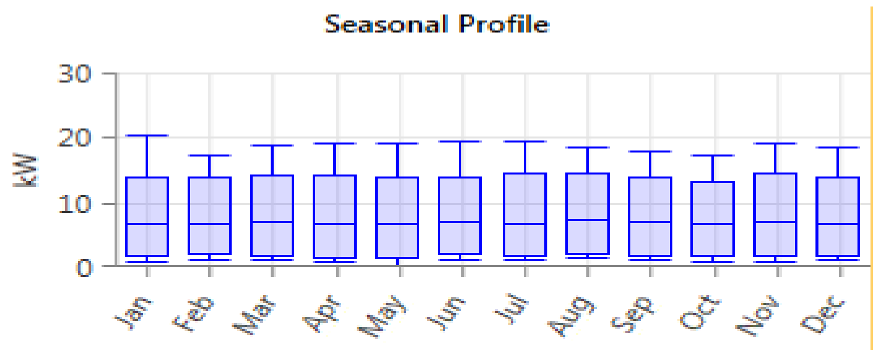
4.3 Part 3 : Case study of Bangladesh (Narsingdi)

Narsingdi is a district in central Bangladesh. It is located 50 km north-east of Dhaka, capital city of Bangladesh. It is a part of the Dhaka_Division. The district is famous for its textile craft industry. Narsingdi is bordered by Kishoreganj in the north & north-east, by Brahmanbaria in the east & south-east, Narayanganj at south & south-west and by Gazipur in the west. Total area of this district is 1,140.76 km^2 (440.45 sq mi) and also Total population is 2224944 according to census 2011.

Narsingdi is a densely industrial area and is home to many textile mills. Narsingdi is rich by several number of jute mills, which plays an important rule in economy. The biggest and renowned Haat (Textile market) of Bangladesh is located here at Madhabdi which is known as Shekherchaur Babur Haat. There are two urea fertilizer industries in palash and ghorashal. Narsingdi has 3923 mosques, 52 temples, nine Buddhist temples and three churches. The communication system of this district is very good. The Dhaka-Sylhet highway one of the important highways of Bangladesh passes through Narsingdi. Inter-district road communication is also better from here. The Meghna, the Shitalakshya, the old Brahmaputra, Arial_Kha, Haridhoa, and Paharea are some of the main rivers that flow through this district. Basically our project will be implement at Shibpur Upazila of Narsingdi__District in the Division of Dhaka, Bangladesh. Shibpur is located at 24.3750°N 90.7375°E. It has 44365 households and total area 206.89 km^2.Shibpur has a population of 237246. Males constitute 50.77% of the population, and females 49.23%. This Upazila's eighteen up population is 117487. Shibpur has an average literacy rate of 32.3% (7+ years), and the national average of 32.4% literate.

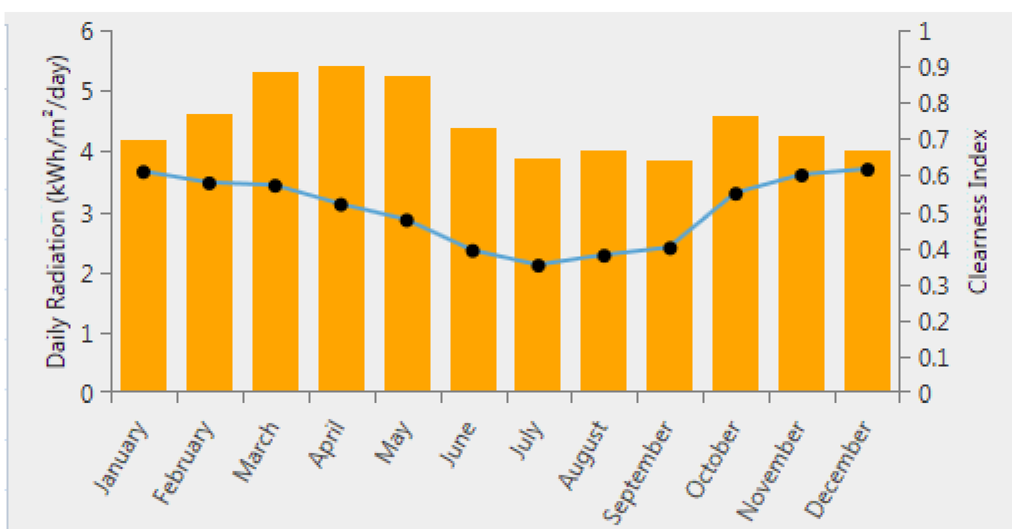
4.3.1 Load :

In this study, a unit of 50 households has been considered. This load is based on 5 energy efficient lamps (compact fluorescent bulb, 15 W each), 2 fan (ceiling fan, 40 W), and 1 television (TV, 40 W) for each family and 4 energy efficient lamps (15 W each), 2 fan (40W).



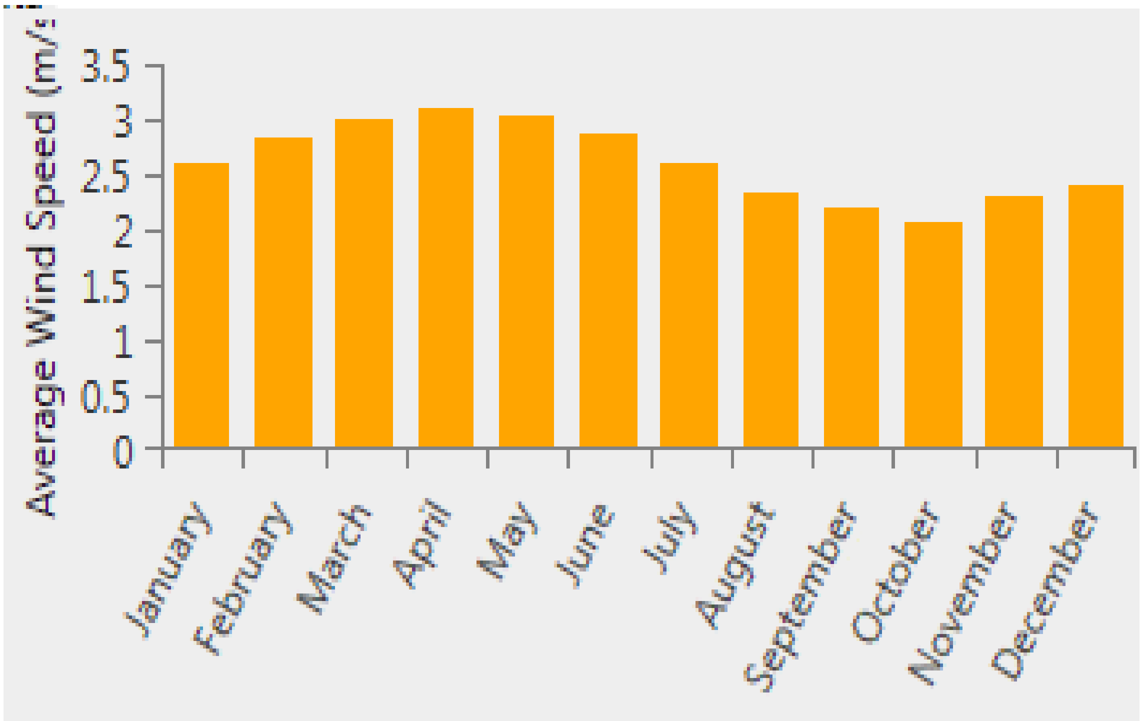
4.3.2 Solar Energy

As hourly data is not available therefore monthly averaged global radiation data has been taken from NASA (National Aeronautics and Space Administration).Clearness index from the latitude and longitude information of the selected site. HOMER creates the synthesized 8760 hourly values for a year using the Graham algorithm. Figure illustrates that the solar radiation is high between March to May.

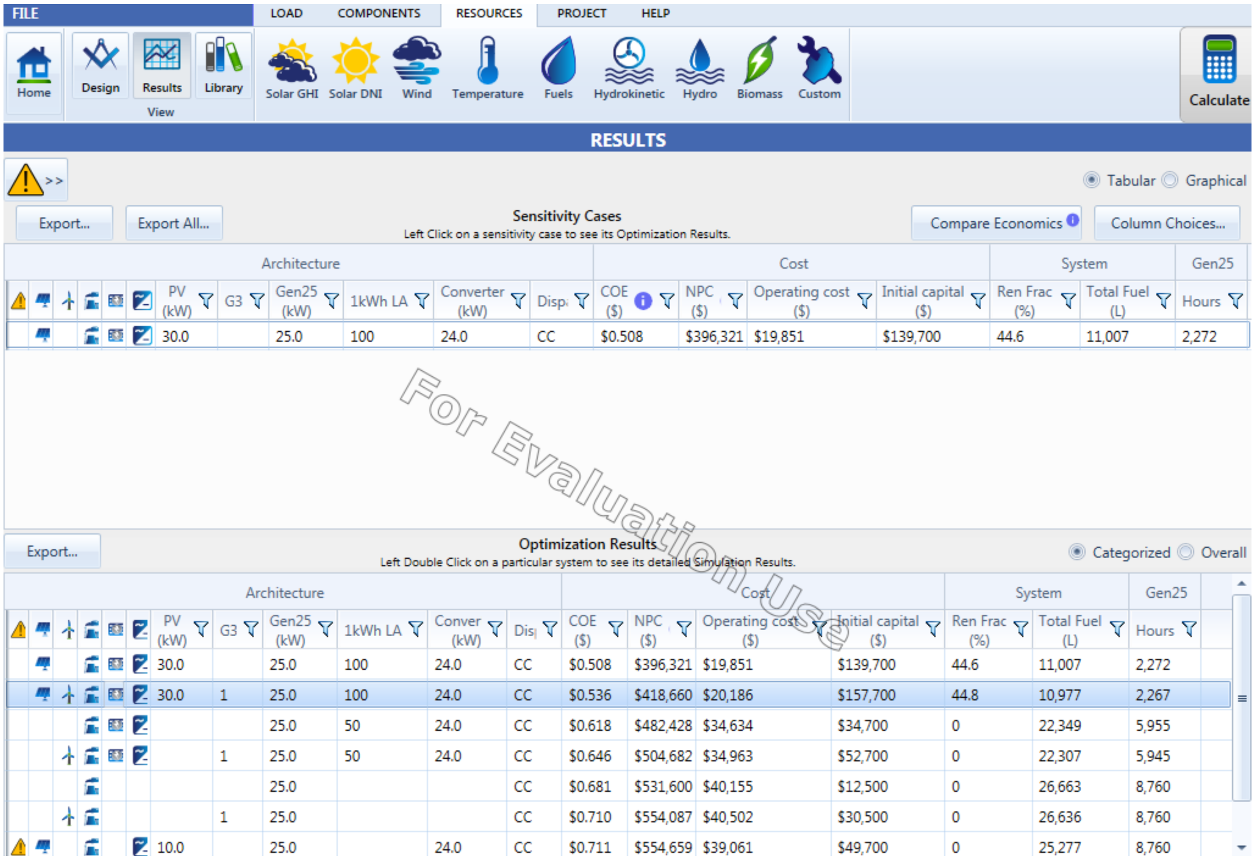


4.3.3 Wind energy

For wind energy in Bangladesh, Peak months could be noted in April when the winds are a bit stronger whereas in the month of October, the winds are low and therefore would not be capable of generation.



4.3.4 Results and discussion



PV (kW)	G3	Gen25 (kW)	1kWh LA	Converter (kW)	Disp	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Total Fuel (L)	Hours
30.0		25.0	100	24.0	CC	$0.508	$396,321	$19,851	$139,700	44.6	11,007	2,272

PV (kW)	G3	Gen25 (kW)	1kWh LA	Conver (kW)	Dis	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Total Fuel (L)	Hours
30.0		25.0	100	24.0	CC	$0.508	$396,321	$19,851	$139,700	44.6	11,007	2,272
30.0	1	25.0	100	24.0	CC	$0.536	$418,660	$20,186	$157,700	44.8	10,977	2,267
		25.0	50	24.0	CC	$0.618	$482,428	$34,634	$34,700	0	22,349	5,955
	1	25.0	50	24.0	CC	$0.646	$504,682	$34,963	$52,700	0	22,307	5,945
		25.0			CC	$0.681	$531,600	$40,155	$12,500	0	26,663	8,760
	1	25.0			CC	$0.710	$554,087	$40,502	$30,500	0	26,636	8,760
10.0		25.0		24.0	CC	$0.711	$554,659	$39,061	$49,700	0	25,277	8,760

Simulations have been conducted considering different values for solar radiation, wind speed,

Minimum renewable fraction and diesel price providing more flexibility in the experiment. Our goal was to keep the Cost of Energy as low as possible (Less than 1).In this project our **COE= 0.508** which is very good because <<1, and the Net Present Cost **NPC is $396, 321**, So the project is feasible. The optimization results for specific wind speed 4.47m/s, solar irradiation **2.62kWh/m.sq**

4.3.5 Conclusion

Improving electricity access and affordability will help the country address poverty through increasing household incomes. Although it is difficult to know the size of the effect of electricity on development, a growing number of studies in developing countries uphold the axiom that electricity increases household incomes. For example, a 2002 World Bank study in the Philippines calculated that electricity access increased household income by $81–$150 per month dependent on the number of household wage earners and the level of economic activity in the home. Similarly, a 2009 study in Bangladesh found that electricity access caused a 12.2% increase in household income. In 2005, the UNDP (United Nations Development Program) found that across villages in Mali electrification led to a $0.32 increase in daily income and raised the annual average income of women by $68.20The improvement in household income in turn affects poverty, as has been shown in Tanzania where electricity access reduced household poverty between 4 and 13%. As the results shown of the case study of Norsingdi District the feasible implementation of a hybrid system, we can duplicate the concept to the rural regions which represent the majority of the Bangladesh landscape.

5 Chapter 5 Generic Issues, Risk factors and conceptual modeling

Thus far we have considered individual renewable technologies and the technical issues and risks associated with each of them. There are however, more general topics applicable to most renewable energy projects which introduce additional complexity, risk, and uncertainty, not just for the developers or project investors, but sometimes also to the development of the industry itself.

All renewable projects require a degree of civil works to be carried out whether at a large scale like building a dam or tidal barrage, or something less obvious such as a concrete base for a small wind turbine. In between there are always requirements for foundations on which to place equipment, buildings to house it, and access roads to sites chosen for development as they are often remote from the existing road network infrastructure. To achieve any of these constructions requires land surveys to establish the ground composition and the extent of ground works required. Also necessary is design input for buildings as well as roads that comply with regulations, local authority permission to proceed with construction and final approval to gain completion certification. The length of time it takes to complete these tasks can be highly variable, so planning for them is difficult.

Delays in construction times can have a serious impact on completion time for a project, especially when the task must be completed before further work can begin e.g. an access road must be completed, before the main site construction can begin. To actually carry out the required civil works will usually mean relying on contractors; a scenario that is often fraught with danger when trying to adhere to a strict project timeline. In general, the greater the scale of the civil works required, the greater the chance often countering difficulties leading to a delay.

One of the biggest challenges facing developers of electricity-generating renewable energy projects is successfully exporting the power produced to the national grid. Often the first issues encountered are in identifying the most viable connection point, how far away this is from the key generation equipment, and how it is to be reached. The local electricity supplier will be able to provide advice on the best point of connection, but how this point will eventually be reached depends on a number of factors. The distance to be covered by a power cable is important in determining cost but the cable installation method also has to be considered:

Overhead – mounting cable across pylons is the easiest and cheapest method

Underground – burying the cable in a trench and backfilling it is expensive

Underwater – necessary for some water sourced technologies, but expensive

As overhead cable routing is the cheapest method, it is also the developers' preferred choice; however local opposition is common, as pylons are commonly regarded as an unseemly blot on the landscape. Placing the cable underground has less visual impact, although the process is considerably more expensive than the overhead solution. It also requires an excavation phase, digging up stretches of land to enable the burial of cable, potentially creating an eyesore and scar on the landscape in this interim period, although with a less unsightly end result. The point of connection will also help determine which switch gear and safety systems are required and the voltage at which transmission will take place.
Perhaps more significant though, is that many renewable energy project suffer from a lack of grid connection points close to the generation site. As sites are generally in remote locations with only small communities nearby being served by the existing distribution network, there is little capacity available on the network without significant investment and upgrading.

5.1 The need for a model

The analysis has shown that there are a series of risk factors associated with each type of renewable energy technology and the associated infrastructure development. It is the premise of this dissertation that these factors can be clustered together and rationalized leading to a summary of the pertinent factors depicting the level of risk associated with each endeavor under construction, thus informing the process of insuring such developments.
One of the more complicated aspects of the insurance business is the underwriting of policies. Insurers predict the likelihood that a claim will be made against their policies using a wide variety of data, and price their products accordingly. To inform this decision making, insurers use actuarial science to quantify the risks they are willing to assume and therefore derive the premium they will charge to take responsibility for them. Based on risk, the rate of future claims is projected through data analysis. Actuarial science uses statistics and probability to analyze the risks associated with the range of technological and economic factors appropriate for a development, with these scientific principles being used to determine an insurer's overall exposure.

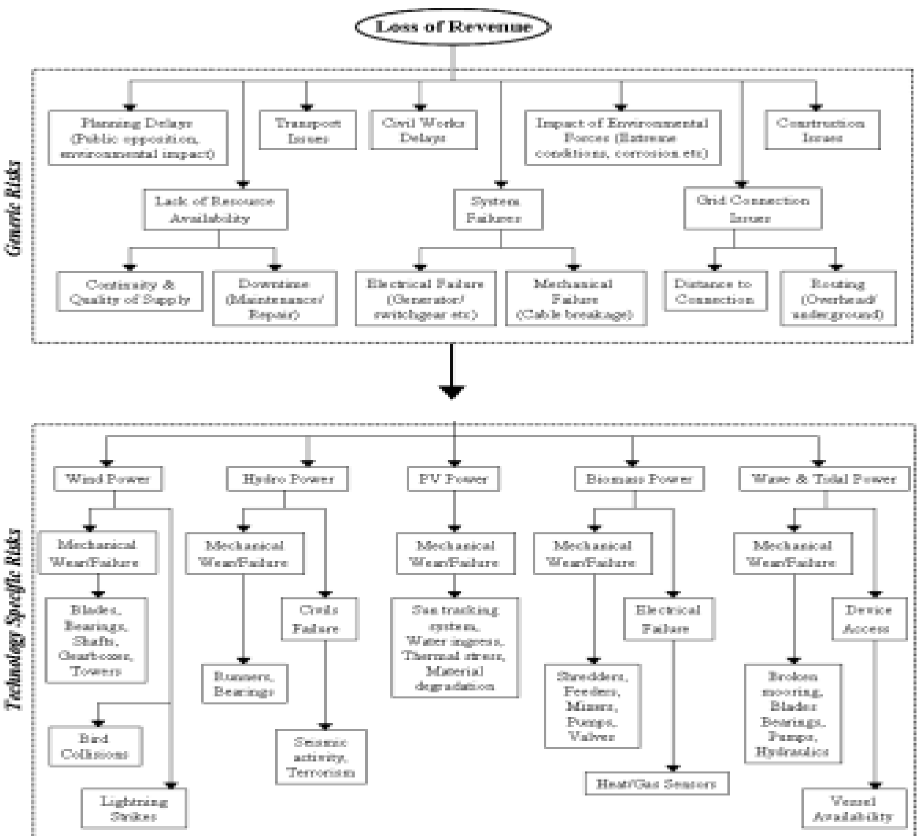
5.2 Profiling

In the field of renewable energy developments, the segments can be classed as each of the key technology types, such as wind, hydro, wave etc. These can be represented pictorially in a decision tree, leading to an overall summary of relevant

factors for a given technology. Classification methods for profiling in insurance alone are often criticized as imperfect, due to the fact that insurance claims are in general very low ratio events, often less than 10%, which can skew the baseline data for decision making.
Insurers have to predict likelihoods based on a very limited data set, an effect that in the renewable sector is further exaggerated due to the limited number of developments, and the relative "youth" of the industry. Classification modeling is, however, a valid first step in the process, and will form the output of this study. The model can only be used effectively when expanded upon with statistical probabilities based on actuarial data

5.2.1 Proposed conceptual model

There is a commonality of risk factors among the technologies, or segments, which lends itself to generalizing at least half of the conceptual model, making it equally applicable for assessment of all forms of renewable generation. Once these generic risks have been accounted for, the second stage of the model allows the root causes of failures and delays to be specifically categorized by technology type.



5.2.2 Proposed Conceptual Model

In the same way that actuaries frequently reassess databases of information for e.g. car insurance, to determine patterns of frequency and severity related to risk factors such as gender, age, car model etc. so must this work be undertaken with the factors represented above. It will then become apparent to both the insurance industry and to developers, the types of project risks to look for, and where possible avoid, minimizing premiums and investing in sound development projects. This conceptual model provides a good basis on which to begin actuarial data collection and analysis.

6 CHAPTER 6: RESULTS AND CONCLUSION

Implementing renewable energy at the DITP has been the result of several factors relating to the resources and priorities within the MWRA and the Commonwealth of Massachusetts. The initial successes can be seen as a result of the MWRA's acquisition of the financial and material resources. Renewable energy technologies were directly integrated into DITP because they appeared to have a moderate payback period and were in line with the plant's function. However, in order to push renewable energy development when the financial payback is not favorable for private entities to implement it themselves, the Government of Massachusetts and the MWRA have had to address several issues. The way that both entities responded to these issues could help inform the actions of other leaders of private and public organizations.

6.1 CONCLUSION

. The conclusion of this thesis summarizes these issues in an effort to guide other organizations through the process of implementing renewable energy. The design experience develops the students' lifelong learning skills, self-evaluations, self-discovery, and peer instruction in the design's creation, critique, and justification. Students learn to understand the manufacturer data sheets, application notes, and technical manuals and component specifications. The experience of teamwork, prototype design and test, which would be difficult to complete individually, gives the students a sense of satisfaction and accomplishment that is often lacking in many engineering courses, not including projects. Furthermore, the design experience motivates student learning and develops skills required in industry. The students were able to make satisfactory estimations and calculations of these projects. Their results reflect that they have understood well all the basic ingredients of the modeling techniques and design of the renewable energy systems. They were also very pleased with the approach used to teach them.

HOMER software package is a useful tool that can really help the undergraduate engineering and technology students in the area of design and analysis of renewable energy or hybrid power systems. HOMER is a very easy to use and learn software package, requiring only basic knowledge in the areas of energy and power systems. The software package demonstrate that with just a little training any undergraduate engineering and technology student are able to design and analyze renewable energy systems. It prepare the students with a useful tool used in industry and maybe to make some students to pursue a career in energy industry or to enroll in graduate programs in the energy field. It is important to encourage students to learn to use such kind of software packages that work with renewable energy systems. Because by taking the advantage of such tools students can learn and adapt better solutions to fix the energy problem issues. It is important to keep in mind that how we are using the energy today will shape the way how we live in the future.

Developing a General Model for Renewable Energy Implementation

The general process of installing renewable energy in our respective countries can be described in terms of the following steps. First, the financial and managerial structures were put in place to allow for innovation within the renewable energy implementation. Next, the options for integrating technologies into the plant were developed. Then, reducing fossil-fuel use and establishing renewable energy became an explicit priority for a variety of reasons. In order to act on this priority, the government created specific goals for the implementation of renewable energy sectors. With specific energy goals, the State channeled human and capital resources toward renewable energy projects and structures, which led to the more efficient, and widespread renewable energy installations. Finally, by emphasizing public examples of success, our various governments and some renewable energy sectors have tried to maintain public support for their energy initiatives. This process represents a general pattern that may be a successful way of thinking about renewable energy and energy efficiency across our respective countries. In order to extrapolate from non-renewable energy sources, the set of processes must be generalized to become applicable to organizations in every stage of the implementation of renewable energy and energy efficiency projects. Such a rephrasing could be:

1. Have renewable energy and energy efficiency projects that present short-term Financial gain been developed and implemented?
2. is renewable energy an institutional priority?
3. What are the specific renewable energy goals the institution would like to achieve?
4. Are the resources and processes in place for renewable energy projects?
5. How can public interest and support of renewable energy projects be maintained?

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