NEAR EAST UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

ECONOMIC FEASIBILITY ANALYSIS AND OPTIMIZATION OF THE SOLAR HOME SYSTEM IN BANADIR REGIONS

MSc. THESIS

YASIR AHMED SALIM

Nicosia
August, 2022

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APPROVAL

We certify that we have read the thesis submitted by Yasir Ahmed Salim titled "Economic feasibility analysis and optimization of the solar home system in Banadir regions" and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Electrical and Electronic Engineering.

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DECLARATION

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

Yasir Ahmed Salim

…../…../…..

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Firstly, I had the opportunity to pursue my studies and also complete this Master's thesis thanks to Almighty Allah for His guidance and safety throughout my life. Therefore, from the very beginning, I thank Almighty Allah; all glory is due to Him. I also thank my supervisor, **PROF. DR. FAHREDDİN SADIKOĞLU**, for helping me to evaluate the Economic feasibility analysis and optimization of the solar home system in Banadir regions, the capital of Somalia, using HOMER software.

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ABSTRACT

ECONOMIC FEASIBILITY ANALYSIS AND OPTIMIZATION OF THE SOLAR HOME SYSTEM IN THE BANADIR REGIONS

Yasir Ahmed Salim

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MSc. THESIS DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

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Some African nations continue to face challenges with energy deficiency as a result of shortages in a number of regions in the 21st century, despite the century's heightened progress in a number of regions. Because heat and fuel are still utilized on a large scale, hydropower is the most prevalent kind of energy generating. This issue arises as a result of the inefficiency and financial deterioration of some nations, such as Somalia, which is among those advancing at a rapid rate. The grid lines from distant places are stacked, and they are rarely matched to the demand for electricity in all areas of the country, especially in remote or urban areas, where each household must use electricity instead of local, conventional, and domestic lighting. This issue can be revealed by using photovoltaic systems and other optional renewable energy sources for provincial electricity. Consequently, this project focuses primarily on the design of SHS that combine financial evaluation and usage of an individual 1710W SHS, so that the needs of the people and the goals of the nation may be efficiently met. Under this project, a case study of one village in Banadir, Somalia, named Heliwaa and located in the Benaadir region has been conducted on the analysis of power use based on single-household families. Based on the photovoltaic capacity, the average main load conditions for consecutive hours per day were determined for the survey. This study's objective was to determine the ideal size of the solar panel and battery capacity that may be utilized to power a home. Ultimately, the developed project and cost will be compared to other private sector power costs to determine which is the most dependable and cost-effective method for electricity generation. According to the data, the cost of electricity is $0.449 per kilowatt-hour, which is less than in the private sector. This solution was deemed optimal. In this project, design and simulation activities were accomplished using the HOMER program. The electricity and financial

facts on the integration of solar systems are a type of SHS and other forms of renewable energy, such as stand-alone systems, to create a dependable and cost-effective system.

Keywords: Battery Capacity, Cost of Energy, Depth of Discharge, HOMER, Kilo Watt Hours, Kilo watt Hours per Day, Levelized Cost of Energy

ÖZET

ECONOMIC FEASIBILITY ANALYSIS AND OPTIMIZATION OF THE SOLAR HOME SYSTEM IN THE BANADIR REGIONS

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Bazı Afrika ülkeleri, 21. yüzyılda çeşitli bölgelerdeki artan ilerlemeye rağmen, bazı bölgelerdeki kıtlıkların bir sonucu olarak enerji yetersizliği ile ilgili zorluklarla karşı karşıya kalmaya devam etmektedir. Isı ve yakıt hala büyük ölçekte kullanıldığından, hidroelektrik en yaygın enerji üretim türüdür. Bu sorun, hızla ilerleyen ülkeler arasında yer alan Somali gibi bazı ulusların verimsizliği ve mali açıdan kötüleşmesinden kaynaklanmaktadır. Uzak yerlerden gelen şebeke hatları yığılmıştır ve ülkenin tüm bölgelerinde, özellikle de her Hanenin yerel, konvansiyonel ve ev aydınlatması yerine elektrik kullanması gereken uzak veya kentsel alanlarda, elektrik talebine nadiren uymaktadır. İl elektriği için fotovoltaik sistemler ve diğer isteğe bağlı yenilenebilir enerji kaynakları kullanılarak bu sorun ortaya çıkarılabilir. Sonuç olarak, bu proje öncelikle, insanların ihtiyaçlarının ve ulusun hedeflerinin verimli bir şekilde karşılanabilmesi için bireysel bir 1710W SHS'nin finansal değerlendirmesini ve kullanımını birleştiren SHS tasarımına odaklanmaktadır. Bu proje kapsamında, Somali, Banadir'de, Heliwaa adlı ve Benaadir bölgesinde yer alan bir köyde, tek haneli ailelere dayalı güç kullanımının analizi üzerine bir vaka çalışması yapılmıştır. Fotovoltaik kapasiteye dayalı olarak, araştırma için günde ardışık saatler için ortalama ana yük koşulları belirlendi. Bu çalışmanın amacı, bir eve güç sağlamak için kullanılabilecek güneş panelinin ideal boyutunu ve pil kapasitesini belirlemektir. Dolayısıyla, geliştirilen proje ve maliyet, elektrik üretimi için en güvenilir ve maliyet etkin yöntemin hangisi olduğunu belirlemek için diğer özel sektör elektrik maliyetleri ile karşılaştırılacaktır. Verilere göre, elektrik maliyeti kilovat saat başına 0,449 dolar, bu da özel sektöre göre daha düşük. Bu çözüm optimali olarakl kabul edilmiştir. Bu projede HOMER programı kullanılarak tasarım ve simülasyon faaliyetleri gerçekleştirilmiştir. Güneş sistemlerinin entegrasyonuna ilişkin elektrik ve finansal gerçekler, güvenilir ve uygun maliyetli bir sistem oluşturmak için bir tür SHS ve bağımsız sistemler gibi diğer yenilenebilir enerji biçimleridir.

Anahtar kelimeler: Pil Kapasitesi, Enerji maliyeti, Deşarj Derinliği, HOMER, Kilovat saat, Kilo watt Günlük Saat, Seviyelendirilmiş Enerji Maliyeti

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ABBREVIATIONS

AC	Alternating Current
AH	Ampere Hour
BC	Battery Capacity
BECO	Banadir Electricity Company
C	Cost
C rate	Rate of Charge or Discharge
COE	Cost of Energy
DC	Direct Current
DOD	Depth of Discharge
HOMER	Hybrid Optimization Model for Electric Renewables
IV	Current Voltage
KW	Kilo Watt
KWh	Kilo Watt Hours
Kwh/d	Kilo watt Hours Per Day
LCOE	Levelized Cost of Energy
NPC	Net Present Cost
NREL	National Renewable Energy Laboratory
O&M	Operating and Maintenance
PG	Power Generation
PV-SYST	Photovoltaic System
RE	Renewable Energy
SHS	Solar Home System
TV	Television
PV	Photovoltaic
$Pyear$	Profit Earned Every Year
$Sscr$	Solar Charger Controller
$Tpayback$	Total of Payback
i'	Is the annual inflation rate (%)

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Chapter 1

INTRODUCTION

1.1 Background of the Project

Renewable electricity resources are growing increasingly more and more appealing in the face of shifting oil costs. Sunlight energy can be converted directly, which opens up a lot of possibilities. Isolated areas can profit from solar photovoltaics for a variety of reasons(Hussain et al., 2018). Photovoltaic (PV) systems are one of the few energy sources that are both clean and abundant. East Africa offers year-round sunshine, making it an attractive power source for a variety of applications, particularly in rural and distant places. In Somalia, there is a lot of solar power. Solar energy has a wide range of thermal applications, as well as the ability to create large amounts of power. Factors including the area's natural location and climate, as well as the availability of resources, determine the accuracy of renewable energy sources (Ermias Benti, 2017). With an average of 10 hours of sunlight every day, Somalia is ideally situated for solar energy production. Furthermore, the average yearly temperature in the United States is 30°C, extending the life of solar PV panels. It's unclear whether it was critical even if it was built in Somalia. Somalia would benefit greatly from a self-contained photovoltaic (PV) system with battery storage.

A photovoltaic (PV) cell is a device that turns light into electricity. Solar cells (or PV) are the most basic component of a photovoltaic system (PV). PV cells can be connected to form a bigger device called a component. To deliver the bare minimum quantity of electricity, these arrays are connected in parallel and series. A set of rechargeable batteries is the most typical energy storage solution because the solar array is only lighted once to generate electricity. The use of charging controllers and converters is required when hazardous batteries are overcharged or discharged.

The size of the PV array, inverter, and battery are all factors to consider when designing a stand-alone solar system. The desired installation site, load needs, photovoltaic modules, inverters, and batteries, as well as their operational efficiency, all require data on solar radiation. Sizing procedures have been refined, and this methodology has been proven to be both accurate and effective in real-world situations (Bouzid et al., 2015).

These best practices assume an infinite number of users as well as control variables. Traditional approaches have relied on the notion of providing power over a long period. These solutions are straightforward and provide the PV system's essential dependability on days when the sun is shining. They're easy to understand and implement. The load requirement is encountered by the storage system in these techniques. The storage systems of solar power systems are evaluated. As a result of autonomy days, people are more trustworthy. The output of a PV array and the capacity of a storage system are not directly related to these systems (Perea-Moreno et al., 2018). The PV array size and battery bank arrangement for a solar PV system may not be suitable.

The optimum project size technique is required to enhance the usage of renewable energy sources, and the sizing of stand-alone PV systems is crucial in the system project, which is a hot topic of research(Bataineh & Dalalah, 2012). The cost of a PV system can be reduced by employing a sizing optimization strategy that does not jeopardize the system's long-term stability. The scheme project may develop too large if there is no system-sizing approach, resulting in a high-cost project (Semaoui et al., 2013). Because of the environment of the energy-unintentional source, there has been a never-ending effort to improve the design of stand-alone PV systems in terms of energy feeding and budgets. When analyzing the performance of a photovoltaic (PV) power system, the cost of producing renewable energy is a key factor to consider.

1.2 Problem Statements

Because of the scarcity of fossil fuels and the rise in fuel prices over the past few years, non-traditional energy sources such as renewable energy have been in high demand. As a result, more reliance on clean, renewable energy sources is a win-win situation for the environment. Solar power can be viewed as a viable and trustworthy alternative to traditional energy sources as they grow more limited.

It is vital to accelerate cost-effective progress through humanizing health and life cycle principles through electrical power access. More effort is needed to satisfy Banadir inhabitants' and private sector partners' goals of electrifying households, however, a significant investment in the energy industry has been made to expedite power entry into homes.

To achieve the above goals, a combination of numerous outcomes focused on geographic location, revenue, and consumption level must be employed as a substitute for using the normal network connection, which is useless in both urban and rural houses. Off-grid PV is a long-term option that ranges from simple SHS generation methods that rely on the house's main equipment to stand-alone systems capable of generating significant amounts of energy for use in homes and other business places. As a cost-effective and trustworthy result, this technology can assist in increasing the rate at which power is acknowledged by the complete urban and remote municipal and national overall. Long-term annual global average irradiation for the aforementioned solutions is directly above 1700Wh/m^2 in various places, according to the study. This shows how many Somali locations are ideal for solar photovoltaic (PV) applications.

Because many rural communities in this area lack access to the country or private sector electric network, the Banadir region province, especially the Hodan, Kahda, and Heliwaa districts in Banadir province, can help families and communities in low-demand areas. These shortfalls are a result of the expensive price of power lines and the high expense of power for each kilowatt, which is approximately $1.50 for lower voltages and $1.00 for intermediate voltage. As a result, the nominated region receives a lot of sunlight, making it perfect for photovoltaic power generation and storage.

1.3 Objectives of the Project

This master's project explains how to address and fix Somalia's solar power system, with a particular focus on Somali energy access challenges. A thriving civil society can be seen in places like Banadir’s Heliwaa district. Transmission lines in the village are extremely expensive due to the high cost per kilowatt-hour of private sector power. SHS and other photovoltaic technologies have been suggested in terms of cost and efficiency. Due to the facility's climatic circumstances, the Banadir area of the facility will receive a lot of sunlight during the day. Solar energy must be used in conjunction with an energy supply system that functions similarly to a battery-to-load system. As a result, these strategies aid the long-term growth of cost-effective countries, resulting in long-term progress. The next objective should be to be able to comprehend the project's planned goals.

I. To construct a stand-alone solar PV system based on a typical household's energy consumption.
II. HOMER Software® is used to create a home PV system design simulation.
III. Using HOMER software, determine the price of off-grid Solar house systems in Banadir area.

1.4 Scope of the Project

The scope of development for the master project only includes solar systems in urban and remote locations with inattentive power generation. Take the following restrictions into consideration when completing the system interpretation assessment.

I. The photovoltaic geographic information system (GIS) in Africa gives valuable data on radiation levels at specific sites. Through design and modeling, it was used in the Banadir region to estimate the budget for a standalone photovoltaic system.
II. During the project's lifetime, the solar energy intake and primary load curve are expected to remain constant. Because solar panels have a 25-year life expectancy, it was assumed that this project would endure at least 25 years.
III. The Banadir region of Somalia, as well as other Somali regions, serve as case studies for the project. Only the design and economic analysis of SHS in the Banadir region will be the focus of this research study. This project will make use of the HOMER® software (Hybrid Optimization Model for Electric Renewables).

1.5 Research Motivation

Renewable energy has a rising market in the country, making it a very profitable option. Standalone and grid-connected hybrid systems are the two types of hybrid systems. When it comes to distributing power to isolated and rural locations, stand-alone systems have a lot of potential. These systems are more reliable, effective, and cost-efficient as compared to single-resource solutions. Because PV and wind power are the most popular renewable energy sources, this study will concentrate on improving stand-alone systems that combine PV and/or wind power with a battery.

1.6 Research Outline

This project report is divided into five sections in total:

(a) Chapter 1: Introduction

The project's beginnings and goals are explained in this chapter. It also provides background information on the project. In addition, a solar-powered home system based on HOMER software® is in the works. The goals and scope of the project are also mentioned, as well as research motivation and a report outline.

(b) Chapter 2: Literature Review

This chapter looks at and discusses earlier research in this field, as well as how it pertains to the current endeavor. As a result, past efforts to align the project's objectives have begun to yield results.

(c) Chapter 3: Methodology

This portion of the book discusses methodology. This chapter shows you how to use HOMER software® to design and build a rising solar home system. It also contains a detailed breakdown of the solar home system's components, meteorological data from the site, load analysis, cost estimation, and, finally, PV module and battery sizing based on the given capacity power, as well as a single line diagram theory about solar home systems and an overview of simulation software used in this project.

(d) Chapter 4: Result Analysis and Discussion

This chapter, which focuses on optimization, also covers how to use simulation findings to determine the most cost-effective solutions.

(e) Chapter 5: Conclusion and Recommendation

This section draws particular conclusions based on the study and project findings. At the end of the paper, there were recommendations for additional research and effort.

Chapter 2

LITERATURE REVIEW

2.1 **Introduction**

This chapter expands on previous research to learn more about stand-alone solar systems and methods to increase photovoltaic system reliability and optimization. This chapter also goes over how to model the components utilized in the HOMER software to better understand the performance of each paper linked to a residential solar system.

2.2 Solar Home System

Solar is a natural generator of pure electricity whose utility is growing. Solar renewable systems create power without producing hazardous emissions, greenhouse gases, or constituent parts created as a by-product of combustion fuels. Solar PV systems run on sunshine and photovoltaic arrays, which are both infinite and free. The price of generating power remains generally accurate and predicted throughout the duration. Because solar PV systems are long-lasting and require minimal conservation. Having a Solar Home System (SHS) might provide peace of mind when compared to energy price rises that affect other power sources. SHS is a self-contained photovoltaic system that provides a cost-effective manner of supplying electrical power to isolated off-grid houses for illumination and other purposes. A solar home system can be utilized to supply a domestic's power consumption while meeting basic electrical requirements in urban and distant zones that are not connected to the grid. Hundreds of thousands of residences in rural places without connection to the national grid have their energy needs met by the worldwide solar home system. Solar household systems typically have a 12-volt direct current (DC) rated voltage and supply electricity for limited-power-DC. -appliances including lighting, radio, smartphones, and refrigerators, as well as small-TV for 4 to 6 hours daily (Syahputra & Soesanti, 2017)

2.3 Electricity Generation and Consumption in Somalia

Because the average irradiation in Somalia's major cities is equivalent to 5.7 kWh/m2/day, photovoltaic solar power systems are best suited throughout the country. The bulk of Somalia enjoys bright sunshine all year long, with an average of 300 days of sunshine each year. There are around 3000 hours of high and continuous sunlight per year. This suggests that the solar system is appropriate for all regions of Somalia.

According to Appendix A, the production and consumption use of power in Banadir have increased in previous seasons, which could be due to community growth as well as a desire to have fun. The installed capacity of electric generators in Somalia in 2015 was 80 megawatts (MW). In 2018, 0.31 billion kilowatt-hours of net electricity were generated. In 2014, 0.29 billion kilowatt-hours of electricity were consumed. Petroleum products imported from other countries are the primary source of electrical generation. People in Somalia have resorted to the most cost-effective and reliable source of energy, firewood or coal, due to the pricey and unreliable nature of power. In Somalia, it appears that production and consumption are increasing year after year(Samatar et al., 2019).

"Appendix A demonstrates that in recent years, the production and use of electricity in Somalia have increased. This pattern aids in population increase as well as the pursuit of pleasure. Figure: 1 depicts the country's electricity consumption. It is reasonable to suppose that the annual usage of energy has increased somewhat from 2000 to 2018. The burning of fossil fuels is the primary source of energy.

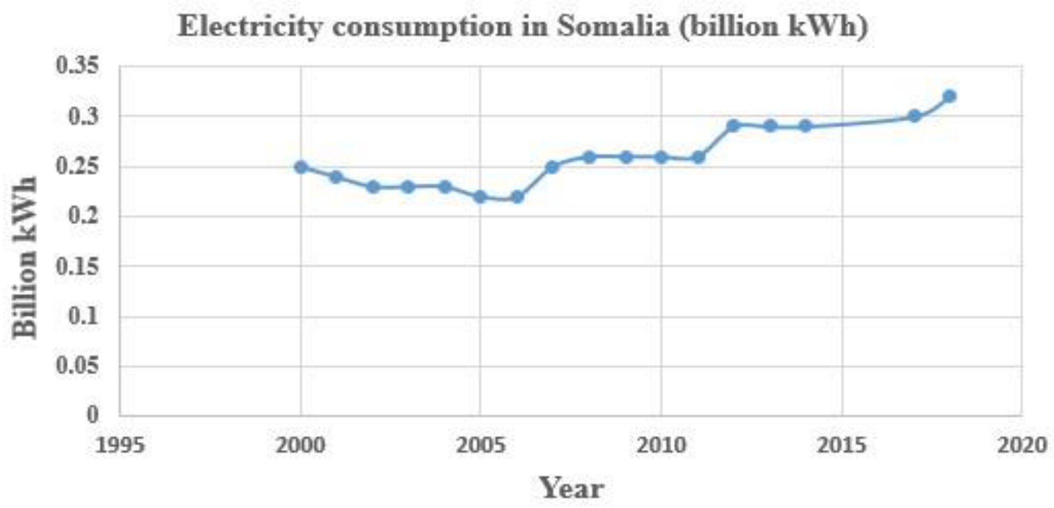

Figure 1 : Electricity Consumption in Somalia (billion kWh) *(Samatar et al., 2019)*

2.4 Renewable Energy in Somalia

Somalia has an abundance of energy resources, including undiscovered oil and natural gas reserves, untapped hydropower, attractive wind farms, and ample sunlight for solar power generation. Traditional biomass fuels such as coal and fuel, which account for 96 percent of the country's total electricity consumption, are the primary roadblocks to the development of these potentially available energy sources: rural and suburban populations rely on traditional biomass fuels such as coal and fuel, which account for the majority of the country's total electricity consumption (BMWi, 2020).

2.4.1 Solar Energy

5.7 kWh/m2/day is the average quantity of sunlight. Somalia is an ideal place for solar energy because it has over 3,000 hours of strong and consistent sunlight per year. Off-grid development and urban water usage in the region have both benefited from solar energy. Solar cooking has helped the community, and solar energy is now considered the primary energy source for recuperation in many of the country's municipal institutions, particularly health centers (Abdilahi et al., 2014).

2.4.2 Wind Energy

Wind speeds range between 3 m/s to 11.4 m/s. Four 50-kilowatt turbines were installed in Banadir in 1988, while wind power was also used for pumping. The UN Trust Fund was founded in Somalia in the 1940s. The country has a large shallow sea along the coast, especially suitable for offshore wind production, and is close to several major loading centers such as Banadir and Berbera. The study predicts that about 50 percent of the country's land area has a sufficient wind speed for electricity production and that 95 percent will benefit from replacing a diesel-powered water pump with a wind turbine (Abdilahi et al. 2014).

2.4.3 Biomass Energy

Somalia's timber area was projected to be about 39 million hectares in 1985 or about 60 percent of the country's land area. These estimates have been greatly decreased due to over-exploitation. Statistics suggest the forest cover could be as poor as 10% in 2001. Sorting of solid and liquid biomass in Somalia appears to have tremendous potential, but primarily in the form of crop and animal residues and marine biomass. Sustainable methods of production of charcoal may also play an important role in the region, as the current production of charcoal has a major effect on the climate (Boyd et al., 2015).

2.4.4 Geothermal Energy

The geothermal energy potential, according to available data, is too low to be economically exploited for power generation.

2.4.5 Hydropower

The potential is estimated to be between 100 and 120 megawatts. According to 1985 estimates, the hydropower potential is virtually untapped. The Jubba River releases approximately 6x109 cubic meters of water into the ocean every year. The dams at Bar-dhere, Fanole, and Sakow along the river might be utilized for irrigation and power generation, but they have yet to be built (Samatar et al., 2019).

In 1982, Fanole had a 4.6 MW capacity. Bardhere, a 105 MW power plant, was being built (pre-war estimates).

2.5 Solar Photovoltaic Technologies

Solar energy is converted into atomic energy using photovoltaic (PV) materials and technologies. The materials used in the construction of integrated photovoltaic panels absorb solar photons and release electrons by absorbing them; DC is generated electrically by creating a direct current (DC). Photovoltaic or solar cells are connected electrically as a specialized component designed to deliver power at a specific voltage. After that, the modules can be connected to create a solar panel, which also is usual for homes and businesses.(Soediono, 1989) the quantity of power generated is approximately equivalent to the quantity of sunlight absorbed by the module or array.

Photons are the fundamental building blocks of light. In solar panels, rays from the sunshine strike the silicon atoms of the photovoltaic modules, producing an energy transfer that causes electrons to be lost and eventually knocked off. All of the action takes place in solar panels, which are made up of microscopic solar cells. Photovoltaic (PV) cells are another name for these solar cells. "Photo" stands for light, while "voltaic" stands for energy. The semiconductor material is intrigued by the dazzling brightness of a cell, which is estimated as a percentage of the light. Fundamentally, the captivated light's energy is conveyed to the semiconductor, which is commonly made of Silicon. As seen in Figure 2, this energy knocks electrons loose, permitting a free flow of electrons (Soediono, 1989).

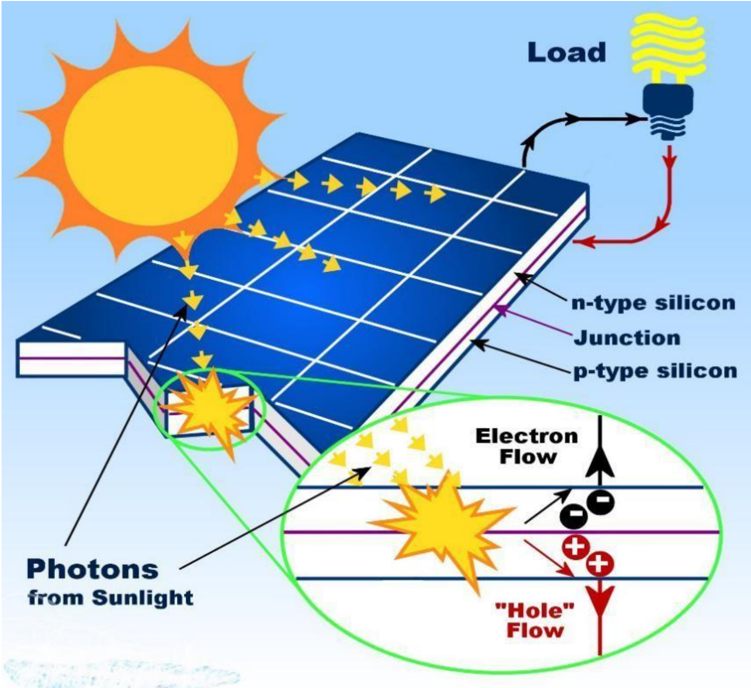

Figure 2: Solar cell basic assembly (Soediono, 1989).

2.5.1 Photovoltaic Operation

A photovoltaic cell, also known as a photoelectric cell, is a semiconductor device that converts light into electrical energy using silicon composites and various materials. The photovoltaic effect is the name given to this phenomenon. While the photovoltaic cell is the sole photodiode relative to the photodiode, and the light falls on the n-channel of the semiconductor intersection, the electron will move and the electron flow causes the current to flow if the photon's light activity is more than the holes. The battery is transformed to a current or voltage flag, but as illustrated in Figure 3, it is normally biased in the positive direction (Birenis, 2012).

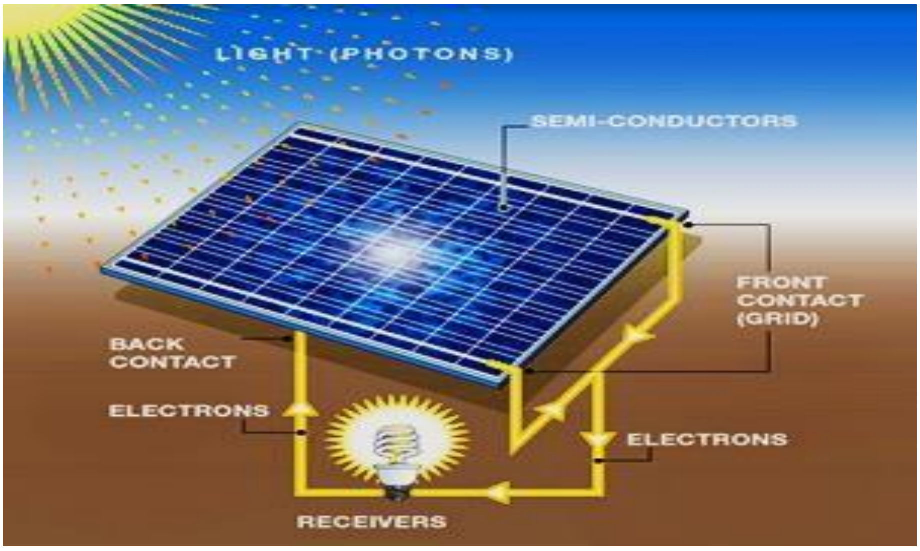

Figure 3: Solar Panel working principle (Birenis, 2012).

One of the most important semiconductor materials utilized in the production of solar cells is crystal silicon. The atomic structure of silicon has unique features. To provide a negative or positive charge, a doping method is utilized to connect another component to the gem silicon (Birenis, 2012). This is done because pure gem silicon is neutrally charged and hence would not perform effectively as a power source."

2.5.2 Photovoltaic Models

The solar cell is the most basic power conversion device in a PV system. Although different materials have been produced, all solar manufacturing companies have adapted silicon material for making solar cells throughout the previous decades (Naik, 2016). Solar cell manufacturing is progressing at a breakneck pace, with cells classed as single crystalline, polycrystalline, and thin film. Because a single solar cell provides an output voltage of less than 1 volt, it is insufficient for common use to generate enough electricity for high-power applications, cells must be coupled in the series-parallel arrangement. They're usually broken down into modules. Commercially accessible PV modules, on the other hand, exist in a wide range of sizes; the most common module includes 36 to 72 photovoltaic modules coupled in sequence to generate the required voltage. To satisfy increased energy needs, the units are linked in sequence and parallelism to build arrays, as illustrated in Figure 4."

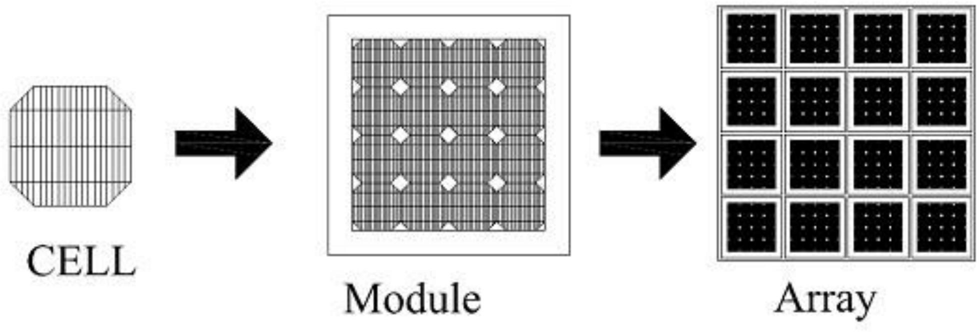

Figure 4: Displayed on the cells, modules, and arrays(Naik, 2016)

2.5.3 Solar Cell Simulation Model for Photovoltaic System

The environmental impact of fossil fuels is becoming more widely recognized. Due to the renewable nature of solar energy and its general availability, solar panels are becoming increasingly popular. As a result, solar cell power generation as a renewable energy source holds a lot of promise. Several experiments were conducted to determine how various operational parameters influenced the efficiency of photovoltaic cells. As a result, strong photo vocal cell models will need to be constructed to make such investigations easier. This work created and discussed the Mat lab Simulink solar cell more to obtain precise performance in a range of circumstances.

Continuous standards in situ limits, such as the converse saturated voltages and thermal ally voltages, are used to evaluate the outcomes. The model uses constant tenets of several parameters, such as reversed saturated voltages and thermally voltages, to estimate the fallouts. In addition, for calm computing, several constraints were removed. As a result of such computations, the accuracy of the models is reduced (Atiq & Soori, 2017).

2.5.4 Solar Cell Model Equivalent Circuit

“In Figure 5, the solar cell's equivalent circuit is displayed.”

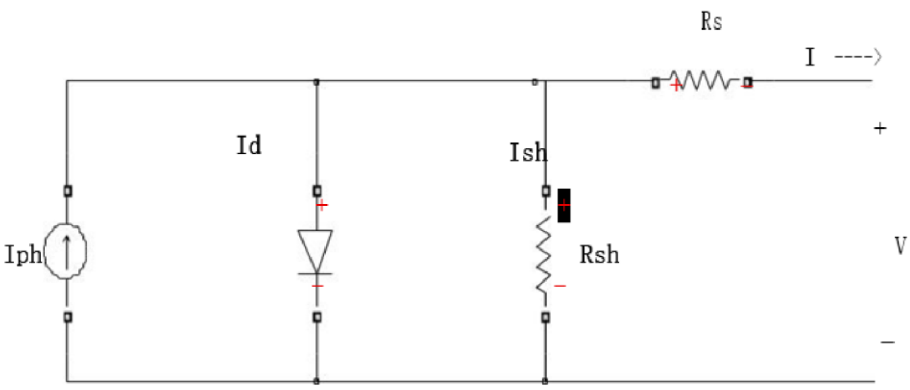

Figure 5: Solar cell model equivalent circuit (Liu & Hou, 2014)

A current source (Iph), a diode, a series resistor (Rs), and a parallel resistor (Rsh) are included in this analogous circuit. Here are the relevant equations: (Liu & Hou, 2014).

$$\text{Ish} = \frac{V + I \times R_S}{R_{sh}} \quad (2.1)$$

$$\text{Iph} = \frac{[Isc + KI \times (T - T_{ref})] \times I_r}{I_{rref}} \quad (2.2)$$

$$\text{Irs} = \frac{I_{SC}}{(exp(q \times V_{OC}))} / \frac{1}{(A \times k \times T_{ref}) - 1} \quad (2.3)$$

$$Is = Irs \times (T / Tref)^3 \times \exp((q \times Eg / A \times k) \times (1/Tref - 1/T))\text{" "} \quad (2.4)$$

$$\text{" } Id = Is \times \exp((V + I \times RS)/(A \times Vt \times Ns)) - 1)\text{"} \quad (2.5)$$

$$\text{" } I = Iph \times Np - Id \times Np - Ish \times Np \text{ "} \quad (2.6)$$

$$\text{"}V = A \times Vt \times Ns \times Ln[(Iph \times Np - I - Ish \times Ip)/Is \times Np + {}_{1]I} \times Rs\text{"} \quad (2.7)$$

Where he shunts current is Ish. A photocurrent is Iph. Tref's reverse saturation current is Irs, and Irs is the reverse saturation current. The diode current is denoted by Id. “I” the load current. The load voltage is V. The reference temperature is Tref. q Is a charge that is generated by an electronic device? The reference irradiance is Irref. The short circuit current temperature coefficient is denoted by KI. Take, for instance, band gap energy. A short-circuit current (isc) is a current that flows in a closed circuit. The open-circuit voltage is referred to as Voc. The actual irradiance is Ir. The optimal factor is

A. The number of units connected in parallel is denoted by Np. T is the actual temperature, and Ns is the number of batteries connected in series”.

2.5.5 Solar Cell Model Implementation for a Photovoltaic System

A solar cell model is developed in Matlab Simulink based on the circuit and equations above. Figure 6 shows the top-level Simulink model.”

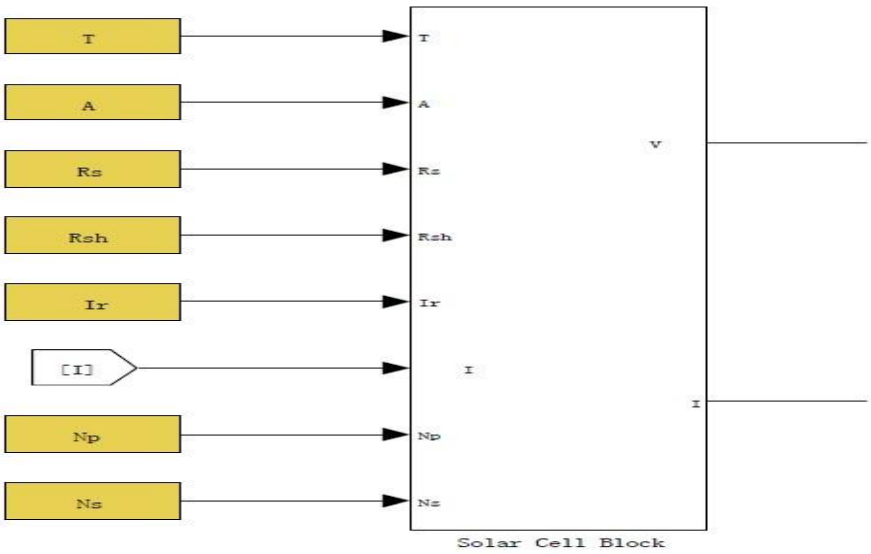

Figure 6: Solar cell Mat lab model top-level (Liu & Hou, 2014)

T, A, Rs, Rsh, Ir, Np, and Ns must all be defined as inputs for the model, as shown in Figure 6. In addition, the output is swept and supplied back to the model, which produces voltage. During the simulation, the V-I and P-I graphs could be constructed. The required constants are defined in this solar cell block. Furthermore, a simulator is used to simulate the required equations (Liu & Hou, 2014).

2.5.6 Solar Cell Performance

Solar cell performance can be influenced by a variety of things in practice. These variables are not constant, but they do change throughout time. Changes in temperature, series and parallel resistance, and irradiation are all factors that solar cells must contend with. An allusion PV curve and an allusion IV curve are available in this unit. Then a variety of situations with varied restrictions were investigated. Finally, unusual effects can be achieved using solar cells in series and parallel (Liu & Hou, 2014).

2.5.6.1 Reference PV and IV Curves

The equivalent reference IV and PV curves are offered in Figure 7, the allusion IV and PV curves are continuously signified in red in all the Figures."

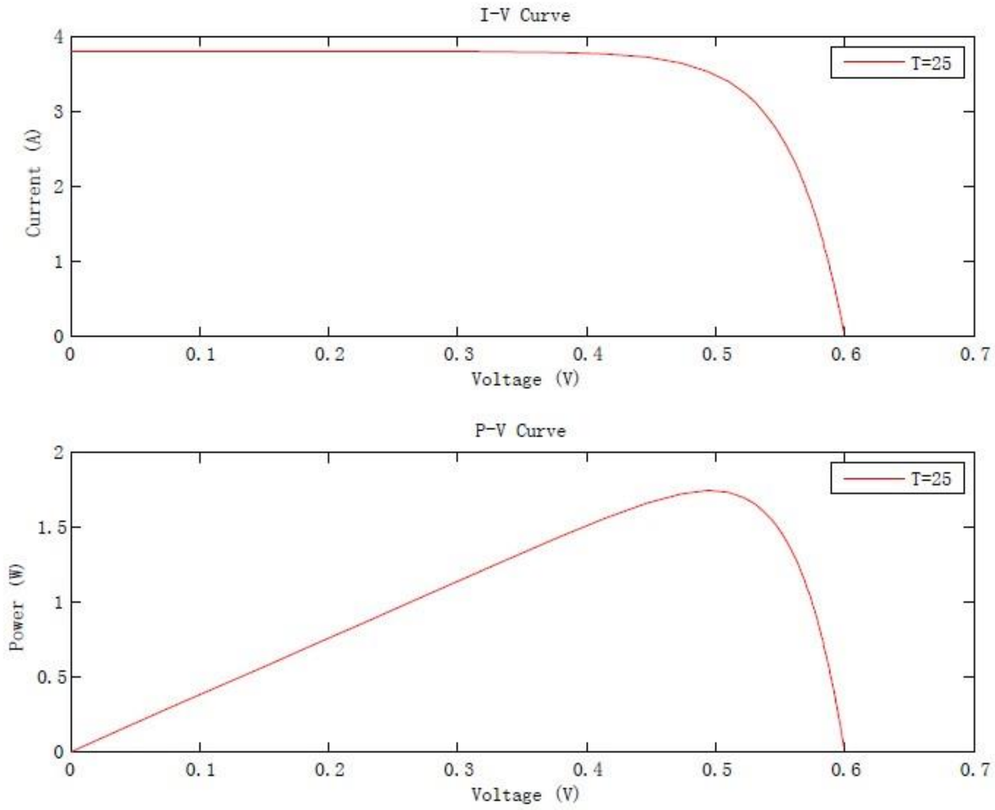

Figure 7: Reference PV and IV curves (Liu & Hou, 2014)

2.5.6.2 Effects of Changing Temperature

The reference PV and IV curves are compared with the PV and IV curves with a temperature of 75 °C in the following IV and PV curves in Figure 8."

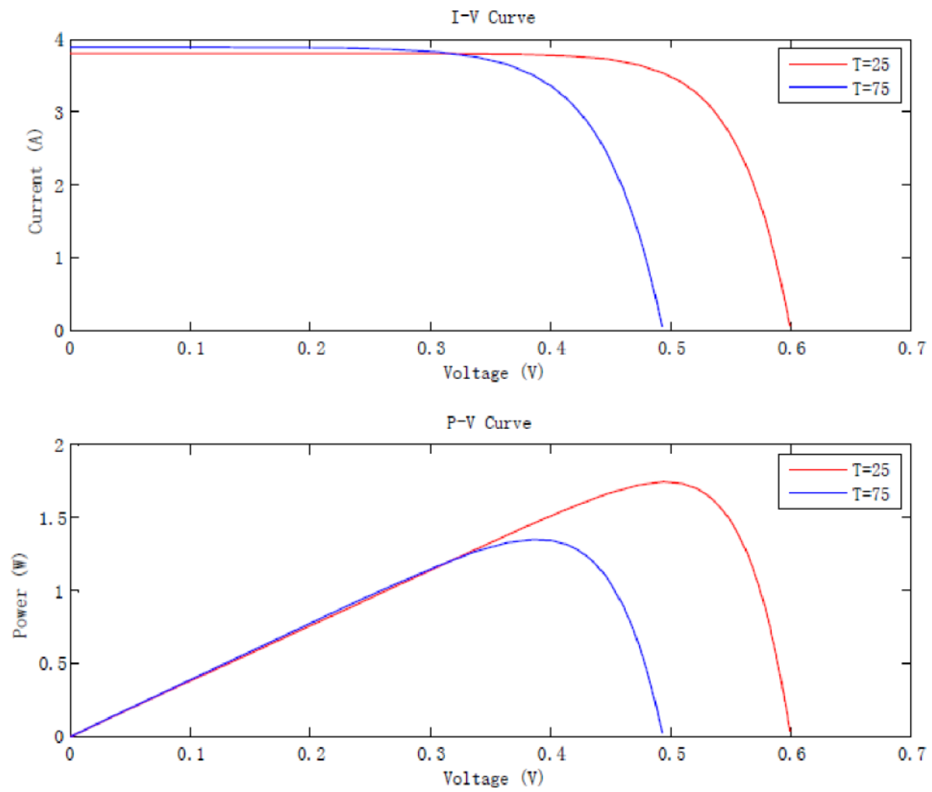

Figure 8: Effects of changing the temperature (Liu & Hou, 2014)

According to the findings, a rise in temperature causes an increase in open-circuit voltage and a little drop in short-circuit current. Equations (2.6) and (2.7) might also be used to justify such changes by substituting equations (2.2) and (2.4) in them.

2.5.6.3 Effects of Temperature Change Irradiance

The ensuing IV and PV curves in Figure 9, show the position PV and IV curves are associated with the PV and IV curves with an irradiance of 1.5 W/m^2 per unit (Liu & Hou, 2014)."

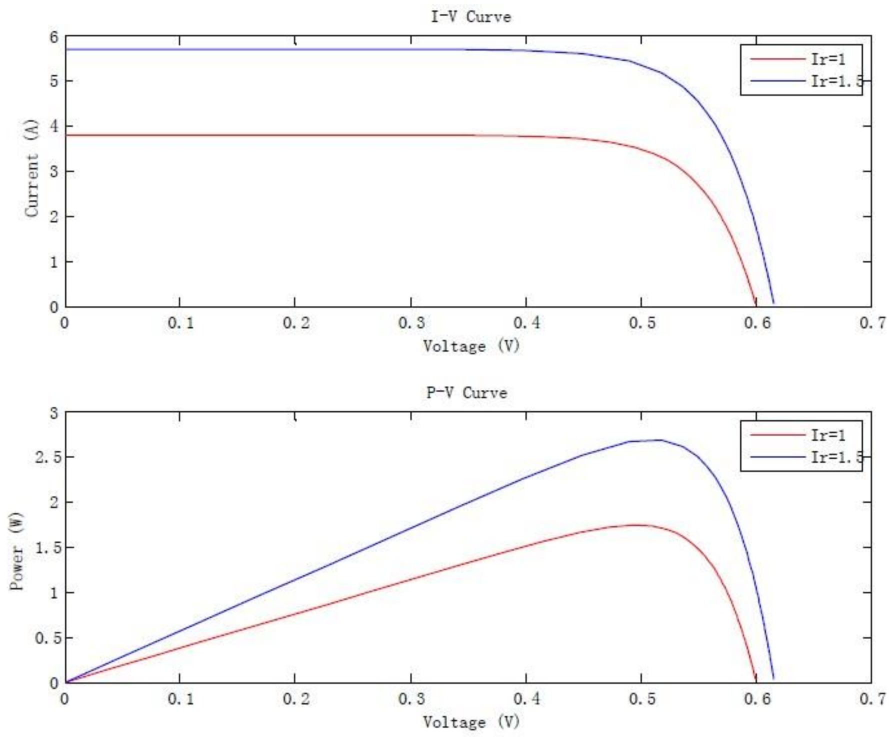

Figure 9: Effects of changing the irradiance (Liu & Hou, 2014)

According to the analysis, rising irradiation causes a slight rise in open-circuit voltage but a huge increment in short circuit current. Equations (2.2) and (2.7) can be used to scientifically validate such irrationalities.

2.6 Domestic Solar Power System

Solar systems are technologies that directly convert sunlight into electrical energy. Solar cells are the essence of solar cell systems (also referred to as solar (PV) systems or solar power systems), which are connected to form solar modules (solar panels) and solar cell arrays. Solar systems are devices that convert solar radiation into electrical energy directly. Solar cells (also known as photovoltaic systems (PV) or solar energy systems) are the building blocks of solar cell systems. Solar cells are combined to produce solar modules (solar panels) and solar cell series. The system's size and configuration are determined by the task it is to perform. The array can be used to charge the battery, run the motor, and power a variety of other devices. The solar system may produce AC power that is compatible with any conventional equipment (AC) and can be operated in parallel with the utility grid and interconnected with it using the proper power conversion equipment (Deepak M. Patil, 2016).

A comprehensive solar system may comprise a direct current and AC converter, a battery bank, a system, a battery controller, auxiliary power sources, and occasionally the specified electrical load (devices), as well as a variety of hardware for the system balance (BOS). Wiring, overcurrent, overvoltage protection, decoupling devices, and other powder processing equipment are included.

"A direct coupling system is the most basic sort of autonomous system, in which the direct current output of a solar module or assembly is directly coupled with a DC demand, as shown in Figure 10.

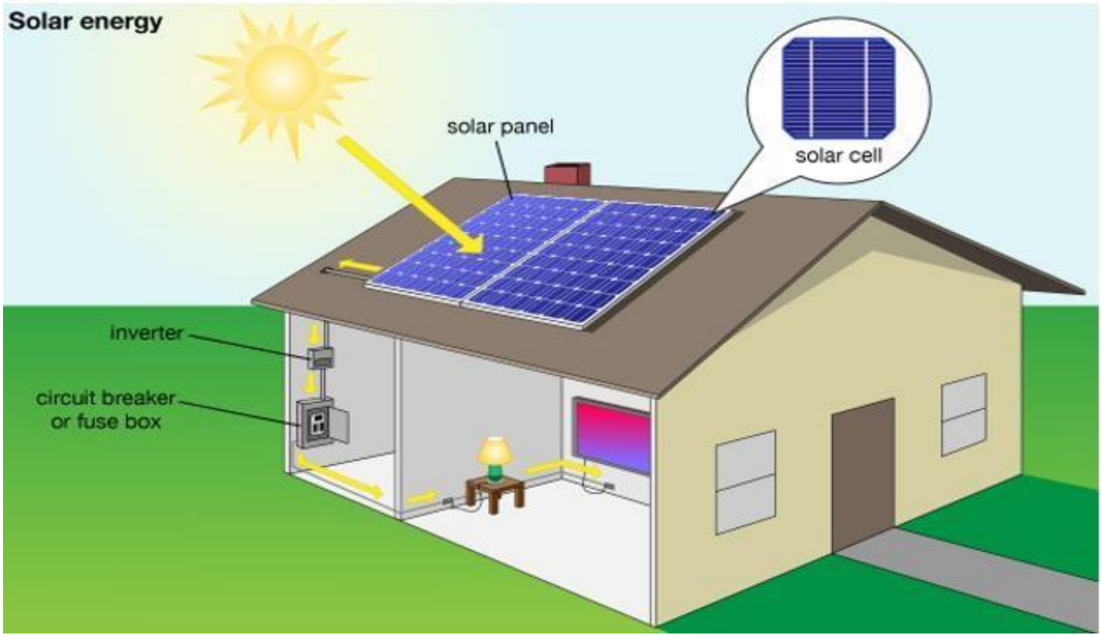

Figure 10: Domestic solar power system (Deepak M. Patil, 2016)

Because no direct electrical storage (battery) is connected, the load operates only during the day, making these designs suitable for general applications such as fans, pumps, and small circulation pumps for solar water heating systems (Deepak M. Patil, 2016).

2.7 Types of Photovoltaic Systems

The photovoltaic model can be very basic, with only one unit and a photovoltaic demand, as in the straight supply of a watering motor pumping, or as complex as a system to light a home. While the water pump only wants to function when the sun is shining, the house system is required to run 24 hours a day, seven days a week.

It may also be required to operate in either AC or DC mode, as well as have reserve power and a backup generator. It can discern three types of PV systems based on system configuration: stand-alone, grid-connected, and hybrid. The core parameters and fundamentals of the PV system are the same in both circumstances. By changing the kind and quantity of the basic constituents, systems can be customized to fulfill specific energy demands. if power demands increase, they can always be increased (Eltawil & Zhao, 2010).

2.7.1 Grid-Connected System

As an integrated building application, grid-connected solar systems are growing in popularity. They use inverters to connect to the network and do not require batteries because the network can handle all of the electricity generated by the PV generator. They can also be used to generate electricity (Eltawil & Zhao, 2010). Figure 11 shows a schematic representation of a grid-connected PV system.

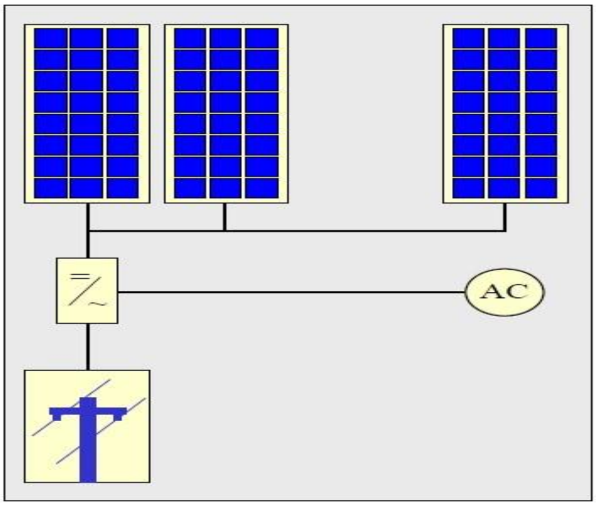

Figure 11: Grid-connected PV system (Eltawil & Zhao, 2010)

2.7.2 Hybrid Systems

Photovoltaic modules are combined with additional devices for generating power, such as diesel, gas, or wind turbines, in the hybrid system. The hybrid system shown in Figure 12 requires more complex control than an independent PV system to maximize the performance of the dual generators of power. In a photovoltaic/diesel plant, for example, the diesel engine should start when the battery reaches a predetermined discharge level and stop when the battery achieves a sufficient state of charge. The backup generator can only charge the battery or the load (Baghdadi et al., 2015).

"A common difficulty with hybrid PV/diesel systems is insufficient to control the diesel generator. If the batteries are kept at a high state of charge by the diesel generator, the energy that could be produced by the PV generator is lost. The operational life of the batteries, on the other hand, will be limited if they are not adequately charged. These difficulties are to be expected when a PV generator is attached to an existing diesel engine without a mechanical mechanism in place to start the engine and manage its output.

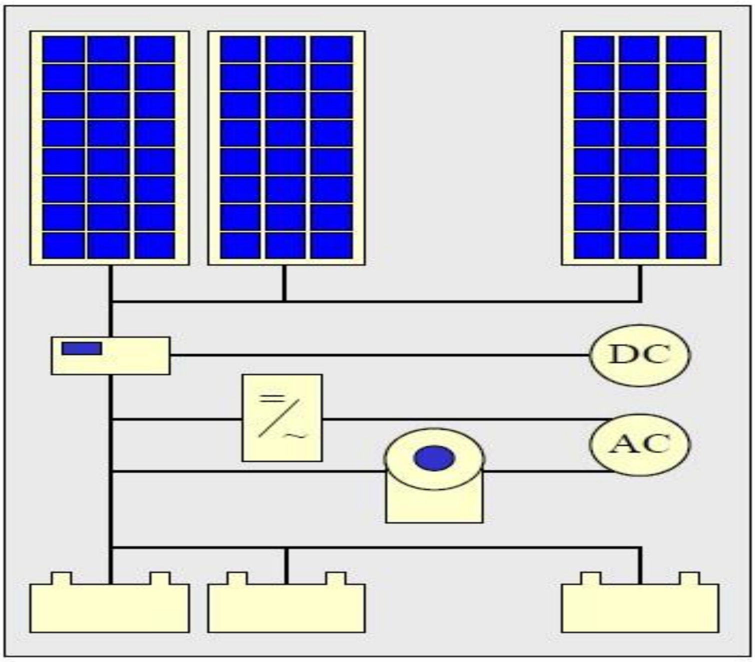

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Figure 12: Hybrid PV system (Baghdadi et al., 2015)

2.7.3 Stand-alone PV System

Stand-alone solar power generation systems are ideal for rural or distant places when other power sources are unavailable or insufficient to operate lighting, electrical appliances, or other needs. Installing simply standalone solar energy generation systems, rather than paying power cables and cables directly to energy suppliers, is more cost-effective in this scenario.

As shown in Figure 13, a stand-alone PV system consists of one or more solar modules, instrumentalists, electrical mechanisms, and a set of one or more loads. Portable solar kits are available from companies that can supply reliable and free photovoltaic power generation wherever they are tough to access or stand.

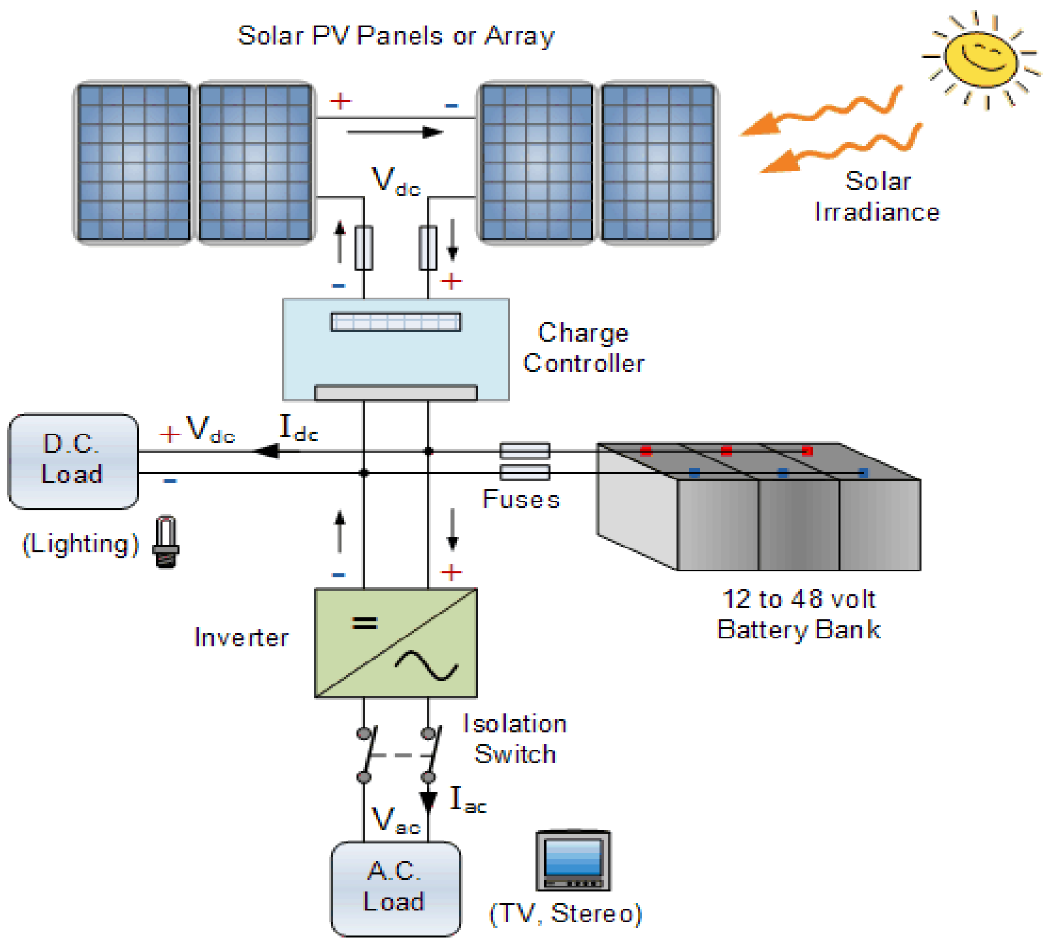


Figure 13: Stand-alone Solar System (Hans S & Beyer)

2.8 Modeling for Stand-alone PV System

A stand-alone PV system is being studied in terms of modeling. Starting with an evaluation of the equivalent model of the system components and a description of the control strategies, a full simulation model of the system and control methods was created in the Mat lab-Simulink environment. Each physical component is modeled as a separate component subroutine and Simulink block in a modular system simulation software. In all of the built models, physical and chemical principles, as well as empirical parameters, are used. The models, as shown in Figure 14, have been designed to be as generic as possible, with all blocks taking into account both design parameters (such as the number of cells in series and/or parallel) and specific component characteristics (such as the current-voltage curve) obtained from manufacturers or experiments(Ş D P, 2008)

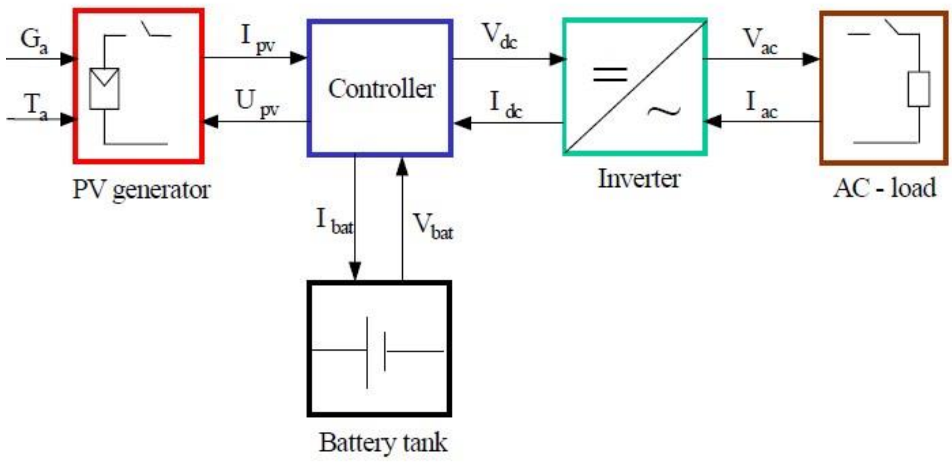


Figure 14: Block diagram of modeling for PV system (Ş D P, 2008).

Figure 14's main function is to show the components of a stand-alone solar power generation system, including solar panels, batteries, controllers, inverters, and loads. Because PV systems are built on a modular framework, various system architectures and element exchanges, such as a DC load instead of an AC load, are simple to model and exchange (Ş D P, 2008)

2.8.1 PV Generation

Solar cells, connectors, protective pieces, supports, and other components make up photovoltaic generators in their entirety. Only cell, module, and array are currently emphasized in current modeling. Solar cells are made of semiconductor material (usually silicon), with one side (the backside) being positive and the other (facing the sun) being properly treated to generate an electric field. When photons from the sun strike the solar cell, electrons are emitted from the semiconductor material's atoms, resulting in electron-hole pairs (Abdi El-Aal et al., 2006). The electron is then captured in the form of a current Iph after the electric conductor is connected to the plus and minus sides to form an electric circuit Iph (photocurrent).

2.8.2 Battery

Batteries are another component of a self-contained photovoltaic system. Because of the variable natural surroundings of the output supplied by photovoltaic modules, batteries are vital in the PV system's structure. As a result, photovoltaic systems provided direct power to the feeder for the duration of the periods of sunlight, and any excess electricity energy was stored in the battery. The solar irradiance became truncated because of low radiation throughout the overnight, the duration period of the shadow, and energies provided to the load from the batteries. The batteries are viewed as a voltage source E in series through an internal resistance R0 in the battery-operated devices, as shown in Figure 15.

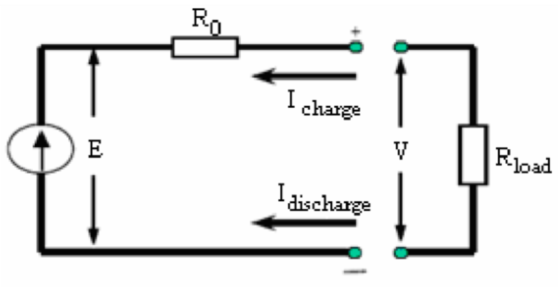


Figure 15: schematic diagram of the batteries (Hansen et al 2000)

The terminal-voltage V_T is assumed by using;

$$V_T = E - R_O \times I \tag{2.8}$$

As the interior voltage E is expected as functioning solitary of the state of charge.

The instantaneous stages of trendy current touch the terminal voltage V_{bat} through the term $R_o \times I_{bat}$. Thus, the interior resistance can be estimated by:

$$\text{Ro} = \frac{V_{bat}}{I_{bat}} \tag{2.9}$$

Where V_{bat} and I_{bat} remain the stages in terminal voltage and battery current, correspondingly.

2.8.2.1 Performance of Battery

The battery concert varies according to the ampere, charge otherwise discharge rate, depth of discharge, and temperature, which will be briefly covered in the following explanations (Mohammad Taufiqul Arif, n.d.)

2.8.2.2 Ampere hour Capacity

In one sense, the battery's current intensity is the number of times the current can be delivered to the dischargeable current. Even if a huge quantity of sunlight is sunk in storage and recharges the battery by charging the battery day, the system designer will have time to spare the steam. The day, and this day are not in any particular order of design (Jallad et al., 2012). As a result, automobile batteries are unsuitable for use in solar systems and cannot be considered an investment in PV systems. Other types of batteries are made to discharge at very low rates for long periods of the periods-hour battery should theoretically be able to provide 200Ah in 1 hour, 50Ah in 4 hours, 4 amps in 50 hours, or 1 amp in 200 hours. This isn't the case at all. Some batteries, such as locomotive batteries, are designed for rapid short-term discharge with minimal damage.

2.8.2.3 Charge and Discharge Rate

If the battery is charged or drained in different proportions than specified, the available amp will rise or fall. The capacity of a battery will usually be slightly higher if it is depleted at a slow rate. Rapider rates frequently result in a reduction in the available capacity (Jallad et al., 2012). C rate refers to the charge or discharge rate. The C rate refers to the amount of current required to fully drain the battery (DOD 100%). The following equation can be used to compute the C rate.

$$C_r = \frac{1}{t} \tag{2.10}$$

Where C_r is the rate of charge or discharge and T is the time in hours to fully discharge the battery. Therefore, from a fully charged battery to a fully discharged one by unrelated C rate means 1 C =1-h 1-hour C=0.5 hours 0.1 C=10 hours. In place of power applications (for example automotive batteries) a large C rate was anticipated, although for energy application solar home systems a minor C rate is desired.

2.8.3 Controller

Every power system must have a control strategy that explains how its many components interact. The presence of a charge controller is required when a battery is used as memory. The battery has been charged to the specified voltage. There are two primary modes of operation for the controller:

1. When the battery voltage swings between the maximum and minimum voltages, this is the normal operating state.
2. The state of being overcharged or discharged. When the battery voltage hits a particular limit, something occurs.

When the voltage differential between the terminals exceeds a given threshold, the PV array is detached from the system Vmax-off. When the terminal voltage falls below a particular value

Vmax-on, the PV array is connected again. This can be accomplished with a switch having a hysteresis cycle, as shown in Figure 16.

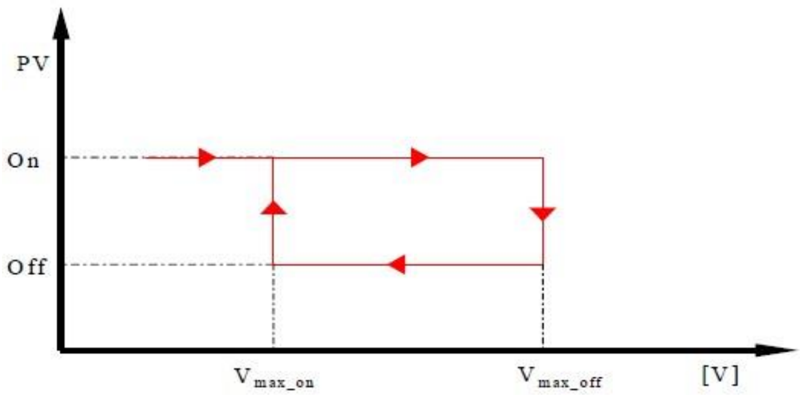


Figure 16: Operating principle of overcharge protector

When the terminal voltage is lower than the specific threshold V_{min_off} and the current required for the load supplied by PV exceeds the specified value V_{min_on}, using the switch with the hysteresis cycle, it is reconnected as shown he Figure 17.

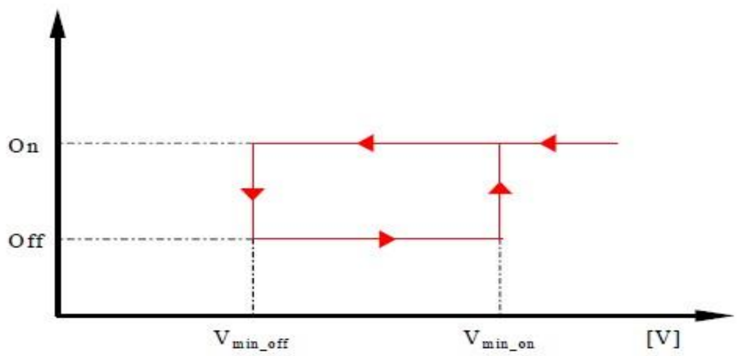


Figure 17: Operating principle of a discharge protector

The stages in the demonstration of the controller procedure exist concisely in Table 1.

Table 1: Summary of the controller process

	CONSTRAINT	COMMAND
1	If $V > V_{max\_off}$ and $Iload < Ipv$	Cut off PV arrays from the system
2	If command 1 is done and $V < V_{max\_on}$	Recombine PV arrays to the system
3	If $V < V_{min\_off}$ and $Iload > Ipv$	Disconnect the load from the system
4	If command 3 is completed, then $V > V_{min\_on}$	Reconnect the load to the system

2.8.4 Load

The load in a PV stand-alone system can fall into one of two categories: DC demand (mobiles, illumination bulbs, fans) that is directly connected to the solar panel, or AC demand (electrical motors, heaters, televisions, refrigerators, fans, and so on) that is directly connected to the invertor. An AC load, in the form of an electrical heater, is included in the PV stand-alone system. This heater is essentially just a simple resistance with a thermostat to control it. As a result, the load can be modeled as follows:

$$\boldsymbol{I_{ac}} = \frac{\boldsymbol{V_{ac}}}{\boldsymbol{R_h}} \qquad (2.11)$$

Where I_{ac} *and* V_{ac} are the current and voltage of the load, separately. R_h is the resistance of the heater, which can be decided by the rated power P_{h}*_nom* and rated voltage V_{h}*_nom* of the heater, as follows:

$$R_h = \frac{(V_{h^i} - nom)}{R_{h-nom}} \quad (2.12)$$

2.8.5 Inverter

Because solar cells produce direct current, when a stand-alone photovoltaic system is connected to an AC load, the DC must be converted to AC. As a result, this part is offered in a condensed form. Inverter. An inverter is a converter that converts power from DC to AC while maintaining a consistent voltage. It generates the appropriate alternating voltage as an input signal, and the output signal is as illustrated in Figure 18.

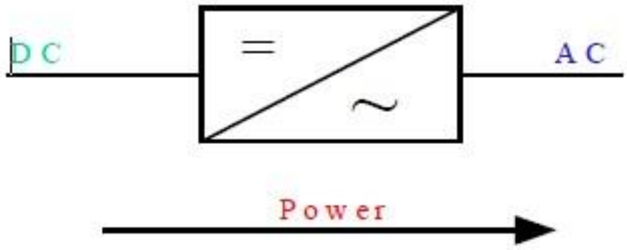


Figure 18: Connection of the inverter

The inverter is considered by an energy efficiency η. The inverter is used to convert solar panels and batteries of 12 V, 24 V, or 48 V DC to alternating current (AC) and 120 V AC or 240 V AC (home current). Electrical appliances, washing machines, freezers, and other equipment. The function of the inverter is to maintain the DC voltage on the AC side and convert the input power to the rated voltage shown on the fourth line. P_{in} into the output power P_{out} by the greatest conceivable efficiency. The efficiency of the inverter is therefore validated as:"

$$\eta = \frac{P_{Out}}{P_{in}} = \frac{V_{ac} \times I_{ac} \times \cos\phi}{V_{dc} \times I_{dc}} \Rightarrow I_{dc} = \frac{V_{ac} \times I_{ac} \times \cos\phi}{\eta \times V_{dc}} \quad (2.13)$$

Where I_{dc} Is the current required by the DC side inverter (for instance controller) sufficient to maintain the AC side rated voltage (for instance load) (Hansen et al., 2000). V_{dc} is the input voltage for the inverter supplied through the direct current side, for instance by the controller P_{out}."

2.9 Working Procedure of SHS

This system's goal is comparable to that of a centralized solar energy system. Because it is a smaller version of the preceding one, the consumer can use all of the elements as requested. It depends on the loads it can power both during the day and at night, as well as in unexpected situations. Many gadgets and electronics may now be powered totally by solar energy, thanks to advances in technology. If a customer possesses these systems, he or she will never have needed to use additional power to maintain them operational for a long duration (Mustafa et al., 2017). As demonstrated in Figure 19, it is possible to reduce the demands and preserve energy.

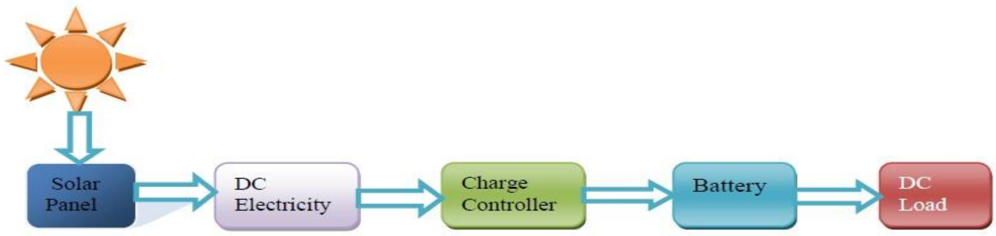


Figure 19: power follow diagram of SHS

2.10 HOMER Software

The United States National Renewable Energy Laboratory developed Hybrid Optimization of Multiple Energy Resources (HOMER), a software for micro-grid model modeling (NREL). The HOMER software allows the user to compare several micro-grid designs based on cost and system operation. Furthermore, this software can represent two different sorts of connections: grid-connected and off-grid (Birenis, 2012). Photovoltaic (PV) modules, small hydro, biomass, generators, batteries, and wind turbines are all examples of sources that can be combined in the micro-grid concept. Various obstacles in creating a micro-grid system, such as many parameters to consider, multiple possibilities in designing a micro-grid system, and unpredictability of renewable resource supply, can be handled with HOMER software. Simulation, optimization, and sensitivity analysis were the three operations carried out by this software. The simulation procedure entails modeling the performance of a micro-grid system to establish the system's technical estimation and life-cycle cost. The ideal system combined with the lowest life-cycle cost is then identified throughout the optimization phase by simulating several types of system combinations. Sensitive analysis eliminates the impact of unknown variables like solar irradiation(El Shenawy et al., 2017). Wind speed and level(Bhattacharyya & Palit, 2021). In a table format, the HOMER software analysis result will display the original investment, net present cost, total generated power, and various types of source combinations. After seeing the results, the worker can choose the best source combination in a micro-grid system for the least amount of money."

2.11 Summary

Because it is relevant to the project's purpose, the solar housing system is the project's main focus. Due to ample sunshine and high solar radiation throughout the year, Somalia has a great potential for solar photovoltaic generation, according to paragraph 2.4, Natural electricity sources include solar panels and turbine generation. The long-term operation, zero solid waste products, pollution reduction, low repair, endless energy resources, and overcoming the fossil fuel issue are only a few of the benefits of solar photovoltaic systems. Photovoltaic (PV) technology (which employs a semiconductor device to catch sun rays) and solar power technology are the two most widely utilized technologies in photovoltaic systems (using a mirror to focus sun rays on a receiver tower). In one of two ways, solar photovoltaic generation can be connected to the grid or used off-grid. Inverter, string inverter, and AC module technology are all used in off-grid PV systems. The HOMER software will be used to evaluate the design PV system. The financial analysis of a PV system design can be simulated using this program. Finally, existing studies on solar PV systems were reviewed to obtain knowledge and ideas that may be used in the development of a solar home system in Banadir.

Chapter 3

METHODOLOGY

3.1 Overview of the Chapter

This study begins with a definition of the project background and problem statement. Simulations are used to verify the findings of theory-building developments and past studies, which serve as the source point. In addition, an original research and idea review will be conducted in advance to gain a deeper understanding of the suggested residential photovoltaic system's underlying theories. This chapter will quickly describe the methods used to determine the design and modeling of solar household systems in the region of Banadir. A review of the literature about photovoltaic (PV) systems was conducted using material from a variety of sources, including reports, journals, conference papers, and thesis. In this chapter, the technique covers a project flowchart, the size of PV modules, the PV system inverter, the placement of the project, an equation for building PV systems, and the modeling of a Solar household system by applying HOMER software.

3.2 Overview of Project Methodology

A Diagram of a research study is a diagram showing the significant steps required to complete a task. This system's flowchart, seen in Figure 20, consisted of many significant phases. The results of the theoretical analysis and literature evaluation will be utilized to develop a solar house system in Banadir, Somalia. Multiple sources, including journals, theses, conference papers, and technical reports, will be scoured for the desired information. Next, data and information necessary for the drawing and evaluation of a solar home system in the Banadir zone will be gathered in the Banadir region. The needed data include solar home system load and statistics for a particular family in the Banadir region. If the gathered data are insufficient for the design and analysis process, they must be re-requested from the Banadir area.

Then, the PV module will be designed to predict the highest amount and size of the Photovoltaic system that can be put on chosen homes in the Banadir region, based on rooftops plan and roof areas. The next stage is to calculate the PV system's size, cost, and payback time. Then, the primary design and analysis are performed by analyzing the PV system's total price and electricity output using the HOMER program. The outcomes of this investigation may then be completed and it can be demonstrated that the solar system in the Banadir region has a tremendous amount of potential.

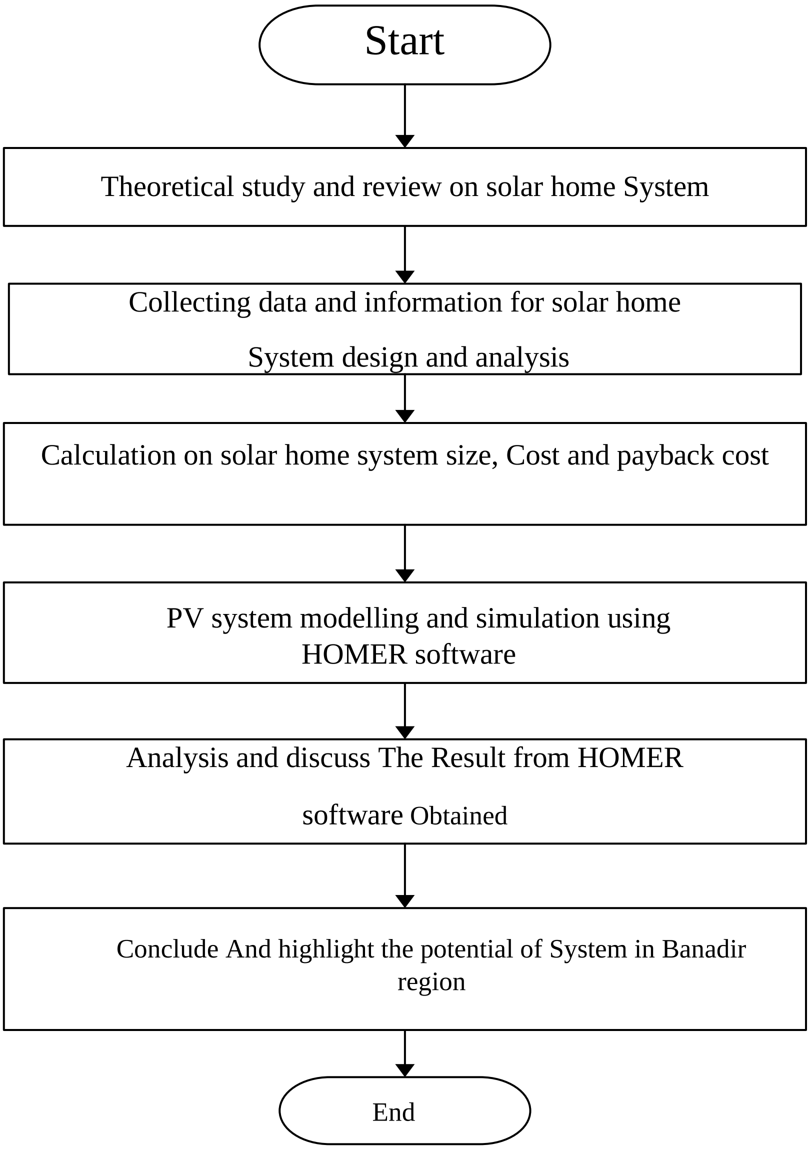


Figure 20: Project Flowchart

3.3 PV System Design Process

In this part, we address the phase of project completion. The PV design of the work is displayed in Figure 21. Irrespective of the relevant research, the shape consists of a scanning site, home data collection, and loading evaluation. The interpretation and budget of each element of a photovoltaic scheme is the greatest essential factor that must be considered before the design process. This section describes the main components. Flowchart of a supported sun energy network, the Renewable PV machinery' behaviors and prices, Solar system architecture, and the size of the storage and charging controller. Using the HOMER program, the purpose of this part is to create a simple solar home system. The design approach begins by estimating the primary input data that confirms the technological provisions, resources data, and expenses connected with the effective implementation of the strategy inside the HOMER software application.

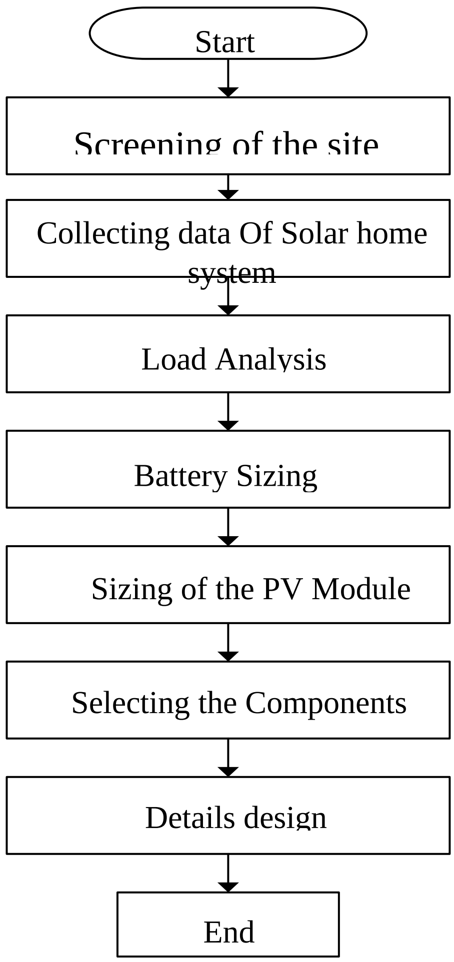


Figure 21: Flowchart of the photovoltaic system design process

The photovoltaic system design process is referred to in Figure 21, the procedure begins with site screening. This means it must be located in a place with plenty of sunshine. The design and optimization of photovoltaic systems require the collection of data as a preliminary stage. Then, the second phase is an estimate of the load, and after the size of the battery, the size of the system is estimated. Then select other system components, such as the load control unit and voltage converter (if needed). In the process, the entire system design was processed.

3.4 Data Collection and Selected Site

The design and optimization of photovoltaic systems need the collection of data as an initial platform for the successful implementation of the task. This includes choosing sites that will implement the project in future work, load analysis of selected villages, solar irradiance analysis of selected areas, and available renewable resource assessments, considering the geographic characteristics of the location.

3.4.1 Banadir region Map and Electricity Access

The largest proportion of the population of the Banadir region is in urban areas, but there is a lack of electricity in the surrounding areas of rural areas. In urban areas, electrification varies by region. Banadir region and Hargeisa’s recent optimistic estimates account for 60% and 68% of the population, respectively, while only 23% of small cities like Markka are related to electricity services. In areas where the number of internally displaced persons is high and difficult to track, estimates of electricity supply may be overestimated. In fact, according to a recent author of a study called Banadir regions.

“First Population Study” for twenty-five years, the city’s electrification rate is only 46%. About electricity supply and prices in Somalia: “This East African country with a population of 10 million is one of the most expensive electricity in the world. One kilowatt of electricity in the Somali capital costs up to $1.50 per hour in normal areas, and in some places, Electricity is more than that. This is five times more expensive than neighboring Kenya and 10 times higher than the United States (Note, 2018).

Banadir region consists of 18 districts. Warta Nabada was formerly known as Wardhigley District and was officially renamed in 2012. Kahda District was established in 2013 and the map of the district is absent, as shown in Figure 22.

Figure 22: Banadir region map

The situation in the Somali energy sector shows that "Somali people have Access to modern energy, especially electricity, is very limited, a problem that affects the quality of life and limits production. The city's municipal electricity resource is limited in quantity, quality, and reliability, and Tension (voltage) drop and the impact of frequent failures (Sector et al., n.d.). Furthermore, the poverty line is determined by the level of household consumption of each adult. According to the family category, the family is considered normal domestic as shown in Figure 23.

Figure 23: Typical house for the family in Banadir region areas

3.4.2 Load Profile of Single Household

The selected household in a target area in the Banadir region is assumed to be a family household of about 6 people. The family uses different electrical and electronic appliances including 8 lamps of 18w; 4 smartphones; 2 laptops of 60w; a washing machine of 1700w; an iron of 1400w; a TV of 41w, and 2 fans of 55w. these are the basic appliances people use in Somalia, most of the time the weather of Benadir region is normal and people tend to use fans instead of Air conditioning due to the high cost of electricity bills and normal temperature. The selected household is a small villa and its natural spring water directly comes from high tanks of water supply companies, therefore we do not need to use water pump. Table 2 Shows the calculation of the hourly power consumption of the appliances in watts/hour and the overall daily consumption of the selected single household family.

Table 2: Daily load evaluation for single house in Banadir region.

Energy Demand for Single home in Banadir, Somalia						
NO	**Equipment**	**Quantity**	**Power (w)**	**Total Power(W)**	**Hours/day (h)**	**Total wh/day**
1	Lamps	5	18	90	8	720
2	Cell phones	4	10	40	2	80
3	Laptops	2	65	130	1.5	195
4	Washing Machine	1	1700	1700	0.35	595
5	Iron	1	1400	1400	0.3	420
6	TV	1	41	41	7	287
7	Fan	2	55	110	5	550
8	Fridge	1	15	15	24	360
9	Water pumps	0	750	0	1	0
10	Air condition	0	1800	0	5	0
Total				**3526**		**3207**

As constructed on the values, Figure 24 depicts and illustrates the unique daily load curve for a single home with hourly resolution. The maximum power consumption associated with the load curve generated by the selected individual house is approximately 500W. Daily and hourly noise make the load data for each day and step by step more realistic. The energy consumption is approximately 3207 Wh/day.

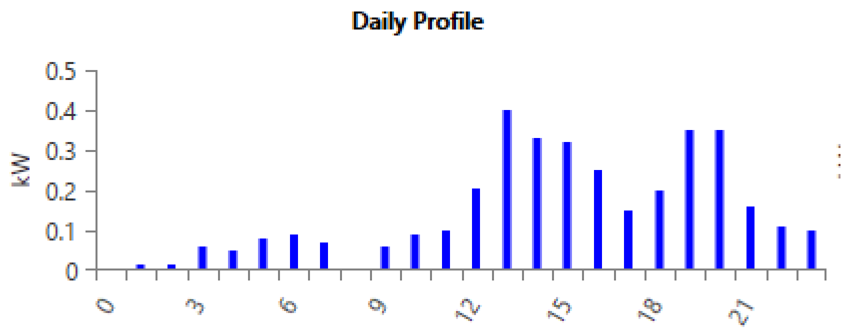


Figure 24: the single household load profile in the Banadir region remote

3.5 Solar Resources Analysis for Banadir region

Near 2 latitudes and 45 longitudes, the Banadir area is situated. The tilt angle is defined as the tilt angle of the modules calculated in the horizontally plane. Due to the site's location at 2° north latitude and 45° east longitude, the optimal angle for photovoltaic modules is 10 degrees south. The output of the PV array is dependent on the light strength, environmental temperature, battery temperature, state of load, and characteristics of each PV module in the PV array. The hourly worldwide emitters on the horizontal plane must be translated to the hourly worldwide irradiance on the PV module, as the PV array studied in this study is slanted 10 degrees south. To predict the performance of solar power generation systems in a certain area, we need to collect weather data or environmental data on the location of the sites under consideration Figure 25 displays monthly average photovoltaic irradiation information on a horizontal top layer gathered by the HOMER program using the National Solar Radiation Database. The incidence of solar energy is particularly high in regions where the summer's water level is estimated to surpass 6 kWh/m2/day. Figure 25 reveals that the average irradiation of the Banadir region is around 5.7 kW/m2/day. This renders the Banadir region a bright location with the greatest number of peak sun hours for generating massive PV solar power. This can help residential solar system project research to utilize our free solar energy in a way that saves money, reduces pollution, and frees us from dependence on fossil fuels.

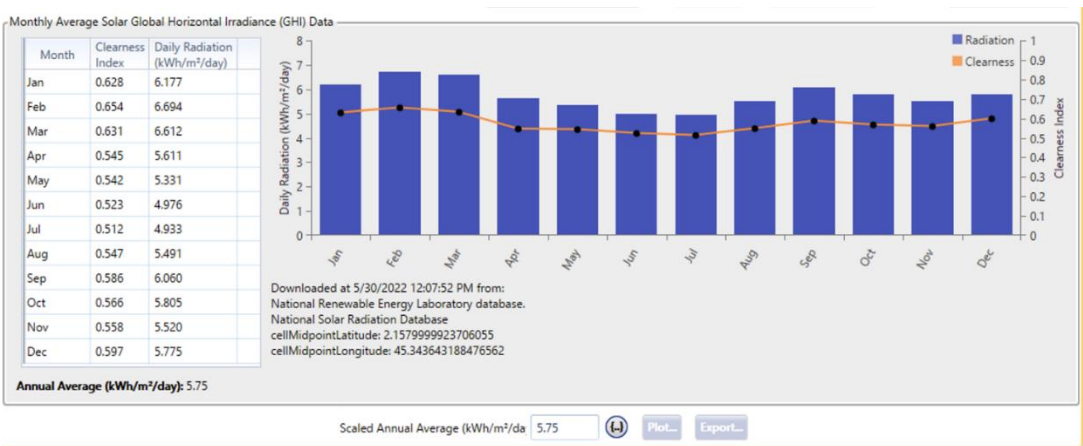


Figure 25: Monthly global horizontal radiation data for the Banadir region

To utilize effusively photovoltaic energy, it needed to fully understand all the data that explains the potential of solar energy in that area. Since this value is 6.694 kWh /

m 2 / day, a large amount of solar radiation may be observed at the place selected in February. As shown in Table 3, the annual average solar radiation was 5.75 kWh/m^2/day and the corresponding average sharpness index calculated by Homer was 0.57.

Table 3: Monthly global level radiation data for the Banadir region

MONTHS	**"CLEARNESS INDEX"**	**DAILY RADIATION (KWH/M^2/DAY)**
Jan	0.628	6.177
Feb	0.654	6.694
Mar	0.631	6.612
Apr	0.545	5.611
May	0.542	5.331
Jun	0.523	4.976
Jul	0.512	4.933
Aug	0.547	5.491
Sep	0.586	6.06
Oct	0.566	5.805
Nov	0.558	5.52
Dec	0.597	5.775
Average"	**0.57**	**5.7**

From Figure 25 and Table, 3 gives a good assumption for, Somalia's radiation that taken from National Renewable Energy Laboratory Database."

3.6 PV System Sizing and Components

The performance and cost of each component of the photovoltaic system are the most important parameters to consider before the design process. There are numerous categories of PV system configuration provisional the voltage system and bus type that interconnect power supply and load. The two most common types are called DC-coupled systems and DC/AC coupled systems. In this project, a DC-coupled PV system was chosen because the PV generator is connected to the DC bus to supply the DC load to the selected residential area of the Banadir region. A typically solar PV system is revealed in Figure 26.

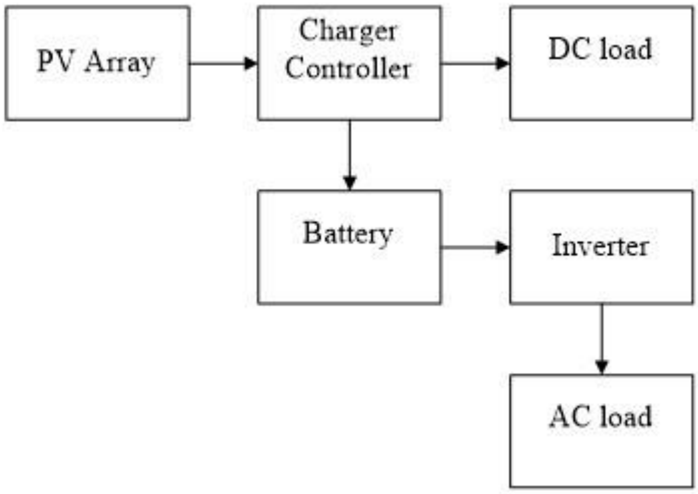


Figure 26: Block diagram of a typical solar PV system

3.6.1.1 Determining the Power Consumption Demand

Table 3 displays the overall daily electricity usage. This electricity usage is caused by a mixture of reduced and rising components that operate for a certain number of periods. Table 3 reveals that the overall daily energy use is around 3,240 Wh/day. To analyze and design the solar system, first, we need to collect data from field visitation and physical equipment count down. Second, we need to calculate the power consumption of the electrical appliances and their hourly usage. Third, we need to determine the number of solar panels, an inverter, and battery energy requirements needed to support the design of the solar system and cover the energy demand of the family.

3.6.2 Battery

Energy storage is an important portion of any energy system, as well as chemical storage in batteries, is the most commonly used long-term storage technology, as shown in Figures 27 and Figure 28. It becomes a core component of a general system in any photovoltaic system with batteries, which has a significant impact on the price, conservation necessities, dependability, and the design of solar power systems. Electrochemical battery storage is the most commonly used technique of storage electricity. Knowing the characteristics of the battery is critical to understanding the operation of the photovoltaic system due to the large impact of the battery in a complete photovoltaic system. For PV systems that are the only source of power, storage is often required because the actual match between available sunlight and load is prohibited for certain types of systems. The battery capacity (BC) required for solar installations is as given formula;

$$\text{BC} = \frac{Total\ Energy\ Demand}{(no\min al\ battery\ voltage \times DOD\%)} \times D\ of\ autonomy \tag{3.1}$$

Figure 27: Trajan SSIG 06 375, 12 V, 375 Ah Battery storage

Batteries are considered to be a key cost factor for small-scale stand-alone control systems. In this simulation, the commercially usable battery bank Trojan SSIG 06 375 (6V, 376 Ah) was considered. The projected lifespan is (5 years) and the cost of the battery is ($250) with a replacement cost ($250) while the operating cost is expected to be ($5/year).

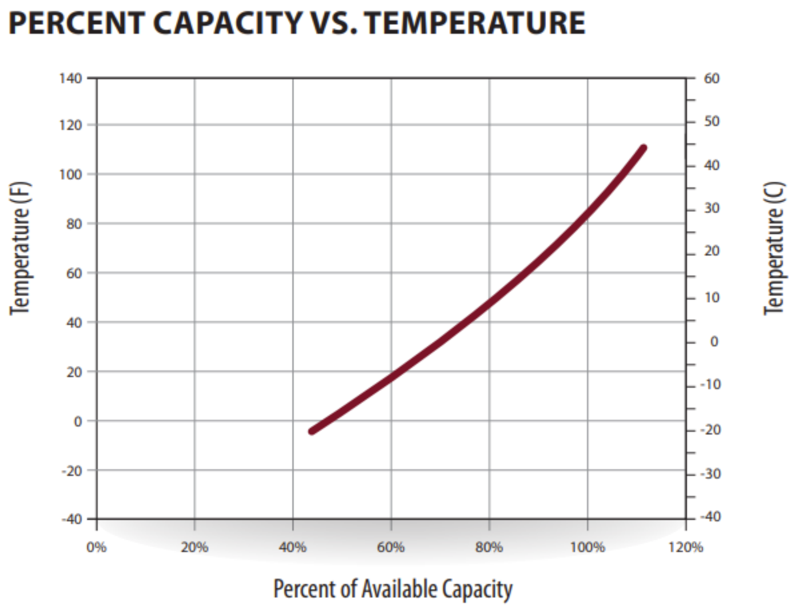


Figure 28: Capacity curve vs temperature of Trajan SSIG 06 375, 12 V, 375 Ah

Chemical reactions internal to the battery are driven by voltage and temperature. The higher the battery temperature, the faster chemical reactions will occur. While higher temperatures can provide improved discharge performance the increased rate of chemical reactions will result in a corresponding loss of battery life. As a rule of thumb, for every 10°C increase in temperature the reaction rate doubles. Thus, a month of operation at 35°C is equivalent in battery life to two months at 25°C. Heat is an enemy of all lead-acid batteries, FLA, AGM, and gel alike and even small temperature increases will have a major influence on battery life.

3.6.3 PV Solar Modules

The PV panel is comprised of several linkages of solar cells (often two connected in series), which are summed under a single, continuous, stable part. Approximating the total watt maximum rate necessary for PV parts will work for residential applications; these total hours' watts per workday are needed from the Photovoltaic modules. Above may be an individual component in forming a panel. In the same manner that solar irradiance changes from location to location, so does the capacity of solar panels. Consideration will be given to the adjustment factor for some renewable Photovoltaic modules when calculating the panel's capacity. As a general rule, (Bellia et al., 2014) provides the enhancement factor for a single renewable Photovoltaic module.

$$\text{Total PV panel capacity needed} = \frac{TOtal\ Energy\ Demand}{Sunshine\ Hrs \times Efficiency} \quad (3.2)$$

3.6.4 Inverter

In solar household systems, the converter is necessary to convert the Dc source signals from the battery AC appropriate for the electrical outlet. In terms of the inverter's size, its input rating must not be less than the overall watts of the device. The nominal voltage of the inverter must match that of the battery being utilized. Since we are employing a stand-alone system, the converter must be capable of handling the complete watts at once. Think that the size of the inverter should be 25 to 30% larger than the total wattage of the device. In the case of equipment motors and compressors, the size of the inverter must be at least 3 times the capacity of these devices and it must be added to the ability to handle the inverter's initial surge current was determined depending on the loaded appliance of a single-family home with no requirement for an inverter. However, alternative loads for the population type were addressed in the upcoming planning procedure.(Design & Loudiyi, 2017)”

$$\text{Inverter size} = \frac{Total\ rating\ (W) \times current\ load\ factor}{Efficiency} \quad (3.3)$$

3.6.5 SHS Net Profit and Payback Period Calculation

Net profit is the profit earned by the customer or investor after subtracting the solar home system installation cost during contract period and payback period is the number of years for the investor to get back their investment money through PV system(Yenilmez, 2016) .

The Net profit earned by the solar home system installation can be calculated by using equation (3.4)

$$\text{Net}_{\text{profit}} = \text{Profit}_{\text{total}} - \text{Cost}_{\text{install}} \quad (3.4)$$

the payback period, $T_{payback}$ is the initial investment cost divided by the total rate of profit per year (Yenilmez, 2016). The payback period can be calculated by using equation (3.5).

$$\text{T}payback = \frac{C_{invest}}{P_{year}} \quad (3.5)$$

Where C_{invest} is the investment cost of the PV system and profit_{year} is the profit earned every year.

3.7 PV System Design-Using-Homer-Software

The modeling of solar power systems was designed using basic solar home systems with the assistance of optimization software called HOMER. In the design process, you must first specify the important input data, resource information, and cost of the entire system using the HOMER tool.

3.7.1 Design of Solar Home Systems

The following information as data inputs used to design the solar home system also the design has been done using Homer software so that the result will be associated with the sizing and result discussed in this part. ‘Solar panel size is 300W, capital investment is \$ 1400, and replacement cost is \$ 100, annual operating cost and maintenance assumption is \$ 10. The average load demand is 3210W, the peak load is 700 W, the average demand is 0.14 kWh/d, and the load factor is 0.2. The solar radiation is 5.7 kWh/m^2/d, the removal index is 0.57, and the average temperature is 27.1 °C. The solar irradiance is 5.7 kWh / m2 / d, the sharpness index is 0.57, and the average temperature is 27.1 °C. The project's designated battery is Trajon SSIG 06 375, 12 V, 375 Ah Battery storage with a nominal capacity of 375 Ah (0.66 kWh), a round-trip efficiency of 96%, a capital expenditure of \$500, then an estimated replacement cost and an operating and maintenance fee for this battery. Units are assumed to be \$400 and \$10/year, respectively.’

3.7.2 Working Procedure of SHS

The operation of a PV household system is nearly identical to that of a grid-connected system. However, with the advent of modern technologies, there are two approaches to administering nowadays. Recent inventions of solar-powered gadgets have reduced reliance on conventional electricity. Solar heater, solar refrigerator, solar cooker, solar fan, etc., in addition to DC-powered fan, light, etc., will eliminate the need for an inverter in a solar home system. Alternatively, if a person wants to utilize an inverter in his home system, he must use all of the same AC equipment as a grid-connected system. The system comprises batteries, a charge controller, solar panels, and occasionally an inverter. Figure 29 shows the system structure of the suggested single-line diagram.

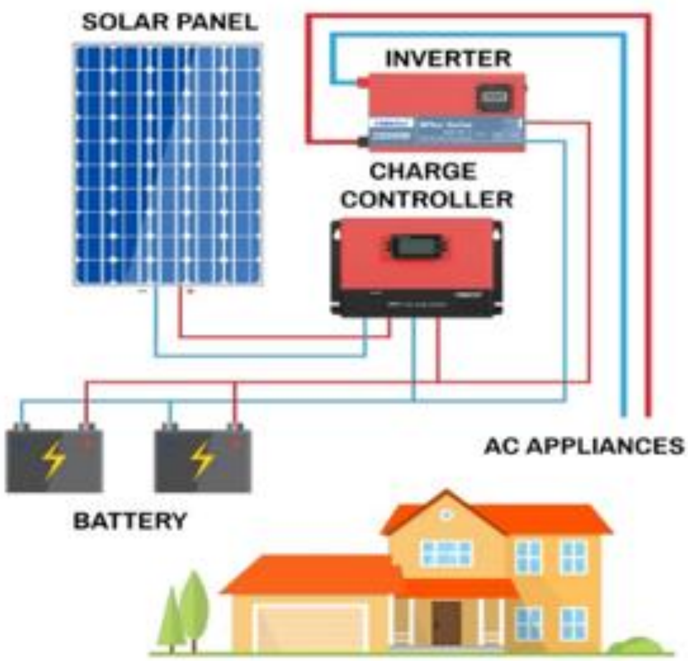


Figure 29: Single line diagram of the SHS system in Banadir region Areas

Each section's conclusion According to the SHS, the photovoltaic panels are the most essential and useful component. The objective is to convert solar radiation into electricity and then either store the electricity in batteries or use it to power loads directly. Most residential solar systems utilize acid batteries. The function is to save power when there is sufficient sunshine and release it when needed. Batteries are the primary source of energy for loads mostly at night or when there is little sunlight. The charge controller provides both overcharge and over-discharge protection for the battery. In regions with significant temperature fluctuations, a competent controller must include a temperature compensation feature. It is difficult to establish a solar home system cost-effectively since it is a standalone system for lighting individual homes. Inverter alone is quite expensive, thus battery-capable products can be used to lower the cost of the inverter. As PV panels are often put in the residences of SHS owners, transmission losses are minimal.

3.7.3 Configuration and Design of Solar Home System

The scale of the energy system mechanism is accomplished using the HOMER design software established by the National Renewable Energy Laboratory, which is enough to reliably predict system performance. HOMER is a perfect optimization that can run hundreds or thousands of approximate simulations to design the best system. The HOMER in the PV system design reduces the costs, time, risks, and errors associated with preparing the project feasibility study. Providing low-cost preliminary design methods for project developers and industries can increase the start of project research to help determine the best opportunities for successful PV project implementation. The system configuration is configured for various PV array sizes to operate along a storage (battery) system. Figure 30 shows the HOMER simulator for a completed solar home system that considers load consumption. Household energy composition.

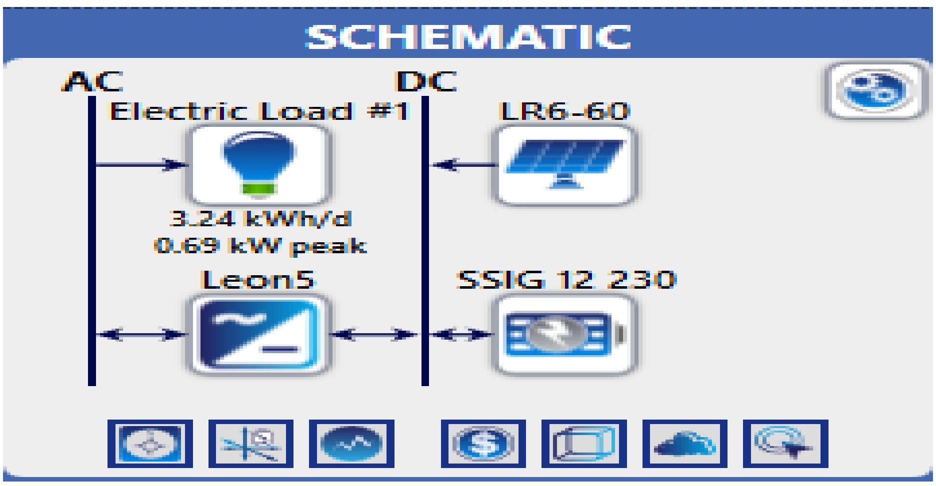


Figure 30: Proposed system design

3.7.4 Main load input

The inherent load of a detached house is to instantly meet the required load, so the load is not ignored. The load is measured in each time zone of the selected house in the selected house of the Banadir region, and the average load distribution for the day and the accidental distribution of common single rooms are obtained. As shown in Figure 31 the hourly input value is based on the type of AC load.

Figure 31: proposed system design

The baseline data is characterized by the same number of 8,760 masses recorded per hour, used to represent the average of the power demand, expressed in KW. There are two ways to generate baseline data, one is to create data using HOMER, and the other is to import data from the selected document every hour. HOMER only surrounds one load profile. This is expressed as a specification of various electrical load values every 24 hours. You can also enter different load profiles for different months and weekends. On the other hand, if you enter a single load profile, it will be used periodically.

3.7.5 Photovoltaic-Inputs

In this project, the type of single monocrystalline solar panel Canadian solar Max Power was selected, and the data sheet and manufacturer specified the relevant specifications on the nameplate. By using the HOMER software, the selected PV system type is considered to operate at the maximum power point to obtain the desired output power from the system. The parameters required for HOMER to input PV are shown in Figure 32.

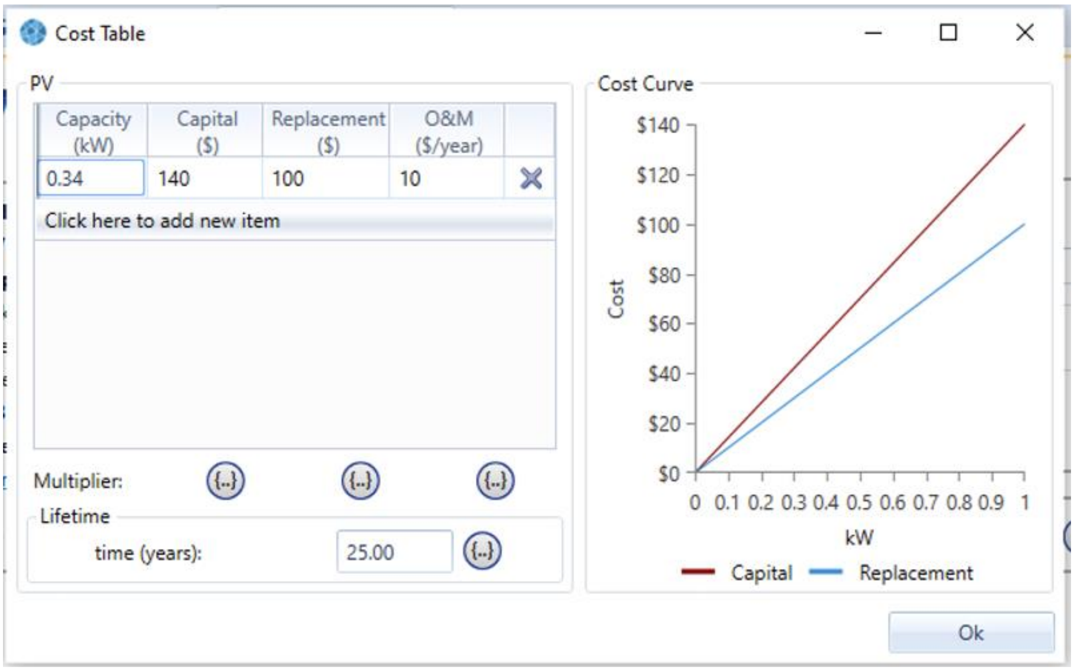


Figure 32: Input PV used for PG for a house in the Banadir region

The Figure 32, to display the cost characteristics curve of the photovoltaic panel, the PV input window is used for the election of a range of sizes for obtaining a system optimal for the analysis of a single house by evaluating with the HOMER software and display of the site of the solar panel it will be implemented. The budget of solar panels is determined by system estimates as given impression by the budget desk trendy Figure 32. As photovoltaic expenses should be directly related to size, you only need to use a single line. During the project's advancement, the capital investment cost of the selected solar panel’s size of 300W is determined and is $1,400, and the replacement cost is expected to be $140 each. Maintenance and operating are $10 per year as well.

3.7.6 Battery Input

The battery type selected for this project is the Trajon SSIG 06 375, 12 V, 375 Ah as the rated current. For a solar home system configuration, one battery is sufficient, as shown in Figure 33. To get the optimal number of batteries used, Homer software users can use the nameplate shown in the figure and choose which type to choose first.

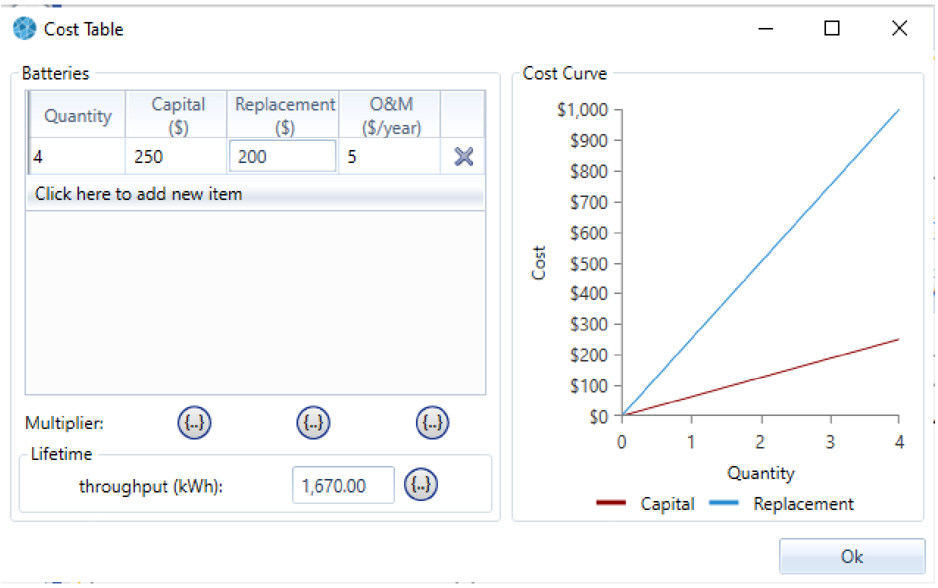


Figure 33: Battery storage window with properties in HOMER

The input screen, seen in Figure 33, comprises all of the rechargeable battery power kinds offered by the HOMER library section. When a HOMER client wants to select which battery to purchase, they may simply click the Information" option to view a range of battery types and their respective attributes. It is simpler to pick the correct battery type from the listing based on established specifications that can be efficiently matched to the PV system in use. After selecting the optimal battery type, the client must input the chosen quality to determine the initial investment, cost of repairs, operational cost, and maintenance cost. Considering the number of batteries per string, the nominal voltages and amperage required, and the optimal design when determining the size of the backup system. As indicated by the formula, the program assumes that battery charging performance equals the square root of round-trip efficiency.

$$\eta\text{batt, c} = \sqrt{\eta batt, rt} \qquad (3, 6)$$

$$\eta batt, d = \sqrt{\eta batt, rt} \quad (3, 7)$$

Where, ηbatt, c is charge efficiency, $\eta batt, rt$ is Round-trip efficiency, and ηbatt, d is discharge efficiency

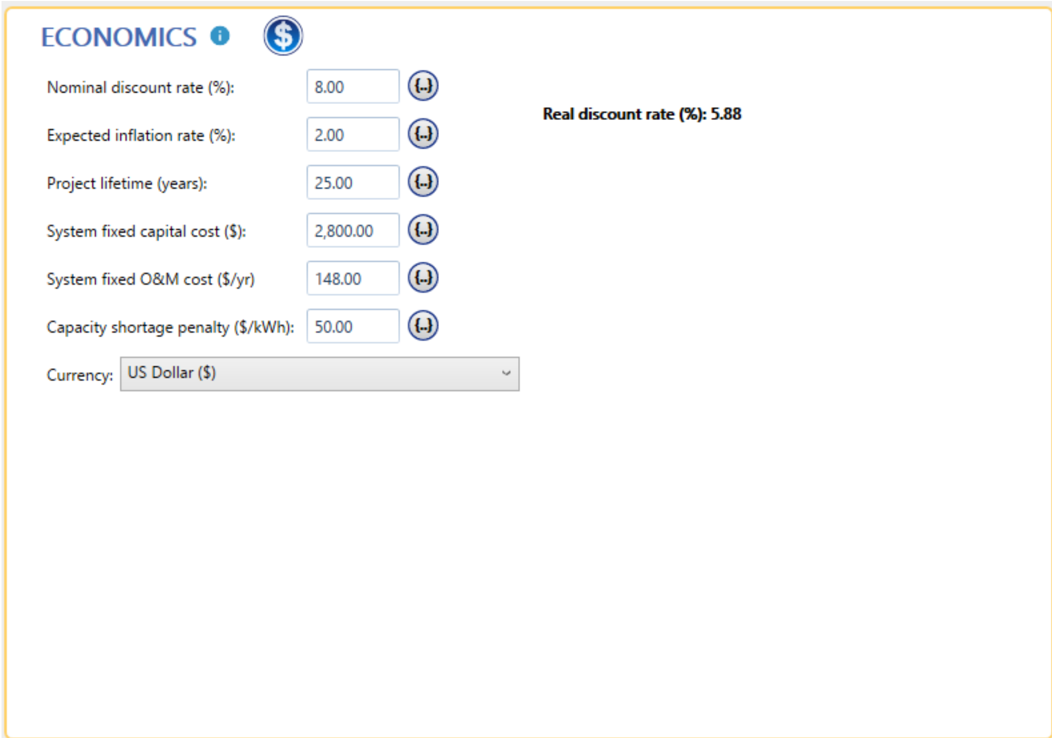
Figure 33 characterizes the input data which was set up entirely the essential information concerning storage nominated for this circumstance study. These details include asset and cost estimates, including capital and exchange costs, and annual operating and maintenance costs. To summarize the total cost of the battery, the various costs of the battery unit are considered as follows. Shows an initial capital investment of $500, and replacement of $250 each, and an annual operating maintenance (O&M) specification of $5.

3.7.7 Economic Inputs

HOMER software helps the optimum system configuration constructed on the Level zed cost energy LCOE study by figuring the Net-Present Value-(NPV) containing all the expenses for the lifetime of the project. Also, HOMER categorizes different kinds of configuration-depending on what incremental-is the total NPC also LCOE-values as shown in Table 4.

The HOMER software helps to obtain the optimal system configuration based on the average cost energy LCOE study by calculating the net present value (NPV), including all costs over the life of the project. In addition, HOMER classifies various configurations depending on what is incremental in the total NPC also LCOE value has been analyzed as shown in Table 4.

Table 4: *Economic inputs using HOMER for calculated the NPC for the system*



The net present value (NPC) of a system is the difference between the present value of the considerable cost incurred during the period of the project and the present value of all income over the life of the project. The formula is used to determine the net present value to estimate the cost that can be completed in n years.

$$CNPC = \left(\frac{1+i}{1+d}\right)^{n} \quad (3.8)$$

Where $i'$is the yearly inflation rate (in percentage) and d is the nominal interest rate (in percentage). The interest rate is used to change concerning one time-costs in addition to annualized costs (Gangwar et al., 2015). It is otherwise called the discount rate. Since sustainable power source innovations, for example, Solar PV systems have high capital expenditure but operating and maintenance costs are low, and the system must be balanced COE analysis based on lifetime to simplify the economic evaluation of independent systems provided by solar photovoltaic systems. On the other hand, fuel costs for fossil-fuel-based power generation systems, generator maintenance, and replacement costs have lower capital expenditures, but higher operating and maintenance costs compared to currently projected sustainable power innovations. In this way, LCOE analysis can be used to analyze the economic viability of different technical solutions in terms of cost feasibility.

3.8 Simulation Using HOMER Software

National Renewable Electricity Lab created the hybrid optimization models for electrical renewables (HOMER) as a simulation program (NREL). This program is utilized for the size, optimization, techno-economic, and environmental study of renewable energy sources. It is capable of doing modeling, optimization, and sensitivity analysis of hybrid energy systems, and can be used to analyze both grid-connected and off-grid distributed generating systems. It may analyze both the economic and technical elements of energy systems. Throughout the simulation process, the entire system is modeled, and HOMER assesses the lifetime and technical viability of the system. In the optimization phase, HOMER simulates numerous configurations until a solution with the lowest NPC and COE is determined. Lastly, during the sensitivity's evaluation, many optimizations are conducted utilizing a variety of input variable ranges to examine the impact of a parameter change on the selected configuration. The HOMER entry data consists of component pricing and sizes, demand profile, climatic data, and economic limitations.

Based on the input parameters, the HOMER program calculates system cost, component size, and other economic factors.(Wuerttemberg, 2014). The modeling process is done every hour over the project's lifespan whereby the technical feasibility of a system and whether the demand can be fulfilled is first determined. Consequently, the cost of installing and operating the system over its lifetime is estimated (Semaoui et al., 2013). Figure 34. Illustrates the relationship between simulation, optimization, and sensitivity analysis. The optimization oval encloses the simulation oval to represent the fact that a single optimization consists of multiple simulations. Similarly, the sensitivity analysis oval encompasses the optimization oval because a single sensitivity analysis consists of multiple optimizations (Ermias Benti, 2017).

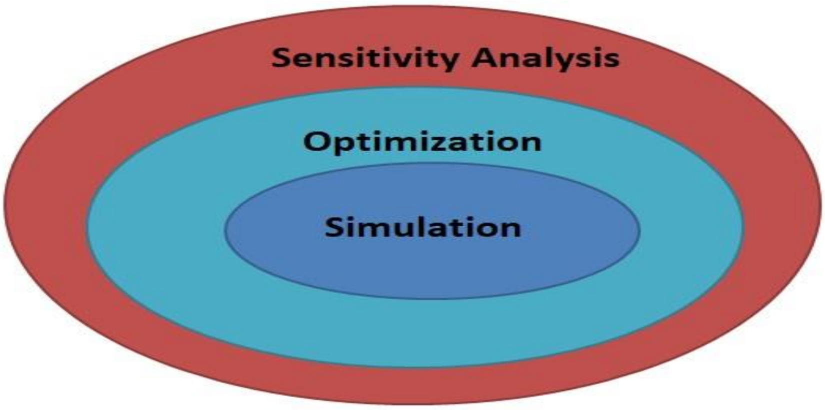


Figure 34 :Relationship b/w simulation, optimization, and sensitivity analysis (Semaoui et al., 2013)

3.9 Summary

As a review for Chapter 3, this section explains briefly every strategy being used to create a solar house system in the Banadir region. This project's approach includes an explanation of the research studied zone, choice of Solar designs and photo-voltaic module, site selection and project area, collection of data, design calculation of solar home system, and parameter setup for HOMER simulation. This initiative examined rural and urban regions in the Banadir region. It is anticipated that the PV system will be implemented utilizing a building integrated photovoltaic system, which will mount or install the PV module on the building frame. The PV module will be put on the roof of the selected single-family residence in the Banadir region districts. Using the Google Maps website, the area of the house's roof is determined. Then, one or two PV modules with varying rated power are utilized in this study to compare the cost and total power that each type of PV module can provide. The connection and power flow for each component of the PV system are depicted using a single-line diagram of the PV system's architecture. Lastly, the designed PV system is simulated using the HOMER program for system performance and economic analysis by entering all relevant data on the HOMER software's input parameter.

Chapter 4

RESULT ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter will focus on the study and debate of the project-related findings from the Homer simulation. It also contains some discussion about the project. The primary goal of this research is to produce a stand-alone photovoltaic system that contributes to the most cost-effective and accessible PV system. The total net present value (NPC), the previously mentioned Leveled cost of energy (LCOE), and operational expenses are the three components of the simulation result that are essential for defining the ideal PV system, which is a system that can generate electricity at a reduced cost.

4.2 Design Model of Solar Home System

The photovoltaic power generation plant intended for residential use purpose has been selected with HOMER software to obtain the simulation results. HOMER has several components built-in mathematical model such as a solar array and the battery is auxiliary equipment. HOMER software has two design options, such as preliminary design and project design.

4.2.1 Preliminary Design

Grid connection systems, stand-alone and pumping, and many others can be designed for these types of systems. This is used to get the user's main idea. There are three steps to designing the system, such as installation, location and system size (PV module type, technology used). HOMER then displays the results of the system to the user. The project his section will consider the requirements of electric housing for participating in the project.

4.2.2 Project System Design

This is more complicated than the preliminary design. There are several options for defining parameters for designing various types of system projects, such as grid connections, stand-alone, DC grid connections, pumping, and more. To design this type of system, this section performs various procedures such as position, range, and system size settings. There are many components, such as modules that display multiple modules in series, parallel, etc., battery storage, battery size selection, size adjustment array, etc., to build the system. After the simulation, the user gets the simulation results. It was developed using the HOMER software.

4.2.3 Solar home system calculation using Excel

Solar home system was designed and calculated using excel before using HOMER SOFTWARE. Number of photo-voltaic panels was founded by using Demand of energy/ (sun-hours*PV efficiency), then the invertor size was calculated by multiplying system capacity and reserve demand power which is 50% for our case. Therefore, the selected invertor capacity for this household is 3Kw to use for future system expansion without the need to replace the invertor.

Table 5: Solar home system calculation using Excel

SOLAR PANEL CALCULATION	
Daily Energy demand (wh)	3207
Peak Sun Hours in somalia	4.5
System Capacity (Wp)	1710.4
Selected PV panel power in w	300
No of panels	10
Invertor design	
Invertor power in KW	2565.6
Invertor Efficiency	96%
Battery Sizing	
Daily Energy demand in (wh)	3207
Days of Autonomy	2
Maximum Depth of Discharge	50%
Normal Batery voltage	12
Daily Amps-Hours needed(A-H)	1113.5
Selected battery Amps	250
No of bateries	4

4.3 Physical Calculation on Battery Sizing

To determine the type of battery and PV module that we require, we must first calculate the battery's size based on the technique. Deep-cycle batteries were given as the battery type recommended for use in solar PV systems. Rapid charging occurs daily for years on deep cycle batteries. The battery needs to be large enough to store enough energy to run the appliances during the evenings and overcast days. The calculation based on equation (3.1) revealed that four batteries with a capacity of 209 Ah each are required to meet the battery capacity needs.

During the calculation was used the following parameters to calculate; 0.8 is the loss value when the battery loss is 20%, and 0.8 is the value when the battery discharge depth (DOD) is 80%. Autonomous Day. The number of automatic days refers to the number of days required to operate the system when the photovoltaic panel does not generate electricity The essential battery factors that influence the functionality and performance of an electrical phenomena system are the battery conservation requirements, the battery's operational lifetime, the amount of available energy, and the battery's capacity.

4.4 Sizing of Photovoltaic Modules

Typically, modern solar panels produce peak power between 50W, to 440 kW (e.g., LONGI Solar 300 WP DC) under controlled conditions. This is called the ‘rated capacity or 'rated output' and it depends on the panel size and efficiency. There are a lot of solar calculators that your chosen solar system brand might offer. Still, there is a basic formula for determining the kWh of electricity (kWh) generated by the photovoltaic panel installation. The average amount of sunny hours in Banadir is 4 to 6 hours. Converting electricity from the sun to DC power and converting DC power to DC or AC power is lost. The ratio of AC to DC is called the "derating factor" and is usually about 0.8. This means that approximately 80% of the DC power is converted to DC or AC. This situation is better than ever, but the loss is predictable. Referred to equation (3.2), the physical calculation of the PV panel capacity after calculation was founded that the module Photovoltaic capacity needed in this proposed system is 300w.

4.5 Simulation Parameters on Solar Home System

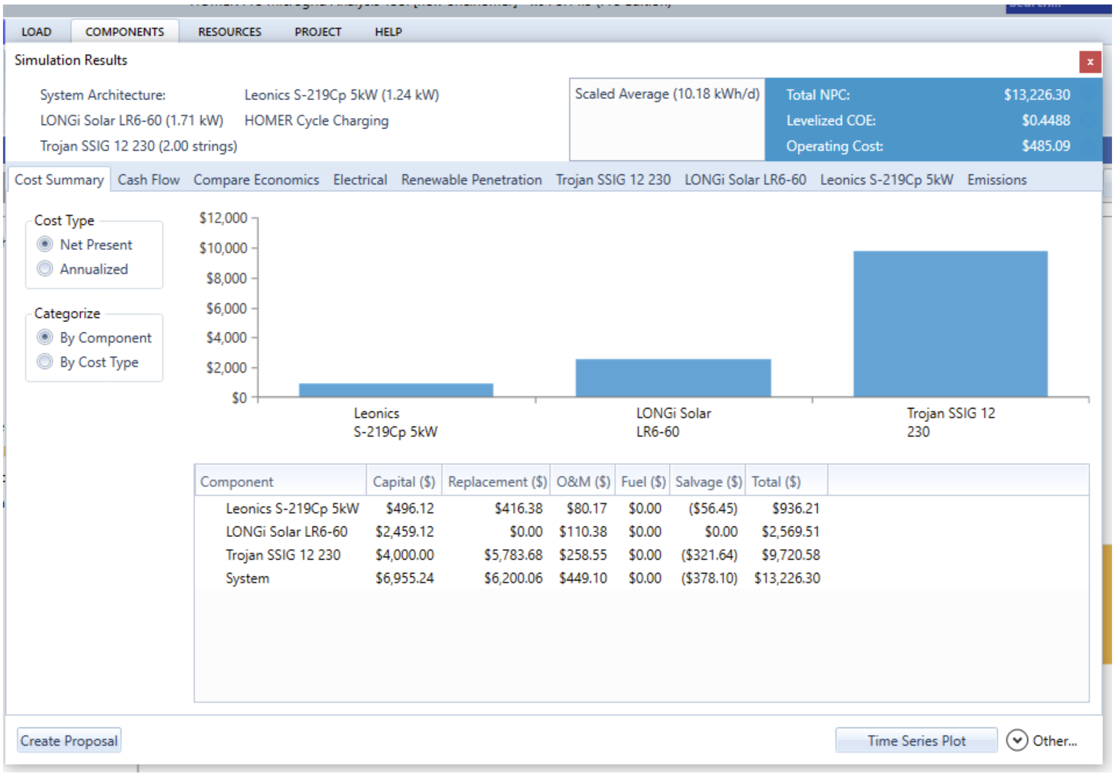
First, it conducted a preliminary design to obtain the main knowledge and then designed a home solar housing system. Currently, the project's location, direction, and horizon have been defined. Somalia was chosen as a good place. The latitude and longitude of the Banadir region are particularly popular throughout Somalia. Since the development of photovoltaic systems is critical, you can choose modules and batteries, define monthly energy rates, and declare the power required for production. The structure is specified in Table 6.

Table 6: The model considerations for a solar home system

Simulation-parameters	Depiction
Collector-plane-orientation	Tilt-: -10 degree
-Horizon-	Free horizon
PV-module	LONG Solar LR6-60
Total No. of modules	10 modules
System parameter	System type: Solar home system
Battery	Trojan SSIG 12 230 Voltage, Amper:209Ah
Total No. of Battery	4 (In two string)

4.6 Simulation Results Based on the Design

With the help of the HOMER software, the analysis was improved by the size of the PV system, especially for systems with a capacity of 1.71 kW, as it is more economical and does not interfere with accessibility. Figure 35 shows the results obtained from different sized solar PV systems, summarizing the cost of the entire system based on current net cost (NPC) and similar cells with a single solar cell. Banadir home solar system for AC load based on performance analysis. The capacity and maximum size are 1.71Kw. The battery is specified, after which it requires the nominal voltage and current capacity of the Banadir solar home system convention.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Leonics S-219Cp 5kW	$496.12	$416.38	$80.17	$0.00	($56.45)	$936.21
LONGi Solar LR6-60	$2,459.12	$0.00	$110.38	$0.00	$0.00	$2,569.51
Trojan SSIG 12 230	$4,000.00	$5,783.68	$258.55	$0.00	($321.64)	$9,720.58
System	$6,955.24	$6,200.06	$449.10	$0.00	($378.10)	$13,226.30

Figure 35: Simulation results based on CS and NPC by component

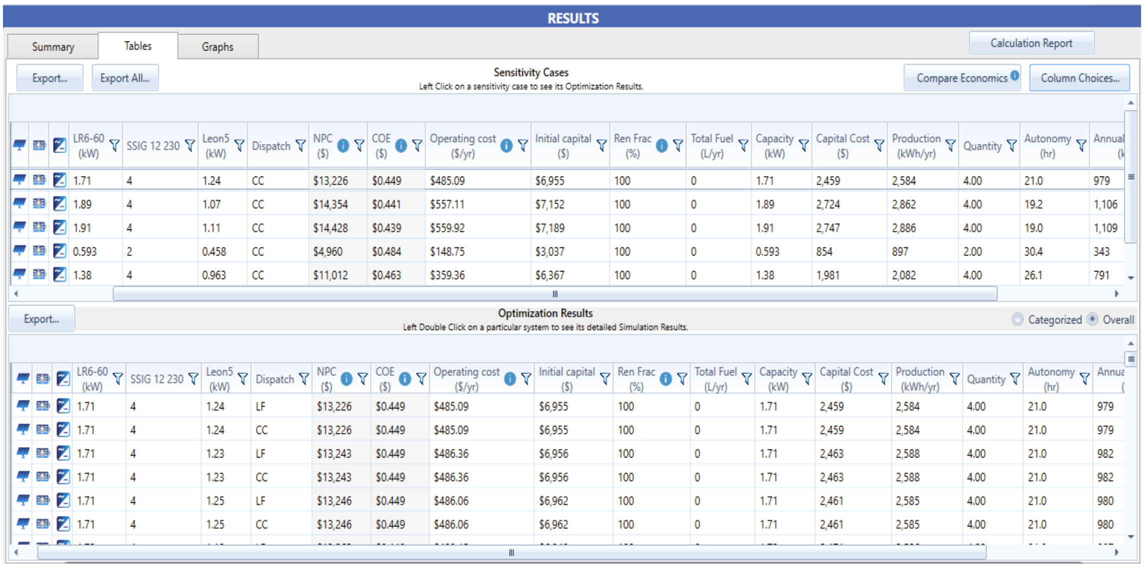
The Figure 35, the PV system screening has been selected 1.71 kW capacity and a battery taking a string battery is referred to as a Trojan SSIG 12 230. The net cash cost calculated by Homer is equal to $13,226.30, and the average energy cost LCOE and operating value are $0.4488 per kWh and $485.09 per year. These costs are calculated by soft the ware and are long-term costs but after discounts. The estimated cost becomes the recommended cost. The resulting system architecture is based solely on detailed simulation results of cash flow summaries and NPC classifications, considering funding, replacement, remediation, operations, and, maintenance costs.

4.6.1 Overall Optimization Analysis from Homer Software

The photovoltaic dwelling technology has been premeditated for a representative single dwelling in the Banadir region and is composed of 1.71 kW of photovoltaic generation capacity and 209 Ah of battery system having an average voltage of 12 volts Because the rated capability is equivalent to 2.508 kWh, this means that if the radiation intensity at the selected location is low, the storage system used can deliver energy for two days at different loads in the home.

The optimization results are shown in Table 7.

Table 7: Overall optimization result without capacity shortage



RESULTS

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Sensitivity Cases

Left Click on a sensitivity case to see its Optimization Results.

LR6-60 (kW)	SSIG 12 230	Leon5 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Capacity (kW)	Capital Cost ($)	Production (kWh/yr)	Quantity	Autonomy (hr)	Annual
1.71	4	1.24	CC	$13,226	$0.449	$485.09	$6,955	100	0	1.71	2,459	2,584	4.00	21.0	979
1.89	4	1.07	CC	$14,354	$0.441	$557.11	$7,152	100	0	1.89	2,724	2,862	4.00	19.2	1,106
1.91	4	1.11	CC	$14,428	$0.439	$559.92	$7,189	100	0	1.91	2,747	2,886	4.00	19.0	1,109
0.593	2	0.458	CC	$4,960	$0.484	$148.75	$3,037	100	0	0.593	854	897	2.00	30.4	343
1.38	4	0.963	CC	$11,012	$0.463	$359.36	$6,367	100	0	1.38	1,981	2,082	4.00	26.1	791

Export...

Optimization Results

Left Double Click on a particular system to see its detailed Simulation Results.

Categorized | Overall

LR6-60 (kW)	SSIG 12 230	Leon5 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Capacity (kW)	Capital Cost ($)	Production (kWh/yr)	Quantity	Autonomy (hr)	Annual
1.71	4	1.24	LF	$13,226	$0.449	$485.09	$6,955	100	0	1.71	2,459	2,584	4.00	21.0	979
1.71	4	1.24	CC	$13,226	$0.449	$485.09	$6,955	100	0	1.71	2,459	2,584	4.00	21.0	979
1.71	4	1.23	LF	$13,243	$0.449	$486.36	$6,956	100	0	1.71	2,463	2,588	4.00	21.0	982
1.71	4	1.23	CC	$13,243	$0.449	$486.36	$6,956	100	0	1.71	2,463	2,588	4.00	21.0	982
1.71	4	1.25	LF	$13,246	$0.449	$486.06	$6,962	100	0	1.71	2,461	2,585	4.00	21.0	980
1.71	4	1.25	CC	$13,246	$0.449	$486.06	$6,962	100	0	1.71	2,461	2,585	4.00	21.0	980

The HOMER optimizations outcomes for the screen screenshots in table 6 show a summary of the results for the numerous size PV systems used in the simulation. No scarcity. This includes initiating the capital, annual operating costs, total net present value, insufficient capacity per system, clarification of the renewable parts of system availability, and supply reliability from small to large scale including improvements. The optimal configuration of the system selected by the project case study of this project is that the photovoltaic power generation system has a scale of 1.71 kW, the power supply and the power supply planning method will depend on the load demand.

The optimization results are shown in Table 8 based on the overall optimization results with the capacity shortage.

Table 8: Overall optimization results with capacity shortage

RESULTS

Summary | Tables | Graphs | Calculation Report

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Sensitivity Cases
Left Click on a sensitivity case to see its Optimization Results.

LR6-60 (kW)	SSIG 12 230	Leon5 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Cap Short (%)	Cap Short (kWh/yr)	Capacity (kW)	Capital Cost ($)	Production (kWh/yr)
1.71	4	1.24	CC	$13,226	$0.449	$485.09	$6,955	100	0	50.0	1,859	1.71	2,459	2,584
1.89	4	1.07	CC	$14,354	$0.441	$557.11	$7,152	100	0	49.7	2,018	1.89	2,724	2,862
1.91	4	1.11	CC	$14,428	$0.439	$559.92	$7,189	100	0	50.0	2,055	1.91	2,747	2,886
0.593	2	0.458	CC	$4,960	$0.484	$148.75	$3,037	100	0	49.4	633	0.593	854	897
1.38	4	0.963	CC	$11,012	$0.463	$359.36	$6,367	100	0	50.0	1,494	1.38	1,981	2,082

Export...

Optimization Results
Left Double Click on a particular system to see its detailed Simulation Results.

Categorized | Overall

LR6-60 (kW)	SSIG 12 230	Leon5 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Cap Short (%)	Cap Short (kWh/yr)	Capacity (kW)	Capital Cost ($)	Production (kWh/yr)
1.71	4	1.24	LF	$13,226	$0.449	$485.09	$6,955	100	0	50.0	1,859	1.71	2,459	2,584
1.71	4	1.24	CC	$13,226	$0.449	$485.09	$6,955	100	0	50.0	1,859	1.71	2,459	2,584
1.71	4	1.23	LF	$13,243	$0.449	$486.36	$6,956	100	0	49.9	1,856	1.71	2,463	2,588
1.71	4	1.23	CC	$13,243	$0.449	$486.36	$6,956	100	0	49.9	1,856	1.71	2,463	2,588
1.71	4	1.25	LF	$13,246	$0.449	$486.06	$6,962	100	0	50.0	1,857	1.71	2,461	2,585
1.71	4	1.25	CC	$13,246	$0.449	$486.06	$6,962	100	0	50.0	1,857	1.71	2,461	2,585

Table 8 shows the results of optimization considering a 50% shortage of maximum capacity which is a 100% portion that can be a renewable fraction. The energy cost of the solar home system is 1.71 KW, which is $ 0.449 / kWh. A solar home system of 0.593 kW has an energy cost of $ 0.4484 / kWh. Therefore, it is more cost-effective to use a 1.71 kW solar power generation system instead of using more than two 0.593 kW systems.

4.6.2 Sensitivity Analysis

The period of calculation and analysis with the help of HOMER software is considered to be without limitless and regenerative fractions as well. The best technology sizing for a domestic solar power plant that is fully planned to sustain HOMER is an initial capital cost of $6,955 and an operating cost of $486.09 per year. The sensitivity findings are displayed in Table 9 depending on the absence of a capacity deficit.

Table 9: Sensitivity analysis without shortage

RESULTS

Summary | Tables | Graphs | Calculation Report

Export... | Export All... | **Sensitivity Cases** Left Click on a sensitivity case to see its Optimization Results. | Compare Economics | Column Choices...

Sensitivity	Architecture				Cost				System		LR6-60			
Electric Load #1 Scaled Average (kWh/d)	LR6-60 (kW)	SSIG 12 230	Leon5 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Capacity (kW)	Capital Cost ($)	Production (kWh/yr)	Quantity
10.2	1.71	4	1.24	CC	$13,226	$0.449	$485.09	$6,955	100	0	1.71	2,459	2,584	4.00
11.1	1.89	4	1.07	CC	$14,354	$0.441	$557.11	$7,152	100	0	1.89	2,724	2,862	4.00
11.3	1.91	4	1.11	CC	$14,428	$0.439	$559.92	$7,189	100	0	1.91	2,747	2,886	4.00
3.51	0.593	2	0.458	CC	$4,960	$0.484	$148.75	$3,037	100	0	0.593	854	897	2.00
8.19	1.38	4	0.963	CC	$11,012	$0.463	$359.36	$6,367	100	0	1.38	1,981	2,082	4.00
9.18	1.55	4	0.973	CC	$12,112	$0.454	$424.99	$6,618	100	0	1.55	2,228	2,341	4.00

The sensitivity results are shown in Table 10 based on the sensitivity analysis with the capacity shortage.

Table 10: Sensitivity analysis with a shortage

RESULTS

Summary | Tables | Graphs | Calculation Report

Export... | Export All... | **Sensitivity Cases** Left Click on a sensitivity case to see its Optimization Results. | Compare Economics | Column Choices...

Sensitivity	Architecture				Cost				System				Compare Econor	
Electric Load #1 Scaled Average (kWh/d)	LR6-60 (kW)	SSIG 12 230	Leon5 (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Cap Short (%)	Cap Short (kWh/yr)	IRR (%)	Simple Paybac (yr)
10.2	1.71	4	1.24	CC	$13,226	$0.449	$485.09	$6,955	100	0	50.0	1,859		
11.1	1.89	4	1.07	CC	$14,354	$0.441	$557.11	$7,152	100	0	49.7	2,018		
11.3	1.91	4	1.11	CC	$14,428	$0.439	$559.92	$7,189	100	0	50.0	2,055		
3.51	0.593	2	0.458	CC	$4,960	$0.484	$148.75	$3,037	100	0	49.4	633		
8.19	1.38	4	0.963	CC	$11,012	$0.463	$359.36	$6,367	100	0	50.0	1,494		
9.18	1.55	4	0.973	CC	$12,112	$0.454	$424.99	$6,618	100	0	50.1	1,679		

Figure 36: shows the Levelized cost of energy and Photovoltaic array capacity with a set of renewable fractions of 100%.

Figure 36: LCOE vs. PV array capacity with a set RF of 100%

As illustrated in Figure 36, the blue lines represent the horizontal energy costs and the red lines indicate that the capacity of the Photo - voltaic arrays are related to the lack of highest point capacities of the system. Considering the case where the highest point capacities deficit rate is 50 percent and the value of the renewable fraction (RF) is 100% if the capacity is lower than 40%, the energy balance cost and solar capacity over 40% will be reversed. Therefore, the optimal size for SHS determined through HOMER was 0.593kW obtainable and the Initial capital cost is $3,037, operating costs are $148.75 per year and total net present value is $4960, and the cost of energy (COE) is $0.484/kWh, as revealed in Table 10. This specifies that the dependability of the source is founded on the maximum-capacity shortages and the lowest regenerative share of the system.

Figure 37: displays the graphical sensitivity result determined with the help of Homer based on the leveled cost of energy.

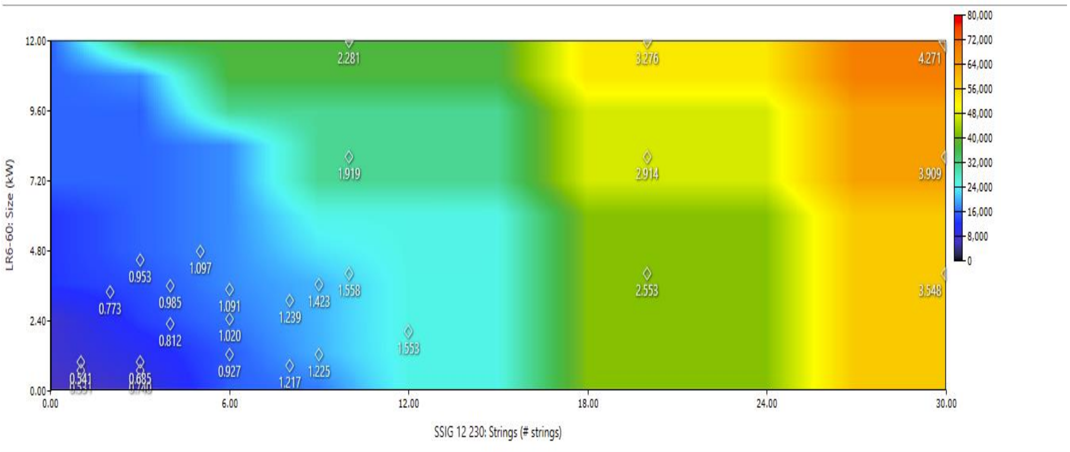

Figure 37: Graphical sensitivity result based on LCOE

The Levelized Cost of Energy, which is defined as the price per kWh of electrical energy used throughout the Photovoltaic System's lifetime, was used to get the graphical sensitivity result in Figure 37. The 25-year lifespan and all relevant costs, including the initial investment, ongoing operations, and maintenance expenditures, were taken into account while doing the LCOE study. The formula below can be used to determine the average COE of the electricity produced by a solar power-producing system.

$$LCOE = \frac{Total\ Annualized\ Cost\ \frac{\$}{year}}{Total\ Energy\ Consumed\ (\frac{KWh}{year})} \tag{4.1}$$

Where, LCOE: Levelized cost of energy

4.6.3 Discussion Based on Optimization and Sensitivity Analysis

During the debate, the design phases were based on the SHS of a typical family in the Banadir region. The single-family home may be found in a normal family's area and commercial location and also Most of the people cannot access electricity from the grid because Somalia still does not have a national grid-connected, since 1991, once the civil conflict began, Somalia has not had a powered grids connection, until and, only the commercial services industry has been operating; they charge as much as they like for power. As a result, the majority of the population does not have access to the local electrical system. While Somalia receives a huge of sunshine with average annual solar radiation of 5.7 kWh/m^2/day. Moreover, Somalia is one of the sunniest areas in the Horn of Africa region of the eastern Banadir province, because it is average temperature is high, at temperatures above 29 ° C, the region has the lowest precipitation in the country, and the average is less than 429 mm per year."

Therefore, in selecting the Banadir region as an interesting place to conduct this research, the above factors have been considered, using solar photovoltaic technology as a renewable energy source. Since Somalia is located near the equator, the Banadir region is not exaggerated by seasonal changes, and the days it does not change length significantly, so the daily load is assumed throughout the year. so the system size is chosen to be higher than the load peak. As a comparison to optimization and sensitivity analysis, the whole system used consisted of a photovoltaic panel of 300 W but was focusing on the best solution refereed to the objectives of the project. The battery consists of the Trojan SSIG 12 230 with a rated capacity of 209 Ah and 12 V. In this system, the Homer environment calculates a maximum annual capacity shortage of 50% and a renewable portion of 100%. Further analysis to determine system efficiency based on several PV sizes of the Banadir solar home system alternating from 593W to 1710 W and solar radiation ability to ensure the system reliability. the optimal system size for the domestic solar system premeditated complete for the assistance of HOMER was observed to equal to 593W to 1710 W respectively, in the 593 W of capacity with a capital initial cost of $3037, operating cost of $148.75 per year, the total net present cost of $4960 and the cost" of energy in $/kWh is 0.484, while the 1710 W of capacity with a capital initial cost of $6955, operating cost of $485.09 per year, the total net present of $13226 and the cost of energy in $/KWh is 0.449.

***Table 11**: Comparison of the results based on cost and size*

Description					
PV (KW)	Battery (6FM55D)	Initial Capital ($)	Operating Cost ($/Yrs.)	Total NPC	COE($/KWH)
0.593	4	$3037	$148.75	$4860	0.484
1.71	4	$6955	$485.09	$13226	0.449

By choosing a bigger system and cost-effectiveness solar PV systems provide the appropriate operating and maintenance systems for urban and rural communities, the system can be operated sustainably, saving costs. Furthermore, the result of the solar home system solution can only be implemented in remote and urban areas if environmental conditions, such as solar radiation, sunshine hours, and temperature requirements. In addition, the performance and efficiency of the PV system should also remain unchanged, but it is possible to move to design a larger solar home system and an off-grid system under heavy load."

The study was conducted to ensure optimal configuration which is considered a 1710W system in terms of size and cost. Banadir urban and rural electrified photovoltaic systems are designed to be fully charged and generated from photovoltaic power generation for so several hrs. Each the battery is filled and photovoltaic systems are producing electricity. To effectively regulate energy flow, an increase in the overall energy storage capacity can solve this issue (Bouzid et al., 2015). Rather than waiting for personal grid electricity, it is preferable to create a larger capacity stand-alone Photovoltaic system with a huge battery storage capacity to feed the entire urban and rural population. This is generally the greatest solution because of the expensive expense of extending the grids to urban and rural towns., with a distribution line of approximately $21.000 per kilometer, and Banadir domestic consumers currently have a private grid electric price in the range of $0.46 – 2 $/kWh. Therefore, the cost of energy consumption is confirmed that the cost of energy consumption is high compared to the alternative use of the photovoltaic system."

4.7 Cost Calculation of SHS

To introduce the proposed solar power generation system into the solar home system, a clear concept regarding the introduction of cost is required. Therefore, the approximate cost is calculated in US dollars. Table 12 shows all the components required to implement a solar home system. These components are solar modules, batteries, mounting structures, other, accessories, wiring, and more. Also need to consider commissioning, design, and installation. Compared with other Banadir region solar companies, the cost is basic. The calculated total cost is **6955** USD.

Table 12: Initial cost estimation after discount

Item #	Description	Qty	Unit price (USD)	Total (USD)	Discount.	Final price (USD)
1	LONGI Solar LR6-60 (200) Watts, mono-crystalline, 25 yr. (IEC), (UL) approved)	10	$140	$1400	7%	1302
1	Professional Deep Cycle Solar Batteries Trojan SSIG 12 230 209AH	4	$250	$1000	5%	950
2	MPPT charge control high-quality city heat sink charger Rated Current: 100A Rated Votage:48V/AUTO Maximum Battery Voltage: 48V Maximum PV Voltage: 150V	2	$100	$200	3%	194
5	Dc cable 1cx4sqm	100	$2.5	$250	2%	245
6	Ac cable 1cx6sqm, Cu	1	$35	$35	------------	35
7	PV Mounting structure for PV modules The original aluminum mounting structure for mounting the PV modules. For rooftop.	1	$400	$400	5%	380
8	Miscellaneous/Accessories	1	$250	$250	2%	245
	Total Cost of Material					$3,351
	Design, Installation & Commissioning	Lot				$3,604
Total						$6,955

4.8 Payback Cost Period

The Payback Period identifies the length of time it takes for a user of a solar home system to recoup their initial cost investment. With a payback period of 3 years and 9 months, the original investment in this solar home system project was expected to be $6955, yielding $1757 annually. The equation was cited (3.6). The cost gained each year as a return cost was based on the current electricity rate, per the Banadir Electric Company, a chosen power provider in the Banadir region, which was constructed on the given load profile that was discovered during data collecting (BECO). It is generally accepted that $1.5 is the base price for power per kilowatt-hour. It follows that the repayment time is 3 years and 9 months. With a payback period of $1757 dollars per year, is this suggested project's original cost and implementation costs regarded to be acceptable?

4.9 Summary

In summary, this chapter has done analysis and optimization on a single house in the Banadir area as well as design and sizing calculations for solar home systems. This study's analysis is separated into two main sections: sensitivity analysis and optimization analysis of Banadir, architecture and price calculations based on a selected single-family residence's energy consumption, and an examination of HOMER simulation findings.

According to the study and daily consumption of Somalia, it can be inferred from the analysis of a single house's annual electricity consumption and bill in the Banadir area that these costs are not too high. A solar house system is suggested for use in the Banadir area as a remedy for these issues. The photovoltaic dwelling technology is a Building Integrated PV (BIPV) system, which implies that the PV module will be installed on the roof of a single residence in the Banadir area the design of one, is a typical family home with ten PV systems was chosen. Based on the maximum valued Photovoltaic systems output & price, -reduction, the home utilizes 300 W Type B (monocrystalline) PV modules. The 1710Wp single-family home in Banadir has the best PV system design, with a 3-year, 9-month payback period anticipated for the system. The HOMER software is used to model and simulate solar household systems. The HOMER software simulates an SHS with a

300 WP rated power. The simulation's output demonstrates that the economic current value of the SHS equipment is marginal to the price of personal power before the first discount owing to the PV system's maintenance, installation, and module costs. However, depending on the bill from the private power cost, the SHS system has been able to successfully lower the higher electricity cost. According to this study, the reduction of the cost of electricity and the system within it have successfully decreased the electricity bill and saved more money. This is because Banadir's power usage of electricity is extremely low, even though electrical firms continue to charge for their services.

Chapter 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The main goal of this research is to build a renewable residential system with a 1.71 kW capability to obtain a cost-effective option for rural electricity in the district and urban areas of Somalia, which is comprised of a single family for this case study. The objective was achieved by taking into account the global horizontal irradiance at the chosen site as well as the primary load obtained from the survey, accompanied by a single-house analysis in daily hours taking into account the value of a private solar home system and the total cost for a single household system. In addition, a comprehensive examination of climatic data and renewable energy resource potential in the region was conducted in order to identify feasible solutions for the entire population.

Technique of aggregation climatic information and solar resource was useful in determining where this approach is most generally applicable. According to the results of the investigation, Banadir is a province with a high concentration of solar radiation and minimal precipitation, especially compared to other regions. Since we do not yet have a national electric grid, the use of photovoltaic technology for production and supply is a sustainable alternative for rural people without access to a private electric grid. Photovoltaic systems cannot be assured without the addition of an additional storage system. Consequently, it has been impossible for the PV panels to provide the necessary electric power during the previous few days, posing a significant challenge. Thus, solar household systems are tied to batteries. In addition, after selecting and characterizing the behavior of components suited for the system, the system models in the HOMER software and executes a system simulation to find the most cost-effective and dependable method for providing electricity anticipating loads in urban and rural regions. Both demand and consumption rise. Simulations indicate that it is more advantageous to utilize a 1.71 kW solar home system for single-family electrification, despite the fact that the initial capital expenditure is greater and less expensive than for the linked system. The energy cost per kilowatt-hour is $0.449. Therefore, the ideal choice in terms of cost and system size was a 1710W system that satisfies both rural and urban power demands.

According to the African Development Bank's study on the energy private sector evaluation and action plan (Sakarya & Of, 2018), Somalia's power costs around $0.46 - 2 per kilowatt-hour during the lifetime of the private network. In addition to being one of the most plentiful renewable energy resources available in Somalia, solar photovoltaic is an excellent option for power generation due to its low cost and contribution to energy independence.

Lastly, the above task research offers a basis as well as structure for the analysis of such a system not just in Banadir, but also in other regions of the country which the light shine is reasonably intense also, depending on the finding of simulated, a further process of generator including the wet seasons. Since SHS are limited to residential applications and supply availability is limited, the 1.71 kW single household system is selected as the most preferred option. The option for transmission line will be impacted by the development of load energy consumption and environmental change, and which will enable photovoltaic systems to sell electricity to the system in the event of Photovoltaic module overproduction and to acquire electricity from the network during the wet seasons.

5.2 Recommendations and Future Work

As a suggestion, it is envisaged that this project's study would contribute to the development of the future electrical distribution system and the development of humanity. Despite efforts to develop renewable energy resources, there is a lack of electricity generation and finance information on the mixture of solar PV, in the type of photovoltaic household technologies, and other electricity generation energy sources, such as solar home systems to provide a reliable and cost-effective system, according to the work presented. Since Somalia, and Banadir in particular, has a high potential for adopting solar production systems, it is also advised to investigate photovoltaic power generation in conjunction with other renewable resources.

The number of solar panels, battery, and charger controllers rating obtained from this experiment will be of great use to a single residence and any other community dwelling in the studied zone or a location with equivalent average irradiance. The purpose of the study was not to maximize the energy that may be captured by putting the panels in different orientations and tilt angles. This can substantially lower or increase the required amount of panels, battery, and charger controllers' ratings, and thus the cost. Therefore, it is suggested that further research be performed on this subject.

Different types of modules have varying rates of energy conversion. This investigation was conducted utilizing monocrystalline modules, which convert energy more efficiently than polycrystalline modules. It is consequently advised that more study be conducted utilizing polycrystalline modules, followed by a comparison of their performance and cost. Of the event of a breakdown in one or two renewable components, sensitivity analysis and system dependability must also be investigated more thoroughly. It is advised to undertake an economic comparison between simulation findings and real costs after implementation in order to confirm the simulation's correctness and to make subsequent decisions about urban and rural electrification. Lastly, it must acknowledge that each residence is unique and, as such, has distinct requirements. For instance, dwellings enclosed by trees have more time to use solar energy than those in the open air. To maintain the stability and long-term operation of this offered solar home system, the following recommendations must be followed:

i. The overload of the system should be avoided
ii. Shadow should be prevented.
iii. Battery packages as well as other system-related components must be properly positioned to maintain the system performance.
iv. The panel's tilt angel should remain unaltered.

- ❖ For further work it was proposing the following research updates;

i. Decreasing proposed budget
ii. Needed system cost payback analysis in terms the project life time
iii. Conduct solar irradiance assessments in live time.

iv. Identify in depth the architecture and market evaluation of photovoltaic systems in Somalia, particularly in rural and urban locations.

v. This should be investigated how to design and size a wind turbine system to meet the very same requirement.

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APPENDIX A

Appendix A: Electricity consumption in Somalia (billion kWh)

Year	billion kWh
2000	0.25
2001	0.24
2002	0.23
2003	0.23
2004	0.23
2005	0.22
2006	0.22
2007	0.25
2008	0.26
2009	0.26
2010	0.26
2011	0.26
2012	0.29
2013	0.29
2014	0.29
2017	0.3
2018	0.32
2000	0.25

APPENDIX B

APPENDIX B: Daily load evaluation for a single house in Banadir area

Energy Demand for Single home in Banadir, Somalia						
NO	**Equipment**	**Quantity**	**Power (w)**	**Total Power(W)**	**Hours/day (h)**	**Total wh/day**
1	Lamps	5	18	90	8	720
2	Cell phones	4	10	40	2	80
3	Laptops	2	65	130	1.5	195
4	Washing Machine	1	1700	1700	0.35	595
5	Iron	1	1400	1400	0.3	420
6	TV	1	41	41	7	287
7	Fan	2	55	110	5	550
8	Fridge	1	15	15	24	360
9	Water pumps	0	750	0	1	0
10	Air condition	0	1800	0	5	0
Total				**3526**		**3207**

APPENDIX C

Appendix C: Hourly power distribution per day for selected single house.

Hours	Load (Kw)
00:00-01:00	0.006
01:00-02:00	0.006
02:00-03:00	0.006
03:00-04:00	0.006
04:00-05:00	0.006
05:00-06:00	0.200
06:00-07:00	0.080
07:00-08:00	0.070
08:00-09:00	0.005
09:00-10:00	0.005
10:00-11:00	0.005
11:00-12:00	0.005
12:00-13:00	0.018
13:00-14:00	0.005
14:00-15:00	0.004
15:00-16:00	0.002
16:00-17:00	0.001
17:00-18:00	0.017
18:00-19:00	0.030
19:00-20:00	0.150
20:00-21:00	0.100
21:00-22:00	0.081
22:00-23:00	0.060
23:00-00:00	0.005