

**Debre Tabor University**

**Faculty of Technology**

**Department of mechanical engineering**

**Research Proposal on:**

Study and Techno-Economical Assessment of a solar PV/wind/diesel hybrid power system for a remotely located population in South Gonder

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# EXECUTIVE SUMMARY

in rural areas of Ethiopia energy needs are mostly covered by the use of traditional biomass sources such as fuel wood, agricultural waste for cooking and heating, kerosene for lighting and small battery or thermal generator units for lighting and communication. Hybrid power generation system is an alternate solution for electrification of remote rural areas where the grid extension is difficult and not economical. Such system incorporates energy producing components that provide a constant flow of uninterrupted power. from hybrid off grid systems will help them by improving their life style as well as reduce deforestation. The main objective of this research is to find the best combination of renewable energy technologies from the feasibility study available resources and economic analysis. Use HOMER software energy balance calculation of a designed power systems.

# ACRONYM

(UEAP Universal Electricity Access Program

(EEPCo Ethiopian Electric Power Corporation

SSA Sub-SaharanAfrica

UEAP Universal Electricity Access Program

IPPs Independent Power Producer

CDM Clean Development Mechanism

CRGE Climate Resilient Green Economy

COE Cost of Energy

EPA Environment Protection Authority

GDP Gross Domestic Product GEF Global Environmental Facility

GHG Greenhouse Gas Emission

GTP Gross and Transformation Plan

HOMER Hybrid Optimization Model for Electrical Renewable

LPSP Loss of Power Supply Probability

MoWIE Ministry of Water, Irrigation and Electricity

NREL National Renewable Energy Laboratory

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

Achieving universal access to electricity is one of the most important goals set for the energy sector by governments in the developing world [5]. Electricity alone is not sufficient to spur economic growth, but it is certainly necessary. Access to electricity is particularly crucial to human development, as certain basic activities such as lighting, refrigeration, running household appliances and operating equipment that cannot easily be carried out by other forms of energy. Sustainable provision of electricity can free large amounts of time, labor and promote better health and education. Electrification can make an important contribution toward achieving economic and social objectives. Access to electricity in Ethiopia is one of the lowest by any standard with only 25% of households connected and 53% of electricity coverage of the country is from Ethiopian Electric Power Corporation (EEPCo) in 2014. Ethiopia is a large, land locked and diverse country located in the Eastern part of Africa between to North and to East. It is the second most populous country in the Sub-SaharanAfrica (SSA) region (estimated 99.4 million in 2015), out of which 80% are rural dwellers. In terms of gross domestic product (GDP) per capita income of USD 669.9, Ethiopia ranks 174 out of 187 according to the HDI 2015 report. Despite the fact that 80% of the population of Ethiopia live in rural areas, electricity supply from the grid is almost entirely concentrated in urban areas. Among other things, dispersed and very low consumption level of electricity among rural consumers limited grid electricity penetration to rural dweller is less than 2% [20]. Based on the hitherto electricity expansion practices, access to electricity does not seem to be the reality of the near future for the greater percentage of the rural communities. However, the recent government’s strategy under Universal Electricity Access Program (UEAP) ambitiously increase access to electricity by connecting 5168 new towns and villages to the grid and the country managed to electrify 1700 rural towns and villages per annum. The UEAP does not only aim to increase access, but also aims to raise the level of national per capita consumption of electricity from 28 kWh in 2010 to 128 kWh by the year 2015 [16]. Ethiopia, Under UEAP, follows two basic strategies in order to electrify rural area. These are: Grid based large and medium scale power generation and, small scale renewable energy standalone/ mini-grid technology options. In rural areas of Ethiopia 70% energy demand for cooking and lighting is from fuel wood. Hence, to access a reliable, affordable, clean and sustainable energy service the government of Ethiopia set a plan to set an energy mix power generation system.

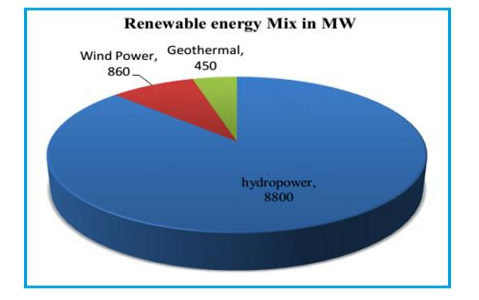


Figure 1‑1 Renewable energy Mix in MW[1]

Status quo of Rural Electrification in Ethiopia Currently, in rural areas of Ethiopia energy needs are mostly covered by the use of traditional biomass sources such as fuel wood, agricultural waste for cooking and heating, kerosene for lighting and small battery or thermal generator units for lighting and communication

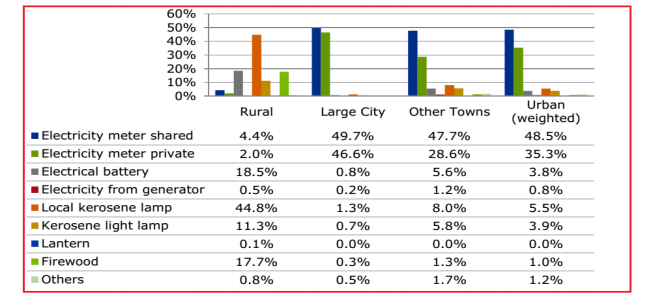


Figure 1‑2 rural electricity in Ethiopia[5]

Decentralized and mostly fossil based energy services used in rural households and communities result in considerable greenhouse gas emissions. As it concerns quite large part of the population and there is strong population increase, electricity needs and consumption are strongly increasing. In combination with the abundance of renewable energy sources available at rural sites in Ethiopia, these emissions contrast with the ambitions of Ethiopia to be a frontrunner in renewable energy and climate policies and practices. Ethiopia does not have its own oil production; it highly dependent on imported fossil fuels. The country spends nearly all of its export earnings to import petroleum products, putting pressure on foreign exchange reserves. This causes a substantial threat on the economy when there are global oil price hikes. This disrupts security of energy supply where escalating oil prices threaten the country’s economy and balance of payment. Availability of fossil energy carriers in rural areas are thus under increasing pressure (both price and availability).

## 1.2 Rural Electrification in Ethiopia

Despite the abundance of natural resources, the difficulties of fossil supply and the absence of modern electricity sources, renewable energy mini-grids have not been widely deployed yet in rural Ethiopia. There are several types of barriers that hamper the deployment of renewable minigrids. These are: Market uncertainty preventing private and other stakeholder from starting developments: Uncertainties about where large scale grid extension will go, what will happen to minigrids if the grid reaches the same are, no agreements on tariffs of options for connection to main grid Difficulties with economic feasibility of mini-grids: Very low grid connected electricity prices in Ethiopia, grid extension costs are not recovered in the electricity price, no successful business models demonstrated in Ethiopian context ⎫ No policy guidance/framework: absence of overall plan and approach, no clear targets on how many or where to develop mini-grids. To solve the current energy problem, the government of Ethiopia (GoE) has an ambitious of developing its electricity generation portfolios in a manner that includes two major changes compared to the current situation: Diversification: Hydro power can deliver electricity at a relatively low cost and essentially without emissions. However, the hydrological conditions vary with dry and wet seasons determining precipitation. According to the ten years master plan, the planned expansion of electricity generation (2015-2025) has three main components: 7,600MW of hydro-power, 5,200MW of wind power, 5200MW of solar power, and 900MW of other power including geothermal. Independent Power Producer (IPPs): A significant share of the capacity expansion (69%) is expected to be produced and managed by IPPs. IPPs planned to produce 3,600MW of solar and wind power.

## 1.3 Current National Policies in Energy Sector

The overall vision of the government of Ethiopia for their energy policy is to ensure access to affordable, clean and modern energy for all citizens and become a renewable energy hub in the Eastern Africa Region by 2025. The mission underlying this vision is to play a significant role for socio-economic development and transformation of the country through provision of sustainable, reliable, affordable and quality energy service for all sectors in an environmentally sound manner. The overarching strategy for this vision is the Climate Resilient Green Economy strategy (CRGE). The CRGE sets the direction to transform Ethiopia to a middle-income country through climate resilient growth and reduction of greenhouse gas emissions (GHG). In the focus area of water and energy within the CRGE strategy MoWIE has identified eleven priorities in four dimensions like power generation, energy access, irrigation for agriculture, and water, sanitation and hygiene.

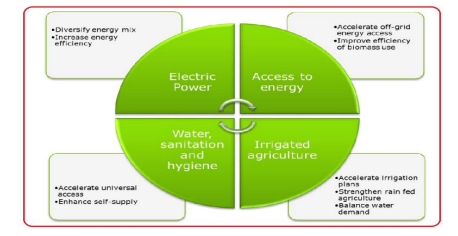


Figure 1‑3 CRGE strategies for water and energy. Source: CRGE (Water and Energy, 2015)

The government policy towards power sector development has been dominated by public managed and public owned utility, leaving little room for concrete private sector interest and participation. The private sector could however play an essential role in accelerated development of the rural energy sector, especially when an enabling environment for this is created by a policy shift at the government. This policy shift to increasing focus on off-grid solutions and involvement of the private sector will generate interest and commitments towards mini-grids development. This ambition for short term electrification of rural villages is to meet basic energy needs and also stimulate energy use for economic purposes to contribute to overall development of rural livelihoods.

## 1.4 Hybrid Power Generation Systems

Hybrid power generation system is an alternate solution for electrification of remote rural areas where the grid extension is difficult and not economical. Such system incorporates energy producing components that provide a constant flow of uninterrupted power. This is a combination of different renewable energy resources such as solar photovoltaic modules and wind turbine and diesel generator as a backup. One of the main problems of renewable energy, in particular of solar and wind is the strong variability of the resources. Indeed, solar radiation is available only during the day and both solar and wind resources vary according to the weather and seasonal conditions. For these reasons, when off-grid loads require supply continuity, large energy storage capacity could be necessary if a single technology is used and power systems need to be oversized in order to produce an excess of electricity for storage. As a consequence, the cost of the system can considerably increase. Moreover, in some cases a single source does not provide enough energy to meet the load‟s requirements. In most of these cases, the implementation of hybrid systems can provide competitive advantages. As a matter of facts, hybrid systems are able to produce electricity even at times when one of the used resources is unavailable.

## 1.5 Types of hybrid system configuration

### 1.5.1 Solar photovoltaic/diesel or wind/diesel

Solar photovoltaic or wind coupled with a diesel gen-set is one of the most common and simple configurations. SPV or wind provides most of the electricity, while the gen-set balances the production when fluctuations of renewable resources occur. In general, the presence of a fully dis-patchable power system makes storage optional. Nevertheless, batteries are often included in the system: in this case batteries meet short-term fluctuations, and the diesel generator takes care of the long-term fluctuations [2]. Typically, this kind of system is used for generation capacities up to 100 kW when quality power cannot be delivered by the intermittent sources alone [7].

### 1.5.2 Photovoltaic and wind

If the site conditions are favorable, a system combining two renewable sources such as solar and wind is more reliable than a system using a single resource [8]. Clearly, the performance of such systems strongly depends on local weather variations, and an accurate assessment of both solar and wind resources during the year is mandatory. The system requires battery storage, inverter and charge regulator [8]: If electricity demand is lower than wind turbine production, the excess electricity form wind turbine and PV is stored; If load demand is higher, the PV array cover the excess load; If load demand is higher than the power supplied from both renewable systems, additional energy is taken from the storage.

### 1.5.3 Hybrid System Connection Schemes

Depending on the kind of voltage system and the bus that interconnect the sources, there are three types of hybrid system connection schemes. AC bus line, DC bus line, or mixed bus line are the most frequently used in remote areas [5].

**AC bus line**: all generating units are connected to an AC bus line for power transmission. PV arrays need a DC/AC converter, while technologies generating alternate current such as wind and gen-set are allowed for direct coupling. Regarding the battery bank, the energy supply is controlled by a bidirectional inverter. AC coupled system is more flexible, easily expandable and it offer a flexibility for extension when necessary. Due to the above functionality this type of connection system has been selected for this work.

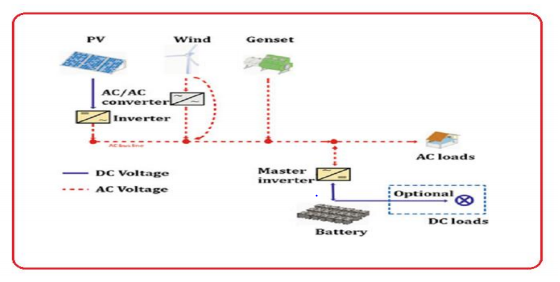


Figure 1‑4 AC-bus line[5]

**DC bus line**: in this case all the technologies generating alternate current need AC/DC converter. This means that the PV generating source is equipped with charging controller and AC generating sources with rectifier this means that the power generated by wind and diesel generator are first rectified and then converted back to AC bus line which reduces the efficiency of energy conversion due to several power processing stages. Due to this reason these connection scheme have not been selected for this work.

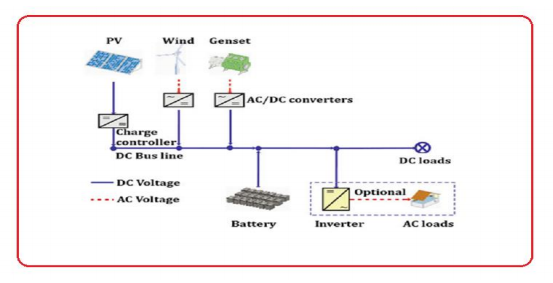


Figure 1‑5 DC base Line [5]

**3. Mixed bus line**: DC and AC generating units are connected to the DC or AC line. This system uses a bidirectional master inverter to link the DC bus and AC bus. In this the efficiency of the generator can be maximized due to the capability of the inverter operation parallel with the AC bus line. Therefore, these connection schemes have not been selected due to its two buses and to ignore the danger which may be generated due to the failure of the bidirectional master inverter.

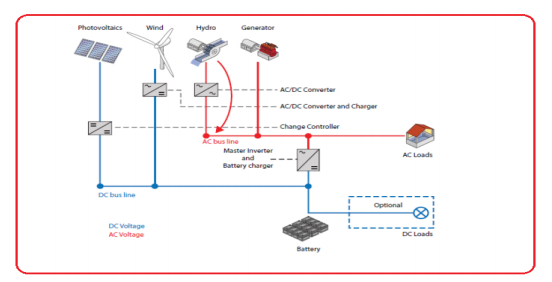


Figure 1‑6 mixed base Line [5]

## 1.6 Statement of the Problem

Developing countries like Ethiopia have serious energy crisis. Satisfying the power demand of the people for the fundamental necessities by itself is in much a bother situation. Hence, governments and peoples started looking towards permanent and never-ending sources of energy called renewable sources of energy such as solar and wind energy. The positive aspect of using renewable resources in our country Ethiopia is that they are available in plenty and also pollution free. Even though Ethiopia is rich in renewable energy sources, majority of the population which live in rural areas depend on biomass for cooking food and lighting [11]. Due to many reasons most of the villages of the country are not getting electrical energy currently. To connect the rural areas to the grid, high costs and adequate power for the whole country is required.

As a result, the government of Ethiopia is trying to electrify the rural areas by expending much money to extend the existing national grid even though most of the rural areas are potentially rich in renewable energy resources. Therefore, extending of the central electricity grid to such areas is either financially not viable or practically not feasible as these locations are geographically isolated, sparsely populated and have a very low power demand [14]. Renewable energy sources can be used as a standalone with minimum cost as compared with the cost required to extend the central grid. Hybrid off-grid systems are the most widely used and cost-effective energy sources for rural electrification where the grid extension is difficult and economically not viable. Such system incorporates a combination of one or several renewable energy sources such as solar and wind energy with convectional diesel generator [16]. Hence supplying energy to the rural community from hybrid off grid systems will help them by improving their life style as well as reduce deforestation. In addition to this hybrid systems can contribute for the achievement of agricultural lead industrialization.

## 1.7 Research Questions

* What effect does daily use of Biomass In rural area for nature deforestation?
* What is the advantages of assessment solar/wind and diesel hybrid system?
* How to evaluate optimum hybrid power generation of the system?
* How does techno economic analysis hybrid system for energy generation?

1.8 Motivation of the study

The motive of this research is to address access to modern energy for the undeserved rural communities of south Gonder rural area in which currently energy needs are covered by the use of traditional biomass sources like fuel wood or agricultural waste for cooking and heating, kerosene and small battery for lighting. Using these types of energy brought health risks (flammability of kerosene, respiratory impacts of fuel wood burning), high costs and absence of constant supply. Moreover, most rural areas in Ethiopia receive an abundant supply of solar, wind and hydro resources throughout the year but due to topographical location most of the remote communities lack access to modern and reliable electricity. Besides recent increase in availability of climate related and donor finance for low carbon and Climate Resilient Green Economy (CRGE) that prioritizes renewables are the main motivating for the study.

## 1.9 Objectives

### 1.9.1 General Objective

The main objective of this research is to find the best combination of renewable energy technologies from the feasibility study available resources in a given area location that can meet the electricity demand in a reliable and sustainable manner and to analyses whether such hybrid option is a cost-effective solution or not.

### 1.9.2 Specific Objective

The achievement of the stated main objectives the ability and the accomplishment of the below objectives is required:

* To estimate and forecast the electrical load for the study area
* To assess the available resources
* To model electricity generation based on multiple combinations of RETs with the application of HOMER software
* To select the best options based on the COE generation
* Cost analysis hybrid energy
* Determine the best hybrid energy systems configuration from economic perspectives that can be feasible for the electrification of the community.

## 1.10 Significance of the study

The significance of the study is to

* Provide comprehensive information on the renewable energy systems mix with convectional diesel generator to electrify the rural community of south Gonder area that have no electric access.
* From this point of view the study could be considered as possible reference solution by utilization of solar and wind energy sources for the electrification of the community of the remote area.
* To promote the socio-economic development of the community

**Beneficiary**

**direct Beneficiary**

* For future renewable energy resources generation plan for the electrification of rural areas.

**Indirect Beneficiary**

* Researcher that interested on this area
* National grid governments and NGOs.

## 1.11 Scope of the Study

The scope of this research is limited to feasibility study and the best technological and economic

Analysis and determining the best combination of renewable energy resource in hybrid configuration for the electrification of south Gonder.

# CHAPTER TWO

# 2. LITERATURE REVIEW

The purpose of literature review is to review some relevant literature on off-grid electricity access using. Hybrid systems also contain storage devices such as batteries or fuel cells. While hybrid energy systems are usually implemented to electrify the community of rural areas those who detached or far away from national grid, they can also operate in parallel with the grid power systems [52].

**Nouni et al. [13**] has used this approach to identify the potential areas for decentralized electricity supply in India. They considered the delivered cost of electricity supply for different load factors and for villages located within a radius of 5-25 km from an existing 11 kV substation for two cases: plain terrain and hilly terrain, where the cost of local distribution tends to be higher. They also considered the cost of supply from decentralized renewable energy options. Considering typical village load data from 1991 Census statistics, they estimated that the average peak load of a remote rural household to be 0.675 kW. Considering the population of villages, they suggested that village’s with less than 50 kW peak load could be considered for decentralized electricity supply through renewable energy technologies. The authors then considered the trade-off between grid extension and off-grid supply to find the cost-effective electricity supply option for remote villages. While this provides a framework of analysis from the cost of supply perspective, the analysis does not consider the external costs related to fossil fuel use, cost of security of supply, cost of stand-by power for renewable energies.

**Moghavvemi et al. [14**] presented a study of the renewable hybrid PV–diesel system to supply power to designated remote controlled FM transmitters located in remote location. The developed system was guaranteed to meet the energy demands of the station with 100% reliability and with less cost of energy production. Furthermore

**Colantoni et al. [15]** presented a mathematical model for out lining future insights and potentials assessment of hybrid photovoltaic/wind installations in Tunisia. The study demonstrated that Tunisia could decrease the dependence on fossil fuels as a result of renewable energy usage.

**Essalaimeh et al. [16]** found that the electricity generated by PV-wind hybrid system under Jordanian climatic conditions can be utilized for electrical heating and cooling through split units and resistive heaters.

**Congo. Li et al. [17]** presented a techno-economic feasibility study of an autonomous hybrid wind/PV/battery power system for a household in Urumqi, China using Hybrid Optimization Model for Electric Renewable (HOMER) simulation software. They recommended a hybrid wind/PV/battery system with 5 kW of PV arrays (72% solar energy penetration), with a one wind turbine of 2.5 kW (28% wind energy penetration), 8 unit batteries each of 6.94 kWh and 5 kW sized power converters for the household.

**Lee et al. [18]** presented the experimental results from the operation of a proto-type PV/diesel green ship in Geoje Island, South Korea. The aim of the green ship was not only to minimize fuel consumption but also to support the power grid as distributed generation connected to the inland smart and micro grids in the near future.

**Koussa et al. [19]** presented a sizing model to predict the optimum dimensions of hybrid PV wind-diesel systems for rural electrification in Algeria. The objective of the optimization parameter is not the production cost but the offered service. They conclude that the major advantage of hybrid system is increased reliability.

**Alireza, et al [20]** has performed a detailed techno-economic analysis of hybrid PV-wind-diesel battery systems by using HOMER to meet the load demand of off-grid house located in the three remote Colombian settlements. The hybrid systems is economically feasible for diesel fuel price above 1.1$/liter. To select the best optimal configuration systems from economic perspective, total net present cost (NPC), initial capital cost and cost of energy (COE) were selected as the economic indicators. The resulting yearly emissions as the environmental index were also determined. The result shows that the combined diesel generator and renewable resources have a very low carbon foot print. In remote area of Puerto Estrella, the emission from hybrid configurations system were about 4262 kg /year, which 2.6% is from the emissions of diesel-based system (162,142 kg /year). The cost analysis revealed that the combination of solar PV-wind-diesel-battery systems with an initial capital cost of $521,078, NPC of $836,210 and COE of $0.473/kWh were the optimal option for this remote area.

**Rehman et al. [21]** designed a PV/wind/diesel hybrid power systems for a rural area of Saudi Arabia which recently powered by a diesel generator power plant consisting of eight diesel generating sets of 1,120 kW each. The study found a PV-wind-diesel hybrid power system with 35% renewable energy penetration (26% wind and 9% solar PV) to be the feasible system with COE of 0.212$/kWh. The system was able to meet the energy requirements (AC primary load of 17,043.4 MWh/year) of the village with 4.1% energy in excess. The annual contributions of wind, solar PV and diesel generating sets were 4,713.7, 1,653.5 and 11,542.6 MWh respectively. The proposed hybrid power system resulted in avoiding addition of 4,976.8 tons of GHG equivalent of gas into the local atmosphere of the village and conversion of 10,824 barrels of fossil fuel annually.

**Lau et al. [22]** analyzed the case of a remote residential area in Malaysia and used HOMER to analyze the economic viability of a hybrid system. The study uses a hypothetical case of 40 households with a peak demand of 2 kW per household. The peak demand is 80 kW and the base demand of around 30 kW is considered in the analysis. Although such high rural demand can be typical for Malaysian conditions, this might not be true for others. The study also does not consider any productive use of electricity.

**Givler and Lilienthal [23]** conducted a case study of Sri Lanka where they identified when a PV diesel hybrid becomes cost effective compared to a standalone small SHS (50W PV with battery). This study considers an individual household base load of 5W with a peak load of 40W, this study considers an individual household base load of 5 W with a peak of 40 W, leading to a daily average load of 305Wh. Through a large number of simulations, the study found that the PV-diesel hybrid becomes cost-effective as the demand increases. However, this study only focuses on the basic needs and does not include productive use of energy.

**Munuswamy et al. [24]** compared the COE from fuel cell-based electricity generation against the cost of supply from the grid for a rural health center in India applying HOMER simulations. The result shows that beyond a distance of 44 km from the grid, the cost of supply from an off-grid source is cheaper. This work, however, just considered the demand of a rural health center and was not part of any traditional rural electrification programmes.

**Hafez and Bhattacharya [25]** analyzed the optimal design and planning of a renewable energy based micro-grid system for a hypothetical rural community where the base load is 600kW and the peak load is 1,183kW with a daily energy requirement of 5,000kWh/day. The study considers solar, wind, hydro and diesel resources for electricity generation. Although the study considers electricity demand over 24 hours, the purely hypothetical nature of the assumptions makes the work unrealistic for many off-grid areas of developing countries.

**McGowan et al. [26]** compared the performance of two computational models (I-IYBRIDZ and SOME& developed at the University of Massachusetts and at Utrecht University in the Netherlands, respectively). Both models yielded similar performance results. The predicted performance discrepancies were due to different subcomponent models and differences in control strategy. Renewable energy sources (RES) play an important role in facilitating issues like energy security, sustainable development, and environment retention (Trieb and Nitsch, 1998) and hence wind and solar energy can be alternatives and need to be investigated continuously.

**Research Gap**

The above review shows the popularity of HOMER as a tool to analyze decentralized electricity supply systems. However, most of the studies do not consider electricity demand in rural areas carefully. Also, they did not forecast the load for the study site within the project lifetime. As the optimal system configuration is obtained to meet the demand, demand analysis plays an important role. Most of the studies also focus on a limited level of supply and do not often consider the productive applications of electricity. In addition, while technology choices are dependent on local conditions; it is possible to investigate alternative combinations more imaginatively. Finally, the studies also limit their scope to techno-economic analysis and do not consider the business issues related to the work. Therefore, this chapter tries to bridge the above knowledge gaps and presents an application of HOMER by including a pre and post analysis to extend the scope of the work and knowledge base.

# CHAPTER THREE

# RESEARCH METHODOLOGY

## 3.1 METHODS

Hybrid Optimization Model (HOMER)

Conclusion and Recommendation

Primary and secondary data collection

Simulation process

Direct Observation

Description of the study area

Result and Discussion

Data Analysis

Data Collection

Problem Identification

Site Identification

Feasibility Study

Figure 3‑1 Flow Chart

### 3.1.1 Problem Identification

Problem identification for the specific study area is under taken by direct observation of the site and collecting relevant information regarding the geography, population and the current energy they used and the impact of the traditional energy sources on the health of the community and environment.

### 3.1.2 Primary and Secondary Data Collection

Primary data are those collected by the direct participation of the researcher conducting the research. During the field survey, data such as the number of primary schools, farmers training centers, health extension post in the study area are collected. Relevant secondary data for this research are: hybrid resources potential will take from NASA. Population size and number of households were taken from Central Statistical Agency. The costs, sizes and technical specification of hybrid system components will be assessed from different websites.

### 3.1.3 Data Analysis and Feasibility Study Hybrid Optimization Model

for Electric Renewable (HOMER) is a micro power design tool used for designing, comparing and evaluating micro power technology options for a wide range of applications such as off-grid village power systems, standalone applications, convectional technologies and emerging technologies (NREL, getting started guide for Homer legacy, version 2.68). It can find the best optimal combination of components that can serve the load at the lowest life cycle cost. HOMER software undertakes this task in three major consecutive steps of simulation, optimization and sensitivity analysis. The detailed data input and analysis in HOMER software is indicated in the Figure 3.2 below. In the simulation process, energy balance calculation of a designed power systems. Results from this stage are used for technical and economic evaluation to determine the feasibility of a system design in meeting the electrical demand under specified conditions and estimate the costs of installing and operating the system over the life. Time of the project, including initial capital, replacement, operation and maintenance cost and fuel.

Figure 3‑2 the three consecutive steps of HOMER software

Project Boundaries

Site Data/Estimates

Result Analysis

Optimization Results

Simulation

Grid Comparison Result

Equipment

Economics

Resources

Load

sensitive

Sensitivity Results

Figure 3‑3 HOMER flow chart

4. Expected Outcome

* Assessment of allocated resource of the selected area
* After study technical and economic evaluation give direction to concerned body to install the system.
* The optimal hybrid power generating system is the one which can supply power demand for the community at the lowest price or the systems.
* System design in meeting the electrical demand under specified conditions.
* Use the resource effectively that solve the shortage of electricity of the Local Community.

# 5. WORK PLAN

Table 5‑ WORKPLAN

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Task | Year 1 | | | |
| Quarter 1 | Quarter 2 | Quarter 3 | Quarter 4 |
| 1 | Deskwork |  |  |  |  |
| 2 | Preparation and  scheduling of  data collection  activities |  |  |  |  |
| 3 | Data collection |  |  |  |  |
| 4 | Organize the collected data |  |  |  |  |
| 7 | Interpretation of the result |  |  |  |  |
| 8 | Report writing |  |  |  |  |

# 6. BUDGET

Table 6‑ Budget

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S/No.** | **Cost Driver** | **Cost Factor** | **Rough Estimate** | **Total Estimate (Birr)** |
| 1 | Investigators per diem | 1. No. of Participants(p) 2. Sites (S) 3. Days(d) 4. Trips (T) | 3p\*5d\*2T\*4S\*343 | 41,160 |
| 2 | Data collector per diem for training | 1. Manpower 2. Time | 3p\*4S\*5d\*150 | 9,000 |
| 3 | Data collector per diem for data collection | 1. Manpower 2. Time | 3p\*4S\*20d\*150 | 36,000 |
| 4 | Daily Labor cost |  | 3labor\*20day\*100 | 6000 |
| 4 | Per diem for purchasing | 1. Manpower 2. Time | 2T\*4d\*1P\*469 | 3,752 |
| 5 | Transportation | 1. Transportation Means (Traditional & Convectional means) | 3p\*2T\*4S\*200 | 4,800 |
| 6 | Data Entry | - | - | 4,000 |
| 7 | Surveying equipment rent |  | 20d\*1000 | 20,000 |
| 8 | Dailey labor cost | 1. Days for each site per diem | 4S\*40d\*80 | 12,800 |
| 9 | Technician cost |  | 150hr\*15birr | 6750 |
| 10 | Software cost |  |  | 15, 000 |
| **Sub Total** | | | | **159,262** |
| **Contingency cost** | | | | **7963.1** |
|  | | | | **167,225** |

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