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DESIGNING OF AN OFF-GRID ELECTRIFICATION OPTION FOR RURAL AREAS USING HOMER SOFTWARE

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A project report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering Technology with Honours



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DECLARATION

I declare that this project report entitled "Designing Of An Off-Grid Electrification Option For Rural Areas Using Homer Software" is the result of my research except as cited in the references. Therefore, the project report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.



APPROVAL

I hereby declare that I have checked this project report, and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

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DEDICATION

This research is dedicated to my beloved parents and friends, who gave me moral support and motivation when this project was being done. I would also like to save to my supervisor, that helped me so much in this project when I faced trouble.



ABSTRACT

Off-grid electrification is the electricity supply without using public electricity and generates electricity. The rural area is far from the urban area, lacking clean water and electricity necessities. The geographic location makes it difficult for rural areas to connect with the grid electrification, and the cost is high if they want to connect to the grid. Thus, this has made the community of rural life an uncomfortable and inconvenient lifestyle. The diesel generator is not used in the off-grid system because the diesel is non-renewable energy and is not eco-friendly. Bahir Dar village, the rural area in Ethiopia, has renewable resources such as solar, wind, and biogas to provide the needed power demand without requiring the national grid is selected. This project assesses the potential and feasibility study on PV-Wind-Biogas hybrid system with the battery storage as the backup system is done to electrify the Bahir Dar village. In addition, electric load demands for the community are considered. The hybrid system optimized by Homer is cost-effective to give electrification support to the EKNIKAL MALAYSIA MELAKA village. The method used to do this project is through a lot of journal research, and then the load estimate is done by observing the daily activities of the villagers. Then, the selected place is simulated in the Homer Software. PV-Wind-Biogas with the battery is the optimization result for the Bahir Dar village with the (NPC) Net Presenting Cost of \$78,517, and the Cost of Energy is \$0.100.

ABSTRAK

Elektrifikasi luar grid ialah bekalan elektrik tanpa menggunakan elektrik awam dan menjana tenaga elektrik. Kawasan luar bandar sentiasa mengalami kekurangan air bersih dan keperluan arus elektrik. Lokasi geografi menyukarkan kawasan luar bandar untuk menyambung dengan elektrifikasi grid, dan kosnya tinggi jika mereka ingin menyambung ke grid.Justeru, ini telah menjadikan masyarakat di luar bandar menjalani gaya hidup yang tidak selesa dan menyusahkan. Penjana diesel tidak digunakan dalam sistem luar grid kerana diesel adalah tenaga tidak boleh diperbaharui dan tidak mesra alam. Kampung Bahir Dar, kawasan luar bandar di Ethiopia, telah dipilih kerana tempat itu mempunyai sumber boleh diperbaharui seperti solar, angin dan biogas untuk yang sesuai sebagai tenaga elektik untuk luar grid electrifikasi tanpa memerlukan grid nasional. Projek ini menilai potensi dan kajian kebolehlaksanaan sistem hibrid PV-Wind-Biogas dengan penyimpanan bateri sebagai sistem sandaran dilakukan untuk mengelektrikkan kampung Bahir Dar. Di samping itu, permintaan beban elektrik untuk masyarakat telah dipertimbangkan. Sistem hibrid yang dioptimumkan oleh Homer adalah kos efektif untuk memberi sokongan elektrifikasi kepada kampung tersebut. Kaedah yang digunakan untuk melakukan projek ini adalah membaca kajian jurnal, dan anggaran permintaan beban elektrik didapati dengan melalui pemerhatikan aktiviti harian penduduk kampung. Kemudian, tempat yang dipilih disimulasikan dalam Perisian Homer. PV-Wind-Biogas dengan bateri sistem adalah hasil pengoptimuman untuk kampung Bahir Dar dengan Kos Pembentangan Bersih (NPC) sebanyak \$78,517, dan Kos Tenaga ialah \$0.100.

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LIST OF SYMBOLS

α	- the ground surface friction coefficient
i	- real discount rate [%]
i'	- nominal discount rate (the rate which can borrow money)
f	- expected inflation rate
αp	- temperature coefficient power[%/ $^{\circ}$ C]
m	- meter
S	- speed
C	degree Celsius
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LIST OF ABBREVIATIONS

Z	- Height where wind speed is to be determined (m)
Zr	- Reference height
Zo	- Measure of surface roughness (0.1 to 0.25 for crop land)
V(Zr)	- Wind speed at the reference height (m/s)
V(Z)	- Wind speed at the height of Z (m/s)
\mathbf{V}_1	- Wind speed measured at the reference height h1(m/s)
V ₂ Y _{PV}	- Wind speed estimated at height (m/s)
f _{PV} G.t.	 P.V. derating power [%] solar radiation incident on the P array in the current time step kW/m²]
Tc	- P , V. cell temperature in the current time step [$^{\circ}$ C]
T.C.,STC	P.V. cell temperature under standard test condition [25 °]
NPC	- Net presenting cost
COE	- Cost of electricity
O&M	- Operating and maintenance
kWh	- Kilowatt-hour
M.W.	- Megawatt

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the globalized world, electricity has become one of the essential requirements in daily life. For example, light up the streets, charge the electronic application, generate a motor, and start a car. This has helped humankind in various activities and improved their daily life. However, some remote regions such as an island and rural areas of a country cannot connect to the transmission system for some reasons. For example, the geographic area required massive cost to install the system in that particular area. This is surveyed by the association of South-east Asian Nations ASEAN about 600 million people, of which around 55% live in rural areas [1]. The rural areas of Cambodia and Myanmar still have deficient access to electricity[2]. The statistics showed that only 31.1% of Cambodia's population and 32% of Myanmar's population have access to electricity. Thus, many parts of the rural area of Cambodia and Myanmar have very low or no electricity at all [3]; Myanmar is one of the lowest electrification rates in the world, with approximately 37% of its population and approximately 16% of the rural population access to electricity in 2016.

Therefore, off-grid electrification has overcome this problem to solve the lack of electricity in rural areas. The diesel generator generates electricity in rural areas or islands in the initial stage. For example, it has been stated that the Dongguan island in China, where no grid is connected to the island, so the residents were relying on the diesel generators to power their residential areas[4]. However, the diesel generator is non-

renewable energy, and the diesel generator is more expensive nowadays, which is not encouraged.

Therefore, the village replaces it with a small wind turbine, solar panel, and battery as their off-grid system with the diesel generator as the backup system. Besides that, the rural communities in Benin chose the mini-grid as their electricity supplier due to its cheaper cost and quick installation as more time is taken to wait for the grid extension project, which is costly and takes a long time for implementation[5].

Off-grid electrification encourages using renewable energy so that the energy produced is clean, renewable, and can bring the least pollutions to the environment. Moreover, there are more convenient and low costs than the diesel generator. The proof can be seen from the remote off-grid region at Ollague, Chile. The village had installed a solar battery diesel generator micro-grid with solar PV:205kWp (Thin Film modules), storage: 725kWh (Sodium Nickel Chloride tech), and wind turbine and battery diesel as backup power, and with this installation, this project has successfully reduced the consumption of fossil fuel and changed the habit of the inhabitants [4]. From the statement above, the structure of off-grid by using renewable energy has more benefits than non-renewable energy. The shortage of fossil fuels, environmental pollution, and high transportation costs should be considered; local renewable sources' penetration has attracted extensive global attention for electricity availability in rural areas[6]. Furthermore, off-grid installation nowadays is more affordable than in the past due to the rapid drops in technology costs which meant that off-grid renewable energy is now the cost-competitive choice for expanding electricity access in many electrified areas [7].

The favourable result of electricity and the development chances of the off-grid can be life-changing. The introduction of electricity into homes and communities makes the community safer and healthier and has expanded opportunities for education and productivity in the rural area of Peru[7]. This has shown that the high demand for off-grid electrification results in the installation of the off-grid more affordable and convenient and increases the countries' economy. Using renewable energy as off-grid electrification can use the local sources as the energy resources, such as in Pakistan, India. This country is considered the world's fourth-largest user of groundwater for agricultural purposes, causing a high electricity demand. Thus, using an off-grid system utilizing hybrid energy resources like solar and biomass can be the most productive solution for reliable electricity supply to rural areas[8]. Although there are convenient, low cost, and quick installation of off-grid, if there is no community cooperation and precise calculation before instalment, it will affect the life after the off-grid system. The problems that arise with access to energy stems from long-term political instability, shortage of financial means and knowledge, rural settlement, and energy location gap[9]. It can be solved using software and calculation as an estimated optimized result like Homer software, Matlab, etc. For example, in the rural place of Chamarajangar district, India, the investigator used Homer software to find an optimized result of the sources installed in the area. The result showed that the solar panels and a diesel generator are suitable for the site. At the same time, wind energy is not appropriate where the wind speed is only 2.82m/s is not enough to generate electricity[10]. The calculation through the software can save the cost and human energy, which the unneeded energy is not suitable to install. The Homer software pro is ideal for the global to design micro grid in all sectors by its simulation and optimize the cost and design where the engineering and economics can work together.

In conclusion, off-grid electrification in rural areas brings more benefits for the country itself and the community of the rural areas. It can boost the social economics of the countries and increase the community's productivity in that particular rural area. For example, in Pakistan, the biomass power system installed and operated by rice millers is

the long-lasting and economical option for rural electrification. The financially viable business model provides the grid quality power to the rural population without grant [11]. Moreover, renewable energy is used instead of non-renewable energy and brings environmentally friendly rural areas.

1.2 Problem Statement

A rural area is far from town and lacks many necessary facilities like clean water and electricity. The lack of these essential facilities has brought many obstacles for the community of rural areas to live. First and foremost, the rural area cannot access the electricity grid, causing the community to have more obstacles to living a comfortable life. For example, without electricity supply, there is no lamp, fan, heater, and other applications depend on electricity grids, the residence cannot do their daily life more efficiently and effectively.

Besides that, the unaffordable, unreliable, and unsustainable sources of electricity hamper economic development. For instance, some rural areas can be promoted as the travel region, such as jungle trekking, and build a hostel for some travel projects. However, without the electricity grid supply, the part cannot be developed and abandoned by the new generation residence because of too behind compared to the urban area. Therefore, rural electrification can play a prominent role in the social-economic growth of the community[10]. But, on the other hand, the lack of facilities and unemployment in remote rural areas can cause massive migration of rural population to the urban areas and create a slum crowd, which can be detrimental to the country's socio-economic growth.

The earth's geography also causes the rural area hard to access the grid electricity in the urban area or mainland. The rural area is in the inner jungle or mountain cause the transmission line cannot access the site. It needs more energy and sometimes may destroy the areas' habitat if forced to connect the electricity grid from the urban to the rural area.

Moreover, the rural area community lacks knowledge and experience to maintain the off-grid electrification, which the support, training did not provide to the staff by the distribution companies. Besides that, online tools need to develop to help utilities manage the off-grid system.

Last but not least, the grid connection from the urban area to the rural area requires high cost and takes time to install. For grid extension, many challenges are identified, such as long-distance from electricity grids, challenging terrain, and vast investment[5].

In conclusion, the grid connection faces many obstacles to accessing rural areas. Thus, off-grid electrification is more suitable for electricity supplies to the community of the rural areas.

1.3 Project Objective

1. To develop a load calculation model for the case study.

- To build off-grid electrification using clean energy and suitable in the particular rural areas.
- 3. To determine optimal sizing of each source's capacity, which provides an effective cost solution.

1.4 Scope of Project

The scope of research is made to design optimized off-grid electrification in a rural area. The Homer software uses to develop off-grid electrification by using renewable sources in Ethiopia's rural areas. Many types of research about the information and journal about the rural areas are done to understand this project completely. The place and the data of the resources can be defined in the Homer Pro software. Besides that, the Homer Software also has many renewable energy resources such as wind, solar, biomass, hydro, etc. This is very suitable for finding the optimized sources for the rural area. This makes the software more suitable for designing off-grid electrification, which economic and engineering work together. Lastly, the result will give the optimal sizing of generation capacity based on net presenting cost (NPC), cost of electricity (COE).

CHAPTER 2

LITERATURE REVIEW

2.1 Electrification around the world

Nowadays, electricity supply looks pretty general in this globalization and is necessary for our daily lives. It can be said that almost all the applications in the home, workplace need electricity to light up either in Dc or Ac supply. Electricity is a flow of electrical power of charge. The word of electricity is from the Latin word *electricus*, which refers to the attractive qualities of amber. It was then that Ben Franklin then defined as negative and positive. The history of electricity is the first where Benjamin Franklin's experiment "with a kite one stormy night in Philadelphia", the principles of electricity gradually became understood. Then, Thomas Edison helped change everyone's life: the light bulb and D.C.

After that, Nikola Tesla discovered the use of Alternating current (A.C.) electricity, which can be transmitted a longer distance than direct current (D.C.)[12]. Because of their inventions bring the impact of today brightness world. We can see through the SE4ALL Global Tracking Framework database led jointly by the world bank, International Energy Agency. The Energy Sector Management Assistance Program had shown the data from the 2016 year to the 2018 year where the access to electricity (% of the population) over the year increased from 87.936% to 89.57%. For the urban area, the percentage population of the metropolitan area increased from 2016 to 2017, and then it dropped a little bit in 2018. That is 96.951% in 2016 and grew to 97.294% in 2017 and dropped a little bit in 2018, 97.252%. The percentage of the rural population that access to electricity also shows the increase data from 2016 to 2018, wherein 2016 the rate was only 79.474% and increase to 82.011% in

2018. This can indicate that more rural areas can access electricity[13]. The urban area is like a city with a high and more modern population. The rural area is the place like an island or inside the mountain, etc. The statistic can prove that there still are sites that cannot access electricity. This may cause the population in that area to live the very behind life, and low productivity and efficiency. The problem that some these rural areas are unable to access electricity is that the cost needs to connect the transmission line from the urban area to the rural area is expensive and also face the challenge to construct transmission line where the geographic location of the rural area is far away from the mainland. Through the statistic of the percentage of the population in the urban area, almost all the people can access electricity; however, there still have poor communities that are unable to serve for some reason like poor.

The countries in the world are separated into two groups, developed countries, and developing countries. The developed countries describe an industrialized country with a highly developed economy, for example, the United States (U.S.), Canada, Australia, Austria, France, Germany, Italy, Japan, and the United Kingdom. In contrast, developing countries can be defined as non-industrialized such s India, China, and Southeast Asia. According to the statistic the electricity consumption worldwide in 2019, by select country, China is at the top of the rank that is 6880.1terawatt, followed by the United States, which is 4194.4 terawatt, and then is India 1309.4 terawatt [14] as can be seen in Figure 2.1. China is a developing country, and why there have high electricity consumption is because of their larger population. The United States has high consumption than India. However, the population size is smaller than India because the U.S. has high GDP per capita (gross domestic product), providing their average residents greater purchasing power. Countries with higher income residential tend to be more urbanized, causes to higher electricity consumption.

Figure 2.1 Electrical consumption in terawatt[15]

The sources of electricity worldwide have been separated into two groups using renewable energy or non-renewable energy to generate electricity. Examples of renewable energy are wind, solar, biomass, hydro, and other energy from the natural and unlimited. As stated by the Centre for climate and energy solutions, had indicated that renewables made up 26.2% of global electricity generation in 2018. That's expected to rise to 45% by 2040. Most of the growth will likely come from solar, wind, and hydropower[16]. Figure 2.2 below is the estimated part of Final Energy Consumption, 2017.

Figure 2.2 Estimated part of total Final Energy consumption[16]

The countries that have a higher proportion of renewable energy according to Smart Energy International, Germany has the highest rank of the percentage of renewable energy used that us 12.74% and followed by United Kingdom(U.K.) that is 11.95%[17]. Renewable energy sources have been used frequently in both countries to generate electricity compared to coal and nuclear power, as shown in Table 2.1.

Rank	Country	% of renewable energy used
1	Germany	12.74
2	UK	11.95
3	Sweden	10.96
4	Spain	10.17
5	Italy	8.8
6	Brazil	7.35
7	Japan	5.3
8	Turkey	5.25
9	Australia	4.75
10	USA	4.32

Table 2.1 Ranking of the countries that use renewable energy

Developed countries use renewable energy mainly because of their massive investment and government efforts.

2.2 Access electrification in rural areas

A rural area is a place were far from the city or town. The rural population refers to the people living in the rural area. According to the World Bank staff estimate based on the United Nation Population Division's World Urbanization Prospects, the highest rank of the rural population is located in India followed by China and Pakistan, and the lowest or can be said no rural population is located in Hong Kong SAR, Macau SAR, Singapore[18]. What are the rural people's faces in their daily life? One of the most common problems is the lack of electricity supply due to the geographic isolation and the massive cost and humankind sources needed to build the transmission line connected to the urban. Thus, standalone electrification or off-grid had been used to overcome one of the rural population's problems. Most off-grid electrification uses renewable energy instead of fossil fuel or diesel to the generator because of the expensive cost and not clean.

Renewable energy can be a good choice for electrification, which transportation of conventional energy resources like natural gas is quite hard. Typical transmission grid extension is also highly capital intensive due to uneven and challenging terrain[19]. The technology for using renewable energy as off-grid electrification is solar power, wind power, biomass, micro-hydropower, etc. Some small areas also used hybrid renewable systems such as solar-wind-diesel hybrid systems in India's rural location, Chamarajanagar District of Karnataka. They say a hybrid energy source creates at least two or more locally available sustainable energy source-based systems and a more cost-effective solution[20]. Solar power is the most common source as solar is the most accessible source and primarily used in Asia like rural areas in India, China, etc. Solar power is also operating in an ongrid system, and the solar system is tied to the local utility's grid. Solar power only generates electricity in the daytime. The utility grid supplies the machine if the system does not produce electricity to power the device like light, fan, etc. In contrast, off-grid electrification uses batteries when there is an electricity shortage. Figure 2.3 show the ongrid and off-grid by using the solar panel.

Figure 2.3 on-grid and off-grid using the solar panel[19].

Wind power as the source of off-grid and grid electrification can also be done because the area has a suitable topology for high speed. China is an example of a country using wind energy to generate electricity on-grid. The capacity holds 149 GW of wind power in 2016, developing 241TWh of electricity, contributing to around 4% of total national electricity consumption[21]. Wind power can also be used in off-grid electrification because the area has high wind speed suitable for electricity supplies. However, in an off-grid system, a wind turbine, solar panel, and the lead-acid battery are also called a hybrid system. This is because wind and solar resources are seasonal in some countries so that the combination can decrease the fluctuation in power output. In addition, the battery can work at an optimal charging level and therefore have a longer lifespan[22]. The hybrid power system that combines multiple resources to produce electricity, as shown in Figure 2.4.

Figure 2.4 Hybrid system[23].

The difference between grid electrification is that on-grid is fundamentally interconnection of various power systems elements such as synchronous machines, power transformers, transmission lines, transmission substations, distribution substations, and multiple loads. The on-grid buildings are located far from the power consumption area, and electric power is transferred through long transmission lines. In contrast, off-grid is a minor standalone power, and the supplier area is smaller than on-grid. The on-grid electrification generates electricity in a place far from the urban area, such as nuclear plants, hydropower by building a dam, etc. is then distributed to all the sites using a transmission line. For example, 440 nuclear reactors are operating in some thirty countries worldwide. One of the most significant plants in France, about 70 percent of total electricity generation was derived from nuclear sources in 2018[24]. The hydroelectric power plant in three Gorges, China, is the world's most giant hydropower plant, generating 22.5GW. The produced power is supplied to nine provinces and two cities, including Shanghai[25]. Therefore, the on-grid system is tricky and needs a massive place and humankind energy to install the system. In contrast, off-grid and the cost are much more expensive if the need to extend the transmission life to the remote regions seems not valuable to the country economy where the population in the rural area is much lower than the population in urban areas.

The solar home system (SHS) is a standalone photovoltaic (P.V.) system that can supply power for lighting and appliances, which already improves thousands of life in rural Peru, where the SHS used to meet domestic energy demand and satisfy basic electric needs[7]. This SHS system includes one or more P.V. modules containing solar cells a charge controller that distributes power and protects the batteries and appliances from damage. At least one battery to store energy for use when there is cloudy or no sun. In Pakistan, the microgrid is based on biogas, the gas from the biomass resources where the cow and buffalos eliminate, solar and hydropower used to generate electricity[11].

2.3 Off-grid electrification

Off-grid electrification is electrification which is no connection to the served by public electricity. Off-grid electricity can be generated variously by renewable or non-renewable energy. Off-grid electrification is being encouraged to use renewable energy as

the alternative energy source to generate electricity. Using renewables are solar, wind, biomass, mini-hydro power, and others that can be replaced and used again. The non-renewable is using fossil fuel, natural gas which the things using cannot be returned and will be ended up one day. Using renewable energy in off-grid electrification needs batteries as a backup system where renewable energy cannot generate electricity during some obstacles. For example, solar panel systems are the sources; when the day is cloudy without the sunlight or at night, the batteries will give the supplies to the load. If the solar panels generate extra electricity without using the supplies loads, it will charge the batteries. The system run is the same as another renewable source as the generator.

As the world still has a rural population, which means it is isolated from the town, it needs to be self-efficient in its electricity, water, etc. From a small house in a Californian wildlife reserve to a rural home in China motivates villagers to be self-sufficient. For example, in the USA, the off-grid guest house as shown in Figure 2.6, where this house is on a remote site in a Californian nature reserve and the power is produced by a photovoltaic system, with a propane generator (a type of liquefied petroleum gas(LPG), a fuel often choice to power the generator) as a backup. In the USA, Maui House in Hawaiian island Maui, the house is designed by LifeEdited developed this family resident as a model for long-lasting, off-grid living. It combines design and technology traits like solar panels and rainwater collection, and the house harvests more energy. Hill Country House, located in the USA, also uses an off-grid system where the geothermal system for heating and cooling and solar panels supply sixty-one percent of its yearly energy usage. In China, a house for all seasons was designed by John Lin as shown in Figure 2.5; this house adapted a traditional rural China courtyard house. Several courtyards are included behind the house's walls, accommodating a pig pen and biogas boiler that produces energy from animal waste. The roof is used to accumulate the rainwater. In Spain, a resident, which is too isolated to

be connected to an electrical grid and water supply, was designed a home in which the orientation of the building helps to produce a solar heat gain. At the same time, two nearby streams give hydroelectricity and clean water for drinking and bathing[26]. From the example, we can see that an off-grid system is vital for the rural population to sustain their daily life. The convenience of renewable energy as an alternative source to generate electricity is enough to cover up the daily usage.

Figure 2.6 The off-grid guest house, USA[26].

2.4 Renewable energy as electrification resources

As in the previous article, renewable energy is clean energy, naturally replenished on a human timescale. Renewable energy consists of solar, wind, tides, waves, geothermal heat, and biomass. In addition, they are using some equipment to transfer the energy to generate the electricity.

First and foremost, the solar panel generates electricity for the sun or solar as renewable energy. There are two types of solar: solar thermal and photovoltaic (P.V.) solar. Solar thermal is generally used for water heating. The panels on the rooftop are the collectors of the sunlight and then heating the tubes, transported into the cylinder and ready to use. The solar panel is divided into a few types: polycrystalline, monocrystalline, thin-film, and HIT (hybrid) solar panels. They absorb sunlight and transfer it into electricity. Hence, the focus is more on photovoltaic solar panels with the title. The basic configuration of the solar panel is like Figure 2.7.

Figure 2.7 Connection solar panel with on grid[27].

How does a solar panel work? Solar panels consist of several individual solar cells composed of silicon layers, phosphorous (provides negative charge), and boron (provides positive charge). The solar panel then absorbs the photons from sunlight, initiating an electric current. Therefore, the energy produced from photons striking the surface of the solar panel allows the electrons to be knocked out of their atomic orbits and released into the electric field generated by the solar cells, which then pull these free electrons into the directional current. Thus, the inverter is needed to convert the directional current into the alternating current in installing solar systems.

Knowing the solar panels' sequence requires some conditions to be aware of when installing the solar system. Firstly, solar irradiance G, the sun's measurement brightness, is directly proportional to the current, which means the highest the irradiance, the highest the current.

Figure 2.8 Irradiance over the wavelength[28]

According to Figure 2.8, the irradiance increases when the sun lights up and decreases in the evening. The second condition is temperature; it will affect voltage and drop when the temperature increases. Therefore, temperature control should be done wisely to optimize the solar panel's output. The action can be done to reduce the temperature, such as using water spraying of P.V. panels to decrease the temperature and

remove the dirt or dust from the solar panels, which will affect the output of the solar panels.

Third, the orientation of the solar panels needs to face during installation such as south-east, northwest, etc., by observing the solar panels can meet the sunlight more during the daytime. Shading is also one obstacle for solar panels to produce more output. When there are the obstacles such as a tree, building, clouds shade one of the solar panels, it will also decrease the output produces. Thus, the place needs to observe before installation so that the obstacles do not shade the solar panels or minimize the chance to shade.

Solar is the easiest way to get in many countries. Hence, it can be said one of the quickest growing energy sources in this global. The ten most significant solar power plant in the World is Tengger Desert Solar Park in China, which generate 1,547MW. The second is in the Sweihan Photovoltaic Independent Power Project, UEA, Abu Dhabi, producing 1,177MW. Next, Yanchi Ningxia Solar Park in China generate 1000MW, Datong Solar Power Top Runner Base, China, 1,070MW, Kurnool Ultra Mega Solar Park, India generate 1000MW, Longyangxia Dam Solar Park China, generate 850MW, Enel Villanueva PV Plant, Mexico cause 828MW, Kamuthi Solar Power Station in India develop 648MW, Solar Star Project in the U.S. generate 579MW and Topaz Solar farm or Desert Sunlight Solar farm generate 550MW[25].

Next, wind power is the system that converts wind energy into kinetic energy into electrical energy. Wind energy is also categorized as slight wind/ distributed wind and utility-scale wind. Small current or distributed wind refers to using wind energy on a small scale for domestics, agriculture, and community. The wind turbines with powers up to 100kW are used to supply the required power. This kind of wind turbine usually is not connected to the grid and is directly employed by the consumer. Utility-scale wind refers to wind energy in large-scale power generation applications. This kind of wind turbine has

sizes ranging from 100KW to megawatts. This kind of wind turbine-generated power is injected into the power grid to be distributed. Finally, offshore wind energy is where the giant wind turbine is installed in the offshore area. This wind energy is usually more significant than land-based wind turbines and can generally produce more power than its land-based counterparts.

Wind turbines are also separated into horizontal Axis Wind turbine (HWAT) and Vertical Axis Wind Turbine (VAWT). The HAWT is widely used in wind turbine installation due to its high efficiency and high power generation capability for the VAWT. The rotors rotate a shaft installed vertically, as shown in Figure 2.9.

Figure 2.9 Type of wind turbines[29].

The wind turbine works on a simple principle: the wind turns the turbine around the rotor, spins a generator, and produces electricity. First, the wind blows toward the turbine's rotor blades. Then, the rotors spin around has some kinetic energy from the wind and turn the central drive shaft. However, the outer edges of the rotor blades move very quickly, the main axle (drive shaft) connected to turns quite slowly. In most large modern turbines, the rotor blades can swivel on the hub at the front to meet the wind at the best angle for harvest energy (pitch control mechanism). Under accurate electronic control, small electric motor or hydraulic rams swivel the blades back and forth in large turbines. On small turbines, the pitch control is frequent entirely mechanical, but many turbines have fixed rotors and no pitch control. The inside of the main body of the turbine sits on the top of the tower, behind the blades (nacelle), and the gearbox converts the low-speed rotation into high-speed rotation. It is quick enough to drive the generator efficiency. Next, the generator promptly takes the kinetic energy from the spinning driveshaft and turns it into electrical power. Figure 2.10 explain how the wind turbines work.

Wind power is one of the quickest-growing renewable energy technologies because the cost is falling, and the usage is rising. According to the IRENA's latest data, worldwide, the wind generation capacity onshore and offshore has increased by the factor of 75% in the two past decades, jumping from 7.5 gigawatts (G.W.) in 1997 to 564GW by 2018[31]. As stated by Ns Energy, the top five countries with the highest wind energy capacity, the top 1 in China, generated 288.32 GW at the end of 2020. 278 of China is onshore wind, and 10GW is based on offshore. Next is in the United States generated 122.32 GW, which almost all is on the coast. In 2020, this county added 17GW of new

capacity. The third is located in Germany, which generated 62.85 GW, where 55GW is based on onshore and 7.7GW is offshore. The fourth is in India, which produces 38.63 GW, and all is onshore. The fifth is Spain which generates 27.24GW and is onshore infrastructure [31].

The hydropower Figure 2.11, the dam builds on a large river where the dam stores a lot of water behind it is a reservoir and then, the bottom of the dam wall is the water intake, the gravity causes the water to fall through the penstock inside the dame, causing the turbine moving—next, the turbine moving to cause the kinetic energy to generate electricity.

Therefore, the largest hydroelectric power generator is located in China, 1302

TWh, followed by Canada, 398 TWh, Brazil 386.TWh as Figure 2.12[34].

Figure 2.12 Statistic of hydropower generator[33].
Another example of renewable energy is biomass as fuel to generate electricity. Some materials that makeup biomass fuels are scrap lumber, forest debris, crops, manure, and some dissipate residues. Biomass power is carbon-neutral electricity produced from renewable organic waste, as shown in Figure 2.13. When burned, the energy in biomass releases heat and steam that turns the turbine to generate electricity or heat to the domestics. The world's largest biomass power plant, first located in the United Kingdom, Ironbridge, has 740MW and the biomass plant is wood pellets. Second is in Finland, Alholmenskraft, 265MW is generated. It also provides 100MW of heat to the paper mill and 60MW of district heat for the citizens of Jakobstad[34].



Figure 2.13 Biomass energy[35]

Wave energy is the energy from the ocean as shown in Figure 2.14. The ocean waves' power is free to last longer, renewables, and produces zero waste. The harvesting of wave energy is then generating electricity. The most common technologies for harvest wave energy use buoys or float systems that rely on swells' rise and fall to drive hydraulic pumps. During the movement of the waves, the buoys flex and bend as waves pass, producing a sign in the wave energy converter, then the machine that transforms kinetic energy into electricity. Besides that, there are also oscillating water column devices

equipped with vertical pistons that use buoyancy and gravity to generate energy. Finally, the trapped channel is a shore-mounted structure that channels and concentrates swells into an elevated reservoir where the hydropower device turns the pressure into electricity.



Figure 2.14 Wave energy[36].

For tidal energy, this energy has used the power from the tides. The high tides and low tides are caused by the moon, where the moon's gravitational pull generates tidal force. The tidal energy results in the earth and its water bulging out on the side closest to the moon and the side farthest from the moon. This causes the tides' flow to convert kinetic energy into electrical energy as shown in Figure 2.15.



Figure 2.15 How tides form[37].

The tidal energy work via a turbine such as the wind turbine, with blades rotating 12 to 18 times a minute depending on tide strength as shown in Figure 2.16. The turbines are then connected to the gearbox that turns a generator, producing electricity.



Figure 2.16 Tide energy[38].

Another type of tidal energy system is the tidal energy system that uses a similar dam called barrage. The barrage is installed across an ocean bay or lagoon in an inlet that forms a tidal basin. Then, the storm controls water levels and flow rates to let the tidal basin fill on the incoming high tides and empty through an electricity turbine system on the outgoing ebb tide. This two-way tidal power system generates electricity from both the incoming and outgoing waves.



Barrage of the tidal power plant on the estuary of the Rance River in Bretagne, France

Figure 2.17 Tidal barrage[39]

The country that installed the tidal power and has the highest power capacity in South Korea with 511MW, followed by France. With 245MW and the United Kingdom with 139MW. Canada ranks fourth in the world with a total capacity of approximately 40MW[40]. However, tidal and wave energy has not been fully explored because converting the point is not as simple as solar and wind. Besides that, the installation cost is high, complicated maintenance and repair logistic causing not popular as solar and wind.

Geothermal energy is also one of the alternative energy for electrification globally. Geothermal energy is the heat derived within the sub-surface of the earth where the water or stream carries the geothermal energy to the earth's surface. Due to its characteristics, geothermal energy can be used for heating or cooling purposes or harnessed to produce clean electricity. The geothermal power plant works in 3 types: dry stream power plant in Figure 2.18, Flash steam power plant, and binary cycle power plant. The dry steam power plant directly takes the stream from the geothermal reservoir to rotate the turbine and generator to generate electricity. The temperature needed is at least 150 °C.



Figure 2.18 Dry system geothermal power plant [41].

The flash steam power plant used high-pressure hot water deep inside the earth and collected it in a steam separator, as shown in Figure 2.19. The high-pressure hot water comes to the surface on its own, and its pressure keeps on reducing as it moves upwards to allow the hot water to change into the stream. In-stream separator, the steam is separated and allowed to rotate the turbine generator. When the steams cools, it is then injected back into the earth surface to be used again. The temperature requires $180 \,$ °C.



Figure 2.19 Flash Steam Geothermal plant[41].

The third type is a binary cycle power plant in which the heat of hot water is transferred to another liquid (secondary liquid) in Figure 2.20. The heat of hot water then results in another liquid changing into the stream, and the stream is used to turn the turbine. The secondary liquid has a lower boiling point than water, and the lowest temperature for the heat is at least 57 C.



Figure 2.20 Binary Cycle Geothermal Power plant[41] 34

The world's ten most giant geothermal plant is the Geysers geothermal complex, the USA, where 18 power plants are made up and an operational production capacity of 900MW. The second is in the Larderello geothermal complex, Italy, which comprises 34 plants, and the net total of the geothermal facility is 769MW. The Cerro Prieto geothermal power station, Mexico with an output capacity of 720MW[35].

According to Irena in Figure 2.21, geothermal energy data, there is an increase in geothermal energy installation globally [42].



Figure 2.21 Geothermal energy data[43].

These are an example of alternative energy as a source of electrification. The use of renewable energy increased from years to years. The benefits of using renewable can reduce the carbon emission to the earth and reduce the greenhouse effect, saving the world.

2.5 Summary

This information and research about the title have been discussed in this chapter. In part one, the electrification in the world has been discussed where the electrification can be separated into on-grid or off-grid. In part two, the study about electrification in rural areas uses standalone electrification instead of grid connection. In part three, the sources of off-grid electrification have also been discussed; the resources used can be renewable resources such as wind, solar, etc., and another one is non-renewable resources such as diesel, natural gas, etc. The last part, renewable energy as an electrification source, mainly introduced and discussed renewable energy such as solar, wind, biomass, etc.



CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is about to introduce the methodology of this project. Some steps are used to achieve the project's objective in this methodology. The software method used in this project will be discussed later. Finally, the simulation for the initial project, compared to the journal, and the initial result will be shown in this chapter.

3.2 **Project Workflow**

This section will discuss the general setup of this project. Figure 3.1 shows the available flow chart of this project.



Software description

Obtain the optimization result

First of all, before doing this project, researching the information and journal about the project title is a must to know more deeply about this project. During the research information, list the objectives and investigate the problem statement this project will face. This project is crucial to ensure that the project can be done smoothly. Next, after many researchers from different places and countries, the Bahir Dar villages' rural areas are selected due to their resources assessment, such as wind, solar, and biomass. The third step is load estimation. The load profile is estimated through the villagers' daily activities and energy demand.

Besides that, the resources assessment is determined through the Nasa web portal from the Homer software through the geographic location area of the longitude and latitude of the study area. Then, the software description is about how to use Homer software to design a rural electrification system. This part will explain the solar panel, wind turbine, biogas generator, converter, and batteries to create the system. The last part is to obtain the optimization result suitable for the rural area through the Homer Software.

3.3 Project Proposal

Firstly, to understand more deeply how this project will be done, many journals have been researched and studied to do this project, such as the rural areas from China, India, Ethiopia, America, and Australia[44]. During the research, many simulations are done in Homer software using the resources stated by the journal to be more familiar with the Homer software. The rural areas that have been done as an example are Khatisitara village in India, Leopard Beach in China, and Globo II, Ethiopia.

After many places have been researched and studied, the rural location was finally determined, located in Ethiopia, Bahir Dar remote village. The 'Bahir Dar" village is located in Tulu Dimtu, Ethiopia. The location's geographical coordinates have a latitude of 8 °53.2' N and a longitude of 39 °7.8'E. This un-electrified village has an average number of scattered households of 150, and the average population is 750. The daily load demand is 101.7kWh/day, with a peak load of 23.88kW. Table 3.1 below show the component of load

demand and their estimated values. The load demand is estimated based on the daily lifestyle and the energy needed for the various activities by the villagers of Bahir Dar. Using the information given by the research, the load curve and load demand can be determined in the Homer software. Figure 3.2 is about the daily primary load for weekends and weekdays; the load demands are different since the villagers' activities and energy are different between the days. Figure 3.3 is about the seasonal and yearly load profile. Bahir Dar has a tropical wet and dry climate[45], where the afternoon temperature is warm and the morning temperature is cool.

Appliances	quantity Load(watt)		Total	Hours of	Watt-hour per	
	ALAYSIA		watt	operations per day	day	
Households		10.				
• LED light tube	4	20	80	5hours	400	
• T.V.	1	55	55	2hours	110	
• Radio	1	5	5	2hours	10	
Total watt-hour per day for					78,000	
all						
Community	Vn .	6				
• School	1	1/	. /			
1. Led light	12	20	240	5hours 9	1200	
bulbs	2**	5	10	3houirs	30	
2. Radio	beiti	55	55	2hours	110	
3. Tv	Rolli	ENNINA		T SIA WELAKA	N	
Community hall	6	20	120	2hours	240	
1. LED light	3	55	165	2hours	330	
bulbs	2	20	120	2hours	240	
2. Ceiling fan						
3. Microphone	5	20	100	6hours	600	
• Hospital	1	20	20	12hours	240	
1. Led light bulbs	1	60	60	12hours	720	
2. Outdoor lightning	1	55	55	4hours	220	
3. Mini refrigerator	1	5	5	4hours	20	
4. T.V.	20	60	1200	12hours	14,400	
5. radio					19,650	
• Street light						
Total watt-hour						
Commercial load						
Grocery store						
1. Led light bulbs	2	20	40	3hours	120	
2. Fan	1	55	55	6hours	330	
2. Fan	1	55	33	onours	550	

Table 3.1 Components of load demand and their estimated value.

3. Mini refrigerator	1	60	60	6hours	3600
Total watt-hour					4050
Total daily load demand					101,700



Daily Primary load profile

Figure 3.2 The daily primary load profile on weekends and weekends.





For the resource assessment, the solar energy assessment of the Bahir Dar village

is done by taking the data from the NASA web portal from the Homer software. Based on the monthly averaged daily global solar radiation, the annual scaled average of solar radiation is calculated as 6.06 kWh/m2/day. The monthly clearness and daily global solar radiation index were given in Table 3.2. The global solar radiation on the horizontal surface based on clearness index and monthly averaged daily solar radiation are shown in Figure 3.4.

Month	Clearness Index	Daily radiation
		(kWh/m ² /day)
January	0.673	6.080
February	0.679	6.570
March	0.635	6.520
April	0.601	6.310
May	0.614	6.360
June	0.567	5.770
July	0.512	5.230
August	0.517	5.360
September	0.567	5.840
October Min	0.644	6.310
shi ()	6	
November la	سيبي يېڪيا 0.686	6.270
December VERSITI TE	0.692 AL MALAYSIA I	6.080 KA
Total scaled annual average	ed solar radiation 6.06 kW	h/m²/day

Table 3.2 Month vs clearness index and daily radiation

Monthly average solar Global Horizontal Irradiance (GHI) Data



Figure 3.4 Global solar radiation based on clearness index and monthly averaged solar radiation.

For the equation 3.4.1 of the solar energy, the output of a P.V. array depends on the rated capacity of the P.V. array, the derating factor, solar radiation, The incident radiation at standard test conditions, the temperature coefficient power, P.V. cell temperature, and the P.V. cell temperature under normal test conditions[46].

$$Ppv = Ypv fpv(\frac{GT}{GT,STC})[1 + \alpha P(TC - TC,STC)] \dots (3.1)$$

 Y_{PV} is the rated capacity of the P.V. array, meaning its power output under standard test conditions [kw], f_{PV} is the P.V. derating power [%].

 $G_{.T.}$ is the solar radiation incident on the P array in the current time step kW/m²].

 $G_{T,STC}$ is the incident radiation at standard test condition [kW/m²].

 α_P is the temperature coefficient power[%/ °C].

Tc is the P.V. cell temperature in the current time step [$^{\circ}$ C]

T.C., STC is the P.V. cell temperature under standard test conditions [25 °].

In Bahir Dar village, the amount of wind energy potential is average. Homer software calculates the annual average wind speed in m/s based on the monthly average wind speed value. The monthly averaged wind speed data is achieved from the NASA UNVERSITY TEKNIKAL MALAYSIA MELAKA Prediction Worldwide Energy database. Table 3.3 shows the monthly average values of wind speed data, and Figure 3.5 shows the month verse averaged wind speed. The scaled annual averaged wind speed distribution is 4.32m/s at the height of 10m. Using the logarithm law, the wind speed at a certain height above ground level can be shown [23].

$$V(Z).\ln\left(\frac{Zr}{Zo}\right) = V(Zr).\ln\left(\frac{Z}{Zo}\right)....(3.2)$$

Where,

Z_r reference height (m)

- Z Height where wind speed is to be determine (m)
- Zo Measure of surface roughness (0.1 to 0.25 for crop land)
- V(Z) Wind speed at height of Z(m/s)
- $V(Z_r)$ Wind speed at the reference height (m/s)

By using power law, the wind speed at a certain height above ground level can be given as

follow.

Where,

ais ground surface fiction coefficient

 V_1 Wind speed measured at the reference height h1(m/s)

V₂Wind speed estimated at height (m/s)

Month	Average m/s
January	4.810
February	4.880
March	4.650
April	4.350
June	4.130
July	3.320
August	3.920
SeptemberSITI TEKNIKAL MALAYSIA	3.600 AKA
October	3.000
November	5.050
December	5.170
Total scaled annual averaged wind speed (m/s).	4.32

Table 3.3 Monthly averages	values c	of wind speed
----------------------------	----------	---------------



Figure 3.5 Month vs wind speed distribution

The biomass resource potential is considered one hundred tons per day for the biomass resources. The biomass is available easily in the form of maize straw. The utilization of biomass energy takes converting maize straw into biogas. The monthly average biomass availability and scaled annual averaged biomass potential are tabulated in Table 3.4. The monthly biomass resources availability and scaled annual average biomass availability are estimated at 103.35 tons/day. The graph of month verse distribution of biomass resources is shown in Figure 3.6 below.

Month	Biomass resources
January	105.4
February	102.0
March	105.4
April	102.0
May	105.4
Jun	102.0
July	105.0

Table 3.4 Monthly average biomass resources

August	105.0
September	102.0
October	105.4
November	102.0
December	105.4
Total scaled annual averaged biomass (ton/day)	103.35



UNIVERSFigure 3.6 Monthly biomass resources

3.5 Software description

HOMER Pro software is a micro-grid software by Homer Energy. It is the world standard for optimizing the micro-grid design in all zones, from rural areas to gridconnected campuses and military bases. It was initially developed at the National Renewable Energy Laboratory and enhanced and distributed by HOMER energy. HOMER (Hybrid Optimization Model for Multiple Energy Resources) clusters three powerful tools in one software product so that engineering and economics work side by side. The place can be determined in the software where it has provided the map inside the software. The data can be obtained from the software from the resources such as solar, wind, and others. The system modeling is shown in Figure 3.8 hybrid PV-Wind-biogas-battery-converter system. Homer selects the optimal system configurations based on the total NPC and COE. The NPC refers to the present value of all associated costs, subtracting the present values of all revenues earned over the project lifetime. The cost comprises capital investment, replacement, operation, and maintenance costs. Moreover, the COE is also a useful metric to measure the system cost. COE is the average cost per kWh of useful electrical energy generated by the system.



Figure 3.8 Hybrid PV-Wind-Biogas battery converter system[44].

The solar panel used in this project is LONGI LR6-72HV-350M. The capital investment cost is taken as 243.10\$/kW. The operation and maintenance are considered as 10\$/year. Therefore, the lifespan of the solar panel is 25 years, and the derating factor is regarded as 90%. The search space for the solar panel array sizing uses homer optimization.

The wind turbine in this system uses a generic 10kW. This wind turbine has a rated output capacity of 10kW. The capital cost investment is 4830\$/kW, and the O&M operation and maintenance is 80\$/year. The hub height of the generic 10kW is 24m, and

the lifespan is 20years. The quantity of the wind turbine is assembly by the Homer optimization.

The capital cost for a biogas generator is 550\$/kW, and the biogas generator used is a generic biogas generator. The operation and maintenance cost (O&M) is 0.10\$/operation time. Therefore, the search space for the generator is 5kW,10kW,15kW, 20kW, 25kW, 30kW, and 35kW.

The battery used in this project is BAE SECURA BLOCK SOLAR 12 V 3 PVS 210. The battery is 12V and 220Ah. The capital cost is 126\$/kW, and the operation and maintenance cost (O&M) is 10\$/year. The battery's lifetime is 18 years, and the search space is assembly by Homer software.

The capital cost for the converter is 300\$/kW, and the O&M is 10\$/year. Therefore, the lifetime for the converter is 15 years, and the efficiency is 95%. The quantity of the converter is assembly by the Homer optimization.

The project lifetime is 25 years. The real discount rate is converted between onetime and annualized costs. The annual real discount rate calculation from the "Nominal discount rate" and "expected inflation rate". The following are the Equation 3.5.1 used to obtain the real discount rate;

$$i = \left(\frac{i-f}{1+f}\right)\dots(3.4)$$

Where:

i= real discount rate [%]

i'= nominal discount rate (the rate which can borrow money)

ALAYSI.

f= *expected inflation rate*

The project discount rate for this project is 8.00%, and the expected inflation rate is 2.00%.

3.6 Summary

The method of how to construct this project was shown in this chapter. In part 1 is the short introduction to the methodology. The project workflow on building the project is also discussed in this chapter. Many types of research have been done to do this project and write the literature review. The place to study was determined in Bahir Dar village, in Ethiopia. Developing the community's load demand is discussed in this chapter.



CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This project is to design the off-grid electrification by using renewable energy in the Bahir Dar village, Tulu Dimtu, Ethiopia, one of the remote area in Ethiopia. The purpose of this chapter is to discuss the result of the project. The result analysis of the simulation is observed when the system is designed.

4.2 Results and Analysis

The Homer performs simulation, optimization, and sensitivity analysis to identify the most feasible hybrid system combinations in cost and technical aspects based on given constraints and inputs. The optimum results are differentiated into two categories: overall optimization and categorized optimization tables based on the initial capital, NPC, COE, and dispatch type. The results of the two categories will be shown in Figure 4.1 and Figure 4.2.

4.2.1 Simulation result

The optimization result of this renewable energy system using solar, wind, and biomass is achieved through several simulations using HOMER software. From the simulation result, the top of the simulation will be selected as the optimal result compared to the following result based on Figure 4.2, since the top result has the most cost-effective system; for example, the system has the lowest net presenting cost, and the energy cost. The energy cost is 0.1\$/kWh which is quite comparable with the energy cost of present conventional resources-based generation. The optimal sizing of various system

components and financial result data were tabulated in Table 4.1. The results show that the PV-Wind-Biogas generator-Battery system is the least cost-optimal to meet the village electricity demand. This system does not require a minimum amount of diesel generators. Therefore the renewable energy penetration is very high. The configuration is at least and emits minimal carbon dioxide CO2 to the environment. Thus, this system can be considered the best system configuration from reliability, economic and environmental points of view.

Optimal component sizing result									
No	System component	Rating	Optimal quantity						
1.	LONGI LR6 solar panel	0.350kW	38.5						
2.	Generic 10kW	10kW	1						
3.	Generic biogas genset	50kW	10.						
4.	System converter	1kW	17.1						
5.	Battery Min	12V, 220Ah	58						
Optin	num system costing result	رسىتى نيك	اويبو						
Total	net present cost (NPC)	\$78,168.00							
Total	initial capital cost	\$32,143.00							
Total	operating cost per year	\$3,560.28							
Cost o	of energy (COE)	\$0.100							

Table 4.1 Optimum sizing and costing result

							Architect	ure				
-	+	-	83		LONGI V	G10 🏹	BIO (kW)	BAE PVS 210 🏆	Converter V	Dispatch 😽	NPC (\$)	COE (\$)
1 de la	+	-	12.33	\sim	38.5	1	10.0	58	17.1	LF	\$78,168	\$0.100
win.	+	-	RE.00	\mathbf{z}	38.6	1	10.0	58	17.2	LF	\$78,169	\$0.100
with	+	-	10.00		39.0	1	10.0	58	17.2	LF	\$78,178	\$0.100
N.	+	-	12.39		39.2	1	10.0	58	17.5	LF	\$78,201	\$0.100
N.	+	-	1239-	2	38.9	1	10.0	58	17.0	LF	\$78,203	\$0.100
-	+	5	10.00	2	38.4	1	10.0	58	17.2	LF	\$78,215	\$0.100
-	+	-	10.00	2	38.6	1	10.0	59	16.9	LF	\$78,216	\$0.100
-	+	-	1018		38.3	1	10.0	58	17.1	LF	\$78,225	\$0.100
uia.	+	-	EB	2	39.3	4	10.0	58	17.1	LF	\$78,232	\$0.100
nin.	+	-	10.00	\sim	38.8	1	10.0	58	17.5	LF	\$78,238	\$0.100
νψ.	+	-	1	2	38.6	1	10.0	58	17.5	LF	\$78,239	\$0.100
uin.	+	-	10.00		38.4	1	10.0	59	17.3	LF	\$78,244	\$0.100
ni.	+	-	10.00		37.8	1	10.0	59	17.3	LF	\$78,247	\$0.100
	+	-	10.10		38.7	1	10.0	58	16.7	LF	\$78,267	\$0.100
win.	+	-	10.09		40.8	1	10.0	58	17.2	LF	\$78,274	\$0.100
wia	+	-	12.13	2	39.8	1	10.0	58	17.1	LF	\$78,276	\$0.100
nin.	+	-	12.30	2	38.6	1	10.0	58	16.6	LF.	\$78,278	\$0.100
w	+	-	12.23	2	38.9	1	10.0	57	17.0	LF	\$78,279	\$0.100
-	+	-	10.30	2	39.3	1	10.0	59	17.5	LF	\$78,280	\$0.100

Figure 4.1 Overall Optimization results based on NPC.

				3	7			2					
-	ł	î	63	Z	LONGI V	G10 🍄	Bio V (kW)	BAE PVS 210 Y	Converter 💡	Dispatch 🎗	NPC 0 9	COE 0 7	Operating cost 0 😵
Ţ	+	£	23		38.5	1	10.0	58	17.1	ŁF	\$78,168	\$0.100	\$3,560
m		-	63	2	46,4		10.0	65	19.4	LF	\$78,517	\$0,101	\$3,691
-			53	Z	96.5			104	24.6	CC	\$94,403	\$0.121	\$3,904
ų	+		53	2	91.6	2		106	24.0	CC	\$96,141	\$0.123	\$3,750
	+	1	13	2	No	3	15.0	39	10.4	CC .	\$121,382	\$0.156	\$7,010
		-	83	2		-	15.0	34	9.30	cc (5	\$143,261	\$0.184	\$9,896
m.		ŝ		2	65.0	4	20.0		9.78	cc	\$263,369	\$0.337	\$16,578
	+	-		U	NIVE	15S	20.0	EKNIKA	LMAL	AYSI.	\$303,774	\$0.389	\$17,043
-		ŝ		Z	159		25.0		19.5	cc	\$317,455	\$0.407	\$20,049
	1		23	2		30		304	79.2	cc	\$323,954	\$0.415	\$9,050
		-					25.0			cc	\$368,589	\$0.472	\$27,448

Figure 4.2 Categorized Optimization result.

The PV-Biogas options consist of a P.V. array of 46.4kW, 65 strings of batteries, a biogas generator with a 10 kW capacity, and a load-following dispatch strategy. This system has a total NPC of \$78,517 and a COE of \$0.101kWh. On the other hand, the Windbiogas options consist of 3 wind turbines and 39 strings of batteries, and a biogas generator of 15 kW capacity. As shown in Figure 4.2, this system has a total NPC of \$121,382 and COE of \$0.156kWh. Thus, this system is not viable from an economic point of view as the PV-Wind-biogas-battery system as the total NPC and COE are higher.

The cost summary analysis based on the net present cost NPC for the system components is also shown in Figure 4.3. The NPC for the LONGI solar panel, generic 10kW, biogas generator, battery and converter is \$32,860.53, \$6,536.2, \$15,302.76, \$14,351.80, and \$9,116.82.



Figure 4.3 Cost summary based on NPC.

The month electricity generation by the various components of the system is also evaluated and shown in Figure 4.4. The contribution of solar panels, wind turbines, biogas generators is 82.4%, 11.8%, and 5.79%, respectively. The dark brown colour represents the solar, the yellow-orange colour represents the wind, and the green colour represents the biogas. From Figure 4.4, in January until April and October until December, the biomass electric production is much lower than in June until September. The wind and solar resources are lower than in months from June until September, based on Figure 3.4 and Figure 3.5. Therefore, the electrical production for biomass is higher than the wind, and solar electric output also decreases. In June and July, the solar panel produces less electricity compared to other months because, in that particular month, the solar radiation is lower than in additional months. Therefore, Homer will choose the higher energy to generate electricity. Biogas production is the lowest in December in Figure 3.6, and wind production is higher. This is because the wind has the most increased wind radiation in that month compared to the other months based on Figure 3.5.





In this system, the discharging and recharging of the battery depend on user demand and renewable energy production. Figures 4.5 and Figure 4.6 show the batteries charge themselves. The power looks positive during the daytime due to energy production from solar P.V. The battery goes down when there is no production from solar P.V. From Figure 4.5, the batteries are not needed during the day because the solar is enough to support the load demand. The graph decreases when the solar is insufficient to charge the batteries. Although the system has three resources, the batteries are still required at night because there is no solar, and the wind speed also decreases during the dark[48]. The biogas is insufficient to support the nighttime load demand since the load demand is higher from the evening until 10 p.m; by referring to the load demand Figure 3.2.



Figure 4.6 Batteries discharge during night.

4.3 Sensitivities Analysis

For the system in Bahir Dar village, changes in solar radiation and wind speed are considered for the sensitivity analysis. However, price and the amount of biomass are ignored as the biomass is available in maize straw. Therefore, the cost is free and the amount obtainable is much bigger for the 50kW biogas fuel generator needed.

For sensitivity analysis, it varies from 6.06 kWh/m2/day to 6.50 kWh/m²/day, and wind speed ranges from 4.32 m/s to 4.80 m/s considering the changes in climatic condition. Results obtained from the sensitivity analysis of the system are shown in Figure 4.7, which shows the optimal system type due to the variation in solar and wind speed according to NPC. The interpretation is not too obvious since the solar radiation and wind speed change are different. However, it can be observed that by increasing the solar and wind, system combined with the PV-Wind-Biogas-Battery system forms a new output.



Figure 4.7 Optimal system type of sensitivity analysis.

When solar radiation is 6.50 kWh/m²/day, and annual wind radiation is 4.80 m/s, considered sensitivity analysis, PV-Wind-Biogas-Battery is the optimal solution with the NPC \$74,845, which also confirms the selection of optimization results. Furthermore, the sensitivity analysis also provides a selection basis of a suitable distributed energy system when changes occur in the availability of natural resources.

4.4 Summary

From this chapter, the analysis of the project has been done to design off-grid electrification in the Ethiopia rural area. The solar and wind resources can be obtained from the Homer software, while the biomass is obtained from the journal study. After done all the designs, run the simulation, and the optimized result will be accepted. The renewable energy solar, wind, and biomass is shown in the optimized result, which is the most suitable to construct. The NPC is \$78,517, and the COE is \$0.100. The wind and solar are intermittent. When there is an absence of one of the systems, another system can replace it. The battery is needed during the nighttime; when there is no solar and wind, the battery can be the source of the electric loads. The sensitivity analysis result is no noticeable change since the input variable solar radiation and wind speed are only slightly different.

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CHAPTER 5

CONCLUSION

5.1 Conclusion

This project is constructed by using Homer Pro software. A lot of information and research has been done before doing this project. The study is located at the Bahir Dar village, Tulu Dimtu state, Ethiopia. This rural area is chosen because it has more than one renewable energy source. The load demand is estimate through observed the daily activity and energy demand needed by the villagers and shown in Table 3.1. The average annual solar irradiance is 6.06kWh/m²/day, the moderate yearly wind is 4.32m/s, and the yearly average biomass is 103.35 tons/ day. Although there are three renewable resources in place, the design and simulation need to be done to reduce the financing waste and increase the appropriate function of the system in the area. The off-grid electrification system design is done using the Homer Software, where the optimized result can show the cost summary and the monthly electrical production. Although the system has three different resources, the battery is still needed because the load demand of the Bahir Dar village is much higher. Besides that, renewable energy resources such as solar and wind are not enough to support the load demand during the night; the solar is absent, and wind speed decreases at night[48]. As a result, both three renewable energies with the battery system as the backup system are suitable in this place, and the net presenting price is \$78,168, and the cost of electricity is \$0.100kW, and the operating cost is 3,650\$/year, which can be used in this rural; area to make them independent of grids. For the sensitivity analysis, when the input of solar radiation and wind speed only has slightly variable due to Bahir Dar's climate change, the result did not change obviously.

5.2 Future Works

For future improvements, the Homer software could improve accuracy to estimate the most cost-effective system to electrify the rural areas as follows:

- The most optimum system used in the rural area is based on the cost, such as the net presenting, operating, electrical, etc.
- The Homer simulation can observe the monthly electricity production based on renewable resources.
- The spending cost of the system in the year of the project lifetime
- Sensitivity analysis with the variable input can change the output result caused by the variable, such as different input of solar radiation and wind speed.



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