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INVESTIGATION OF OPTIMUM SOLAR-WIND HYBRID OR SEPARATE WATER PUMPING AND ELECTRICITY GENERATION SYSTEMS FOR SOMALIA

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Zakaria Ibrahim Ali tarafından hazırlanan "Investigation of Optimum Solar-Wind Hybrid or Separate Water Pumping and Electricity Generation Systems for Somalia" adlı tez çalışması 30/10/2018 tarihinde aşağıdaki jüri tarafından oy birliği ile Konya Teknik Üniversitesi Lisansüstü Eğitim Makine Mühendisliği Anabilim Dalı'nda YÜKSEK LİSANS TEZİ olarak kabul edilmiştir.

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İmza.................................

Zakaria Ibrahim Ali

Tarih: 30.10.2018

ÖZET

YÜKSEK LİSANS TEZİ

OPTİMUM GÜNEŞ-RÜZGAR HİBRİT VEYA AYRI SU POMPALAMA VE ELEKTRİK ÜRETİM SİSTEMLERİNİN SOMALİ İÇİN ARAŞTIRILMASI

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Rüzgar ve güneş enerjisi, dünyada elektrik enerjisi üretmede; yüksek potansiyel, kullanılabilirlik ve çevre kirlenmesi nedeniyle gittikçe popüler hale gelmektedir. Somali birçok bölgesinde yüksek potansiyelde rüzgar ve güneş enerjisine sahip olmasına rağmen enerji sıkıntısı çekmektedir. Bu durum hem güvenlik, hem yeterli bilgi ve teknoloji yetersizliği hem de finans eksikliklerinden kaynaklanmaktadır. Somali'nin merkezi hükümeti 1991'de devrildiğinde, ülkenin enerji sektörü de yıkıldı. Çoğu bölge karanlıkta kalırken özel sektöre ait dizel jeneratörlerle enerji sağlanmaya çalışıldı. Somali, dünyadaki en az enerji tüketen ülkeler arasındadır ve elektrik fiyatı da bölgede ve dünyada en yüksek düzeylerdedir. Nüfusun sadece yaklaşık %15'inin bir elektriği vardır. Kentsel bölgelerde nüfusun %35'i elektriğe sahipken, kırsal alanlarda bu oran ancak % 1'dir. Tezde güneş ve rüzgar enerjisi ile üretilecek elektrik enerjisinin ülkenin hem elektrik hem de kullanma suyu temini için gereken enerji ihtiyaçlarını karşılayabileceği belirlenmiştir. Güneş enerjisi potansiyeli, yılda 5–7 kWh/m^2/gün ile 300'den fazla güneşli güne sahiptir. Somali'de Güneş-Rüzgar Hibrit Enerji Sisteminin ön fizibilitesi yapılmıştır. Ülkedeki farklı coğrafi bölgelerdeki güneş ve rüzgar enerjisi potansiyelleri araştırılmış, daha sonra seçilen yerin elektrik enerjisinin karşılanması Yenilenebilir Sistemler için Hibrid Optimizasyon Modeli (HOMER) yazılım aracı kullanılarak analiz edilmiştir. Örnek bir topluluğun ortalama elektrik yükü talebi tahmin edilmiş ve ölçülen bir topluluğa enerjinin nasıl sağlanacağı konusunda bir fizibilite çalışması sunulmuştur. Elektrik üretimi için seçilen kombinasyon sisteminin teknik ve ekonomik fizibilitesinin bir analizi sunulmaktadır. Üç farklı yerde seçilen üç rüzgar türbininin elektrik üretimi ve kapasite faktörleri yıllık olarak hesaplanmıştır. Rüzgar türbini yatırımı ve ekonomik karlılık maliyet araştırması da sunulmuştur.

Anahtar Kelimeler: Güneş Enerjisi, Hibrit Sistem, Rüzgar Enerjisi, Rüzgar Türbini, Somali

ABSTRACT

M.Sc. THESIS

INVESTIGATION OF OPTIMUM SOLAR-WIND HYBRID OR SEPARATE WATER PUMPING AND ELECTRICITY GENERATION SYSTEMS FOR SOMALIA

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Wind and solar energy are becoming increasingly popular due to their abundance, high potential, availability, environmental pollution, and ease in producing electrical energy in the world. In many parts of Somalia, although there is high potential in wind and solar energy, there is energy shortage. This situation is due to lack of security, sufficient information and technology, and financial deficiencies. When the central government of Somalia collapsed in 1991, the energy sector of the country was destroyed. Residents were forced to rely on privately owned diesel generators while many were left in the dark. Somalia is among the least energy consuming countries in the world, and the rate of electricity is one of the highest in the region and the world. The demand for affordable and reliable electricity everywhere in Somalia is high and increasing. Moreover, Somalia suffers from a deficiency of power in rural communities. Only an estimated 15% of the population has a connection to power. In urban areas, 35 % of the population is connected to electricity while in rural areas, only 1 % are connected to electrical services. The country's energy resources to meet its energy needs are domestic wood, charcoal, and imported petroleum. Solar and wind energy offers a way to deliver current energy needs and challenges associated with the country. There is significant potential in all Somali areas in terms of renewable and alternative energy sources like wind and solar energy but so far, due to both security and funding problems, only very small, timid experiments have been carried with solar and wind power. The solar energy potential varies from 5–7 kWh/m^2/day with more than 300 sunny days in a year. Somalia is also identified by powerful winds. Feasibility of Solar-Wind hybrid Energy System in Somalia is presented in this study. Solar and wind energy potentials at different geographic locations in Somalia was investigated then selected location is analyzed using Hybrid Optimization Model for Electric Renewables (HOMER) software tool. The average electric load demand of a sampled area was estimated and a feasibility study on how to provide energy to a measured area was presented. A analyze of the technical and the economic feasibility of the chosen combination system for electric generation is presented. the amount of electricity production and capacity factors of three selected wind turbines at three different location are estimated annually. Cost investigation of investment of wind turbine and economic profitability also is presented.

Keywords: Hybrid System, Solar Energy,Wind Energy,Wind turbine, Somalia

ÖNSÖZ

Bu tez çalışması sürecinde beni yönlendiren ilgi ve yardımlarını esirgemeyen tez danışmanım Dr.Öğr.Üyesi Faruk KÖSE'ye katkılarından dolayı teşekkür ederim. Tüm hayatım boyunca hep yanımda olan, bana güven ve sevgi veren, maddi ve manevi desteklerini her zaman hissettiren, bütün zorluklara katlanarak yetişmemde emeği geçen aileme ve arkadaşlarıma şükranlarımı sunarım.

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ABBREVIATIONS

A	:Area,m2
AC	:Alternate current
Ah	:Ampere- hour
DC	:Direct current
GWh	:Gigawatt hour
ha	:Hectare
HOMER	:Hybrid Optimization Model for Electric Renewable
kt	:Kilotonne
LCOE	:Levelized cost of electricity
m/s	:Meters per Second
MW	:Megawatt
NASA	:National Aeronautics and Space Administration
NPC	:Net present cost
NREL	:National Renewable Energy Laboratory
O&M	:Operation and maintenance
P	:Power,W
PV	:Photovoltaic
SMT	:Somali Ministry of Transport
v	:Wind speed, m/s
WT	:Wind turbine

1. INTRODUCTION

1.1. Background

Somalia is sitauted on the eastern coast of the Horn of Africa bordering Djibouti Ethiopia, Kenya ,the Gulf of Aden and the Indian ocean,. The total area of its land is 638, 657km^2 and has the longest shoreline in Africa's mainland. Its land mainly consists of plateaus, plains, and highlands. Yearly, hot climate situations remain during the year with seasonal monsoon winds and intermittent rain. Most of the available water resources in Somalia are located in rivers, and There is often lack of rain and a significant need for fresh water for human and animal consumption. In most areas groundwater is salty. Access to safe water is limited in the country. The majority of the community lives in country areas involved in agriculture and livestock husbandry. the most significant exports in the country are livestock and farming products. In addition, Few of the country's mineral resources have been utilized or produced.

Figure 1.1 Somali Map (Googlemap, 2018)

1.2. Problem Statement

When the central government of Somalia collapsed in 1991, the energy sector of the country was destroyed. Residents were forced to rely on privately owned diesel generators while many were left in the dark, and private companies continue to invest their own capital in power supply, as well as in the import and distribution of petroleum fuels (Usaid, 2018). The country's energy resources to meet its energy needs are domestic wood, charcoal, and imported petroleum. Somalia is among the least energy consuming countries in the world, and the rate of electricity is one of the highest in the region and the world. The demand for affordable and reliable electricity everywhere in Somalia is high and increasing. Moreover, Somalia suffers from a deficiency of power in rural communities.

The availability of freshwater and power to access to it are the essential matters challenging the the world's population, particularly in developing nations. Water demand for irrigation and domestic supplies in the world is increasing. The main water reservoir for most people in Somalia is groundwater. Although the community living along the two rivers, Juba and Shabelle, utilize surface streams to satisfy their water demands, the main sources of water of the majority of the people of the country are groundwater from drilled wells, boreholes and springs (Muchiri, 2007). Moreover, the rural and urban community use groundwater to provide household, and livestock water demands in addition to small-scale irrigation. Meanwhile , rainfall is decreasing in Somalia, so surface water is diminishing.

Although Facilities that use water pumps in irrigation systems very often rely on diesel and gasoline generators for power to pump water from the wells and rivers. Their use requires an imported fuel supply which is difficult and risky. Even if fuel is accessible within the country, transporting that fuel to isolated, rural villages can be tough. There are no roads or supporting infrastructure in several remote towns where transportation by animals is still frequent. The use of diesel and gasoline generators releases gases into the environment, causing an increase in the level of pollution in the atmosphere. It also pollutes groundwater and soil with fuels and oils.

In addition, Somalia does not have any chemical and nuclear resources and faces significant economic difficulties when attempting to provide oil; in isolated areas generators engines is difficult and expensive. Alternatively, there are also two sources of energy available and extensive: the wind and the sun. Solar or wind energy is able to sustainably meet the basic electricity need in a sustainable way, which is a suitable solution for basic health. Solar and wind energy offers a way to deliver current energy needs and challenges associated with the country. There is significant potential in all Somali areas in terms of renewable and alternative energy sources like wind and solar energy but so far, due to both security and funding problems, only very small, timid experiments have been carried with solar and wind power. The solar energy potential varies from 5–7kWh/m^2/day with more than 310 sunny days in a year. Somalia is also identified by powerful winds with a seasonal mean wind speed of 1.5 to 11.4m / s (AfDB, 2015).

1.3. Aims of the Thesis

Somalia is one of the least energy consuming nations in the world, and the cost of electricity is among the most expensive in the world. In the capital of Somalia, Mogadishu, a kilowatt of electricity can cost 0.55 $ per hour and other cities it can cost more than double of that price(AfDB, 2015).

Highest power demands are for the water supply, either for drinking or for irrigation and animal watering. The primary financial resource in Somalian is livestock farming and agriculture. The primary goal of this research is to evaluate and design an Optimum Solar-Wind Hybrid or Separate Water Pumping and Electricity Generation Systems in Somalia.

Specific Objectives:

- Discuss energy sector issues in Somalia and the demand for renewable energy.
- Specify power possibilities for rural water pumping uses like water supply, irrigation and livestock watering.
- Analyze the Solar-Wind potential in various geographical places in Somalia by investigating data from several sources.
- To develop a tool in order to design a wind-solar hybrid power system according to energy demand
- Design a solar-wind combined system for a determined appropriate place.
- Financial analysis of wind-solar combined power production system.

1.4. Methodology

Under this study, the potential of wind and solar power from four different cities in Somalia will be studied by obtaining data from various sources and investigating them utilizing a software tool. The gathered data will be analyzed using Hybrid Renewable Energy Optimization Software (HOMER). The software is a model for optimizing microgrids for on-grid and off-grid power systems in different uses.

In this thesis, the process to be followed regarding the target to be reached in the thesis study is stated below:

1. The aim and importance of the study.
2. Literature Review.
3. Investigation of energy resources in Somalia, determination of solar and wind energy potentials.
4. Detecting different places where the potential of wind and solar energy is high, based on data from NASA.
5. Design and analysis of a wind-solar or hybrid system using the HOMER software tool.
6. The average electric load demand of a sampled community was estimated and a feasibility study on how to provide energy to a measured community was presented. A study of the technical and the economic feasibility of the chosen combination system for electric generation will be presented.

2. ENERGY SECTOR IN SOMALIA

Somalia depends on mainly on domestic wood and charcoal and on imported fuel to satisfy its power demands. Somalia has one of the minimum energy consumptions in the region. According to AFREC, a total of 394 GWh electricity was generated in 2015. fossil fuels supplied 97,1% of the generated electricity while final power consumption in 2015 was 197 GWh. (AFREC, 2017).

Estimated and projected total power Statistics of Somalia is presented Table 1.1 below.

Table 1.1 Total Energy Statistics of Somalia (AFREC, 2017)

Total Energy Statistics									
Category	**Unit**	2000	2005	2012	2013	2014	2015	2016	2017
Production of charcoal	**kt**	615	863	1187	1187	1136	1245	1367	1503
Production of electricity from fossil fuels	**GWh**	235	273	331	351	372	383	394	406
Production of hydro electricity	**GWh**	0	0	11	11	11	11	12	12
Total production of electricity	**GWh**	235	273	342	362	383	394	406	418
Final consumption of oil	**kt**	168	167	89	9	91	93	99	105
Final consumption of electricity	**GWh**	181	137	171	181	192	197	209	223
Consumption of oil in industry	**kt**	28	27	16	15	15	15	16	16
Consumption of electricity in industry	**GWh**	35	41	51	54	57	59	62	65
Consumption of oil in transport	**kt**	115	114	58	62	62	64	69	75
Net imports of oil product	**kt**	240	239	140	130	130	133	135	137

According to Usaid (2018), only an estimated 15% of the population has a connection to power. In urban areas, 35 % of the population is connected to electricity while in rural areas, only 1 % are connected to electrical services. It suffers from a deficiency of power in rural communities (Usaid, 2018).

2.1. Biomass

Biomass Energy in Somalia is based primarily on fuelwood (rural) and charcoal (urban), which creates enormous pressures on the ability resource base to supply that fuel. Even though the use of firewood fulfills the most of the energy demands of the rural community, the primary financial production in Somalia is Charcoal. It gives the energy requirement of the country and also provides income to the country. Nearly 97% of city houses rely on charcoal while rural families depend on firewood as their essential source of energy (AfDB, 2013). Traditional biomass fuels like firewood and charcoal, mainly used in rural and poor communities, account for 82% of the country's total energy consumption.

There is a crucial requirement for substitute energy sources and recommendations have shown biofuels from product and animal waste and In addition, improved technologies should be developed for sustainable coal making (REEEP, 2010).

Biomass resources have been exhausted due to the extreme dependence of wood and charcoal as a source of energy. The majority of the Somali community, like 80% to 90%, use conventional biomass, wood and charcoal for cooking and yearly consumption of charcoal is evaluated at 4 million tons per year. (AfDB, 2015).

2.2. Hydropower

The hydropower resources of Somalia are concentrated in the upper Juba Valley near Baardhere town with potential average energy availability of about 500 GWh/year. The Baardhere dam and water infrastructure project consisted the creation of a 600 m long, 75 m high multipurpose dam designed to control Juba flow, produce hydroelectric energy and regulate floods (Salman, 2011). The Project also covered the building of watering and sewerage systems for about 5000 ha of land. The suggested Dam was located on the Juba River, 35 km upstream of the Baardheere city in Somalia and about 350 km from Mogadishu (Salman, 2011). The security situation in this country has severely hampered the deployment of hydroelectricity (Salman, 2011).

Also A few small sites for hydro development exist on the Juba river. The Fanoole dam in Middle Jubba, built from 1977 to 1982, could potentially irrigate 13,000 ha and produce 4.6 MW of electricity (FGS, 2015). Even though the dam had the potential to irrigate about 13,000ha, only 1,800 ha were developed before to the civil war in 1991 (FGS, 2015). Some potential mini-hydro sites have also been identified on the middle and lower reaches of the Shebelli, Somalia's other river . At the existing Fanoole diversion dam, there is an installation of 4.8 MW which generates about 10 GWh per year (WorldBank, 1987). A small storage dam could be built at Saakow with an initial capacity of about 10 MW and an output of 80 to 90 GWh per year. Both the Fanoole and Saakow sites have minimal firm energy capacity that would be developed extensively with river control made possible by the construction of the Baardheere dam (WorldBank, 1987).

2.3. Oil and natural gas

The geology of Somalia and its closeness to fuel producers in the Middle East show the possible presence of fuel resources. Until now, however, the situation was not agreeable to exploratory activities (UNEP, 2017). In addition to offshore oil and gas possibilities in the Indian Ocean and the Red Sea, the Dharoor region in Puntland is reported to have 1.2 billion barrels of oil and could have a capacity of 10 billion barrels of oil (AfDB, 2013). Somalia is dependent on imported fuel for power generation, and in 2015 Production of power from fossil fuels was 383 GWh while Net imports of fuel in 2015 was 133kt (AFREC, 2017). The total projected electricity production in 2017 is estimated at 418 GWh, of which 97% comes from fossil fuels, while the final electricity consumption is 223 GWh (AFREC, 2017).

2.4. Wind

Somalia has a coastline of 3,333 km, the longest in Africa and about 55 percent of its population lives along this coastline (FGS, 2015) As Figure 2.1 Shows. This long shoreline is particularly suitable for wind power generation with the presence of attractive offshore winds. Measurements of wind speeds ranged from 3 m/s to 11.4 m /s (FGS, 2015). Sustained wind speeds more than 6-7m/second, which are needed for wind generation, are very frequent. Four wind turbines with 50 kilowatts rated power each, were installed in the Mogadishu electrical grid and In 1988 these turbines generated 699.4MWh of energy.Wind power has also been used for water pumping, with installations carried out by the Somali trusteeship authority of the United Nations as early as the 1940s (FGS, 2015). Despite the time and the civil war, these facilities have long existed.

The country has vast regions of shallow sea with its shoreline, especially appropriate for offshore wind, with the additional advantage that this area is near to several larger cities, including Mogadishu and Berbera. According Miketa & Saadi to (2015) all countries in the region have tremendous solar and wind potential but Somalia has the highest wind potential of any African country, both in absolute terms and per square meter. REEEP (2012) estimate that about half of the country has appropriate wind speeds for electricity production and that 95% could benefit from the use of wind systems to replace diesel water pumps (REEEP, 2010). In 1991, Pallabazzer & Gabow presented the results of wind power study in the country and they found that the 85% of the country has wind resource that suitable for power production.

2.5. Geothermal

The signs of geothermal potential are poor. The geothermal and lignite resources thus far identified in northern Somalia appear to be too small and remote from energy consumption centers to be of economic significance.

2.6. Solar

Because of its geographical location and climatic situations, Somalia gets huge measures of solar radiation every year. There is abundant of solar energy resources in Somalia. The country receives an average of 2,900 to 3,100 hours of light per year and has one of the highest diurnal percentages of total solar radiation in the globe (REEEP, 2010). Figure 2.2 below shows solar radiation of Somalia.

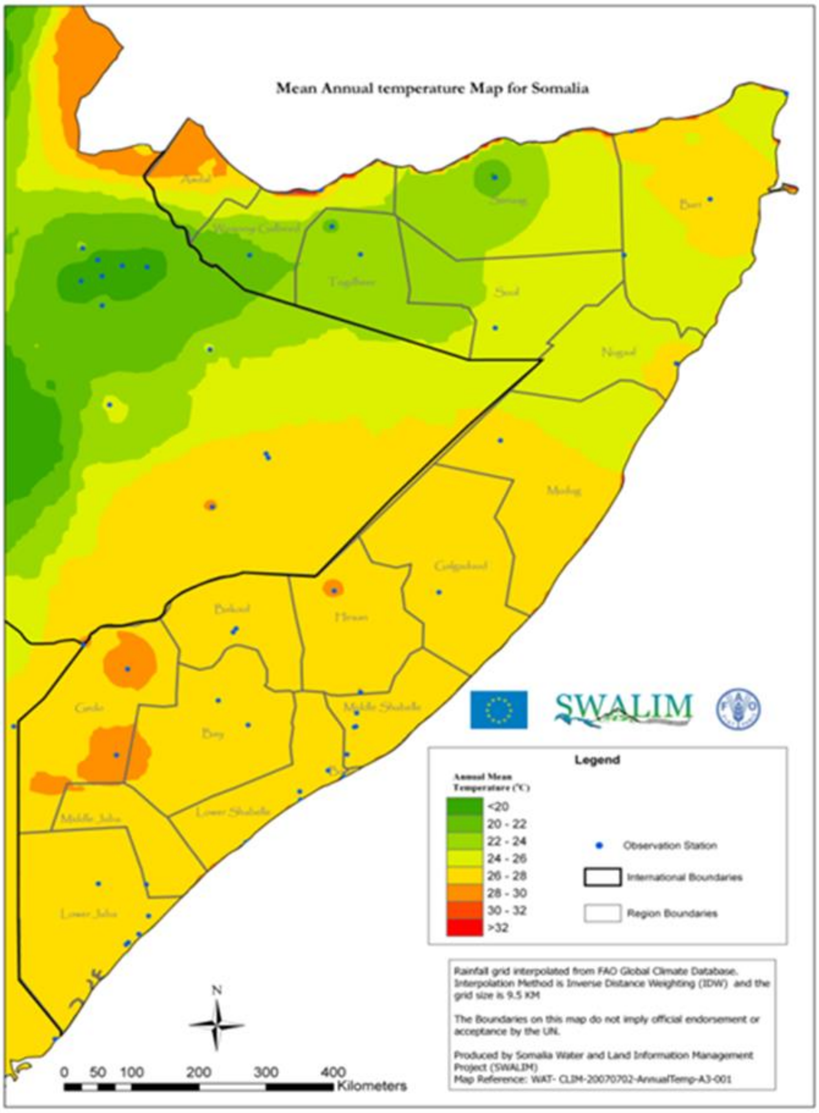

Figure 2. 1 Mean annual temperature distribution (Muchiri, 2007)

The average annual solar radiation is 6.4 kWh/m^2/day.Moreover, the mean annual temperature in the Somalia is 27 °C, a right temperature to allow a proper running time of solar photovoltaic. Somalia gets a mean solar radiation of between 5 and 7 kWh/m^2 /day interpreting into a total power potential of 2,163 million MWh/year (FGS, 2015; REEEP, 2010).

2.7. Literarure Review

Currently, separate wind and PV arrangements have been endorsed round the world on a relatively more significant scale.These separate arrangements cannot give a constant source of power since they are yearly. For instance , an autonomous solar system cannot generate powerful energy on cloudy days. Due to the wide changes in the size of the hourly speed of the wind during the year, the standalone wind system can not meet the requirements of the continuous load. Thus, Costly power storage arrangements will be needed for either of these systems in order to meet the energy demand.. Hybrid energy systems could be used to decrease the demand for energy storage.

A techno-economic analysis of standalone hybrid generation systems planning to success a nearly 11% share of renewable power sources in primary energy supply by 2010 was presented in Algeria (Himri, Stambouli, Draoui, & Himri, 2008). HOMER is utilized to predict power generation, life-cycle prices and reductions in greenhouse gas discharges. The purpose of the research is to conduct an economic possibility research on combining the wind turbine to a present diesel plant related to the grid and providing power to an isolated village to decrease diesel usage and pollution of the environment.

Stand-Alone hybrid power Supply System to supply power to a model village of 200 households studied in Ethiopia (Bekele, 2009). An electric load has been suggested that combines, water pumping, lighting, some clinical facilities and a radio receiver. HOMER software was utilized to analyze for the study. The data used for the software were the mean solar radiation and the mean wind speed determined from chosen places. In the results, many possible combined configurations, with various amount of supplying renewable energy sources, were found.

Aware of the potential of the harvesting the wind energy, Malaysian Government begins on the development of combining energy source at Pulau Perhentian (Perhentian Island). The project included the combination of a generator, solar panel, battery storage and wind turbines. (Darus et al., 2009). The solar-wind renewable combination system comprises two wind turbines with a nominal power of 100 kW each, a 100 kW solar panel and a 120 kW converter to produce 415 VAC on the LV bus.

The technical possibility of a wind-solar combination design in an assigned limit of load demand at Chunnambar island, Pondicherrywas estimated in (Muralikrishna & Lakshminarayana, 2008). A researchof the possibility of a hybrid solar and wind system for the power needs of the road, such as lighting, SOS billboards, etc. was carried out by (Taskin, Dursun, & Alboyaci, 2009).

The best sizing of an isolated hybrid system for the southwest of Iran has been stated in (Ardakani, Dehkordi, & Abedi, 2009). It has been determined that the amount of capacity of batteries in the wind turbine arrangement is greater than that of combined systems and photovoltaic batteries. The reason is that variations of wind speed are more than changes in solar radiation in the place, Therefore, wind energy requires additional storage (Wang & Singh, 2007) & (Taskin et al., 2009).

Designing of two emerging power systems based on renewable power: solar and wind energy was described in (Ardakani et al., 2009). (Halasa, 2010) Proposed wind-solar hybrid power generation to provide 10% of peak electricity demand in Jordan, which represents 2.2 GW (Halasa, 2010). An isolated wind-photovoltaic hybrid energy system was presented with storage of batteries that can power two laboratories with a maximum power of 1072 W(Oguz, Oğuz, Yabanova, Oguz, & Kırkbaş, 2012).

A renewable power design based on a combined PV and wind energy system was installed in Farsi Senkele rural area in Ambo, Ethiopia. (Lakeou & Latigo, 2010). The renewable energy source is used to pump water from a shallow well. The campus of Frostburg State University, Maryland, USA UU., It was developed in a residential combined system with solar and wind power to feed a small building through the net measurement(Soysal & Soysal, 2008). The design, dimensioning and operation of a combined system of renewable power for agriculture was presented by(Le, Giourdjian, Frankyan, Mandany, & Le, 2016).

Aksoy(2011) completed the theoretical and experimental research of renewable hybrid power production system consisting of PV and wind energy for agricultural irrigation at Konya Selcuk University Technology Development Zone garden. The hybrid electricity generation system consists of a 1500 W wind turbine and 4 photovoltaic panels with a total capacity of 480 W (Aksoy, 2011).

A probability analysis of wind-solar hybrid energy system for the Dhahran city in Saudi Arabia was stated in (Elhadidy & Shaahid, 1999). The load was a family house with air conditioning of four rooms (surface of the floor of 198 m 2) (Elhadidy & Shaahid, 1999). A low-cost renewable pivot irrigation system has been developed for crops in the Texas highlands of the United States (Vick & Almas, 2011).

(Abdel-Salam et al., 2011) calculated the energy need of a combined load and irrigation in the Toshka area of Toshka, Egypt. The irrigation pipe system was designed and an finantial feasibility research was carried out for the solar-wind hybrid system to feed this combined load. The size of the components of the hybrid system was studied using the MATLAB code and the HOMER software.

3. WIND ENERGY

Wind results from the flow of air due to atmospheric pressure tendency. Wind moves from areas of higher pressure to areas of less pressure. The higher the atmospheric pressure inclination, the greater the wind speed and therefore, the bigger the wind energy which can be gained from the wind by using wind energy transforming device.

Wind production and flow are complicated due to certain circumstances. The Coriolis effect due to the Earth's self-rotation, uneven solar heating, and regional geographic situations are some of the critical circumstances that affect wind flow and production.

Though the earth intercepts only a little portion of solar radiation, it can provide nearly all of the earth’s power demands. The total solar energy collected by the surface of the earth is estimated to be approximately 1.8×10^{11} MW (Tong, 2010). Only 2% of this solar energy (i.e. 3.6 × 109 MW) is changed into wind power, and approximately 35% of the wind power is scattered within 1km of the surface of the earth. Thus, the usable wind energy that can be changed into different forms of power is nearly 1.26 × 109 MW (Tong, 2010). Given that this value represents 20 times the current global energy consumption rate, wind energy could in principle satisfy all the world's energy needs. (Tong, 2010).

Wind energy is a significant source of new energy production and a significant player in global power needs. Compared with traditional power sources, wind power has many advantages and benefits. Unlike fossil fuels that release dangerous gases and nuclear energy that produces radioactive waste, wind power is a clean and eco-friendly source of energy. Since wind energy is an unlimited and available power source, it is free and abundant in most countries of the world. Moreover, the widespread utilize of wind energy would assist decrease the need for fossil fuels, which could come to an end someday during this century, depending on their current consumptions. Therefore, being the most reliable source of power, wind power is considered to represent a significant part of the world's energy demand in the 21st century.

3.1. History of Wind Power Application

As a source of energy, it seems that the winds have been used even in early civilizations. The ancient civilizations records have shown that wind power was found and utalized separately in many parts of the world. The first possible application of wind power was in the form of sails to direct ships. The Egyptian civilization, even in 3000 BC, used boats and ships with sails (Gipe, 1995).

3.2. Wind Energy Characteristics

Accessible power in the wind is the kinetic energy of extensive sizes of air passing over the surface of the world. Wind energy can either be transformed into electricity by power conversion devices or applied directly for pumping water, sailboats or grinding gain. The blades of the wind turbine collect this kinetic energy, which is then converted into useful mechanical power or electrical energy that can be used depending on the application.

Power of the wind is a particular kind of kinetic energy in the air while it circulates. Wind power can either be changed into electrical power by energy transforming devices or applied directly to pump water, grinding gain or sailing ships (Tong, 2010).

3.3. Wind Energy

Kinetic energy is present when an object of a given mass is in motion with a translation or rotational speed (Tong, 2010). When the wind is in action, the kinetic energy in flowing wind can be defined as follows:

$$E_K = \frac{1}{2} m V^2 \tag{3.1}$$

where m is the mass of the air and v is the average veovity of the wind over a proper time of period. Wind energy can be determined by differentiating the kinetic energy of the wind over time

$$P_{wind} = \frac{dE_K}{dt} = \frac{1}{2} \dot{m} V^2 \tag{3.2}$$

A wind turbine of cross-sectional area A in m^2 is exposed to moving wind with speed V in m/s as showed in Figure 3.1.

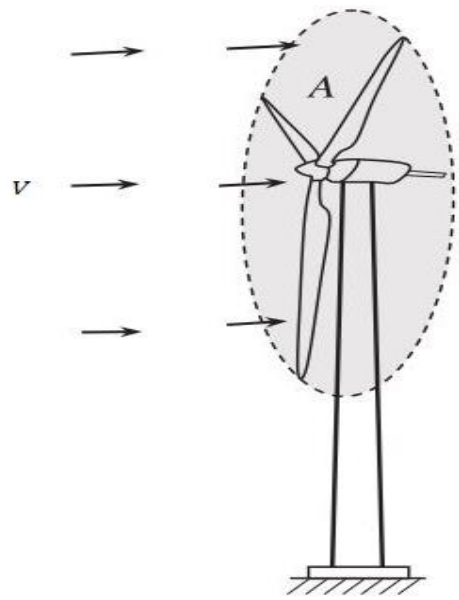

Figure 3.1 Wind flowing with speed V (m/s) towards area A (m2) (Tong, 2010)

Though, only a little amount of wind energy can be changed into electrical energy. When the air crosses over a wind turbine and turns the rotors, the equivalent wind mass flow rate is

$$\dot{m} = \rho A V \tag{3.3}$$

wherever ρ is the Density of the air and A is area of rotor of the turbine and v is the average wind speed. Replacing equation (3.3) into (3.2), the usable energy in wind Pw can be represented as

$$P_{wind} = \frac{1}{2}\rho A V^3 \tag{3.4}$$

An analysis of eqn (3.4) shows that to achieve a powerful wind energy, it needs a strong air velocity, an extensive height of rotors for obtaining a bigger rotor area, and a larger air density. as the generation of wind energy is equal to the cubic energy of the average wind speed, a little change of the speed of the wind can cause in a big difference in wind energy.

The following equation gives the most accurate estimate of wind power density.

$$^{P}/_{A} = \frac{1}{2}\frac{1}{n}\sum_{j}^{n} (\rho_j . V_j^3) \tag{3.5}$$

Where n is the epresentation of wind speed recording $\rho_j$and V_j are the j^{th} th Measure of the density of tha air.

3.3.1. Blade swept area

The swept area of the blade can be determined from the formula:

$$A = \pi[(l+r)^2 - r^2] = \pi l(l+2r) \tag{3.6}$$

Wherever l denotes the height of wind rotors and r is the radius of the hub. Therefore, by multiplying the height of the rotors of the wind turbine, the cleared area can be enhanced by the capacity up to 4.

If $l >> 2r$, $A \approx \pi l^2$

3.3.2. Air Density

Another important variable which directly changing wind energy production is air density that can be determined from the formula of state:

$$\rho = \frac{P_r}{RT} \tag{3.7}$$

Where P_r is the regional air pressure (Pa), and R is the constant of the gas (287 Jkg^{-1} K^{-1}), and T is the regional temperature of the air in K.

3.3.3. Energy Output

The output power curve of a wind turbine is a diagram that shows the production power of the turbine at different wind speed conditions. The turbine manufacturer generally provides the power curve. Accessible wind power from a typical wind turbine power curve is shown in Figure 3.2 and 3.3.

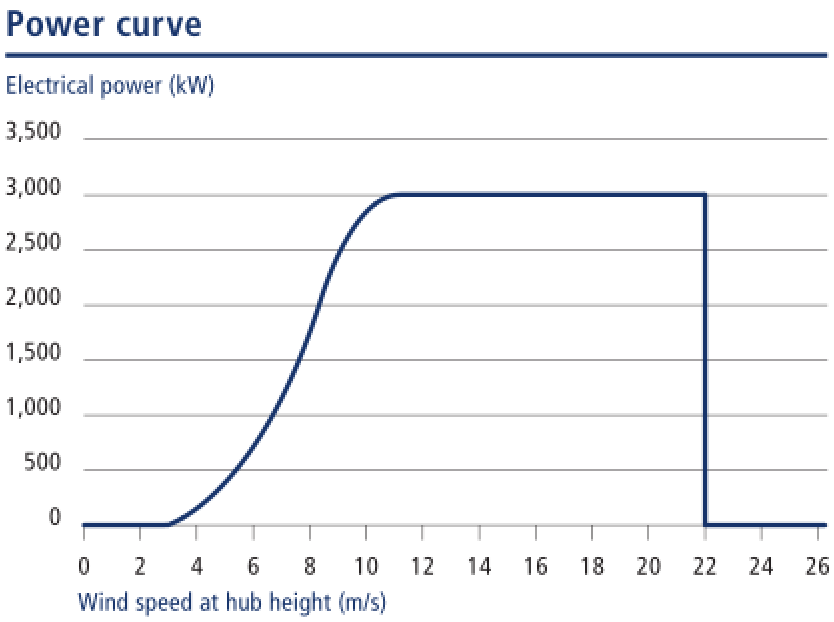

Figure 3. 2 Power curve of Senvion 3M-122

Figure 3.3 shows an illustration power curve of a wind turbine. output energy is zero from 0 to 3m/s wind speeds and that is because there is not enough kinetic energy in the air to drive the blade of the wind turbine. Normally, a technical data sheet where the cut-in speed, rated speed and cut-off wind speed of the wind turbine is provided by the wind turbine manufacturers.

The energy output of a wind turbine changes with wind velocity and all wind turbines have a particular energy production curve. With this kind of a curve, it is likely to estimate the power generation of a wind turbine with no regarding the technical specifications of its different parts.The power curve provides the electrical energy production as a function of the hub elevation wind speed.

Figure 3.3 shows an illustration of a power curve for a typical wind turbine. The operation of a given wind turbine generator can be associated with three essential features on the speed value:

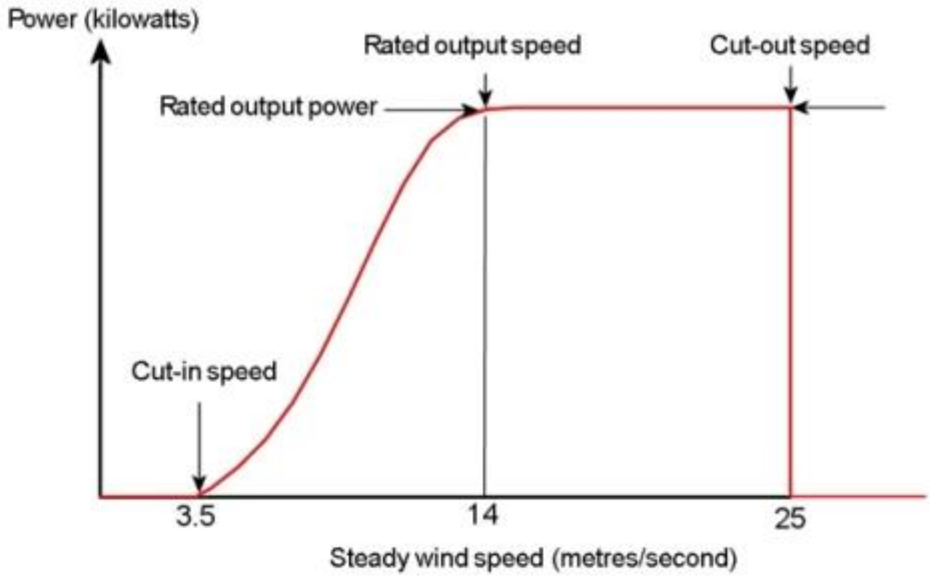

Figure 3. 3 Power urve of a typical wind turbine

- Cut-in: the smallest wind velocity at that the engine will generate usable energy.
- Rated output speed: the wind speed at that the nominal energy(usually the highest energy production of the turbine) is given.
- Cut-out speed: the highest wind velocity at which the turbine is permitted to produce energy (generally defined by engineering design and protection conditions).

3.4. Wind characteristics

Wind varies according to geographic position, season, time of day, and altitude above the surface of the earth, climate, and geographical terrain. Knowing features of wind speed will assist optimize the design of the wind turbine, improve wind speed measurement methods and choose wind farm locations.

In Somalia, the wind is a response to the north and south change of the Inter-Tropical Convergence Zone (ITCZ) and especially the Intertropical Front(ITF) (Muchiri, 2007). In the north, direction and speed of wind are determined by the different topography.

3.4.1. Wind speed

One of the primary features of wind energy production is the speed of the wind. certainly, wind velocity changes in both season and location, decided by several factors like geographic and climate situationssince the speed of the wind is a random variable, determined wind speed data are normally handled by applying mathematical ways.

With the various types of an anemometer, like the laser or ultrasonic, the most popular method is the cup anemometer, that is utilized for measuring the speed of the winds. The direction of the wind is sensed with a wind vane, that normally is installed together with the anemometer. A data logger gathers the speed and direction of the wind data from the anemometer and wind vane. Wind velocities are usually written as an average of 10-minute.

Wind speed is the most important factor affecting the amount of energy a wind turbine can produce. In fact, every wind power design, the speed of the wind is the initial responsible variable. The character of wind is that it is changeable which indicates its speed, temperature, and direction can vary. This variation can be from minute to minute. Therefore, it is exciting and important to study the fluctuation speed of the wind. The speed of wind changes with time, height, terrain and the geographical zone.

3.4.3. Weibull Distribution

The fluctuation speed of the wind at a selective location can be appropriately defined applying the Weibull distribution function, that shows the probability of different mean wind speeds happening at the place throughout a period of time. The probability density function of a Weibull random variable V – is:

$$f(V,k,\lambda) = \frac{k}{\lambda}\left[\frac{V}{\lambda}\right]^{k-1} exp\left(-\left(\frac{V}{\lambda}\right)^{k}\right) \tag{3.8}$$

Where λ is the scale element that is relatively associated with the mean speed of the wind and k is the shape factor that is a size of the diameter of the frequency. This two element can be calculated from the mathematical investigation of determined data of the speed of the wind at the location. It has been stated that Weibull distribution can provide excellent suits to found wind speed data.

4. SOLAR ENERGY

The sun is the most efficient power source in the world, it is also the final source of all power. Energy is released radially from the adequate surface temperature of the sun in the form of electromagnetic radiation called solar energy or sunlight. The sun has a powerful temperature of 5760K (Kalogirou, 2013). In the central area, the temperature is much higher than the surface. In fact, the sun is a constant fusion reactor in which hydrogen is changed into helium. The estimated output power of the sun is 3.8 $x10^{20}$ MW, which is equivalent to 63 MW/m^2 of the surface of the sun (Kalogirou, 2013). This energy spread out in every direction. The world receives a small portion of the released total available radiation that is only equivalent to $1.7x10^{11}$ MW; Although this is only a small part, it was evaluated that 1.4 hours of solar radiation in the world corresponds to global power requirements for approximately 900 EJ for 1 year (Kalogirou, 2013). Solar radiation produces a huge amount of power in the world. The total value of heat released from the sun's surface to the earth is about 10,000 times the annual global power consumption.

The two general methods used to produce energy from solar radiation are solar panels and solar thermal systems. The solar radiation received by the Earth's surface consists mostly of two elements: direct sunlight and indirect or scattered sunlight, which is the light that has been dispersed in the atmosphere by particles of dust and water. It is essential to estimate the average total solar radiation obtained over the year in order to determine the solar panel power production potential for a specific location.

4.1. Assessment of Solar Power Potential

Somalia has amazing sunlight throughout the year. The mean daily solar radiation received on a horizontal surface is approximately 5-7kWh/m^2 (Muchiri, 2007). The average daily total solar energy in regions of Somalia, estimated from the relative duration of sunlight, shows one of the highest in the globe. The solar power distribution in Somalia is also almost similar with average inclinations, not steeper than 16% between areas with higher radiation and others with less radiation which indicates that a solar panel produces almost the similar power, neglecting the position or angle of installation. The average sunlight duration is evaluated around 3000 hours/year (6-8.5 hours/day) (REEEP, 2010).

Figure 4.1 shows solar resources of direct normal radiation is Somalia and figure 4. 1 show Temperature distribution at some selected station in Somalia.

The temperature is not so high with a yearly average of 28 °C that in turn adds to the operational life of solar PV’s. All of these factors make Somalia as the most suitable place for broader application of solar technologies.

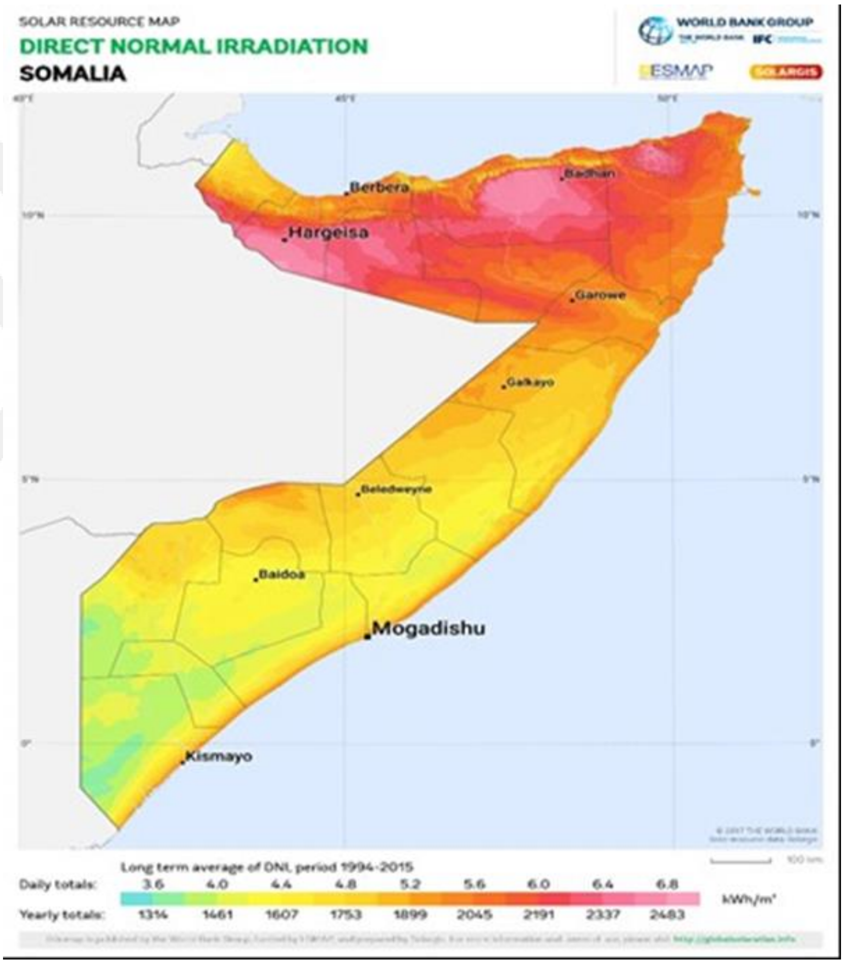

Figure 4. 2 Somalia Solar Resource Map (Solargis, 2018)

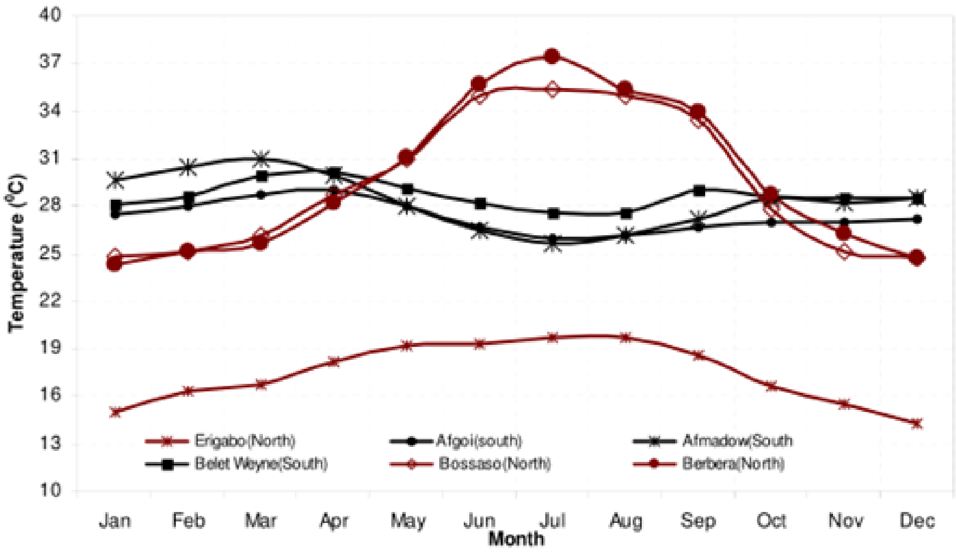

Figure 4. 3 Temperature distribution at some selected station (Muchiri, 2007)

Solar energy is similarly abundant in the Somali region and also a viable option throughout the country and is an increasingly popular option for rural communities, individual businesses, and facilities as the capital and technical skill required to exploit this resource is much lower than for wind. Unlike wind, which is stronger along the central coast and north, the most solar irradiation accrues to the north in Puntland and Somaliland. The use of solar technologies is suitable everywhere in Somalia.

5. WIND AND SOLAR RESOURCE ANALYSIS

Somalia is a windy nation thought the speed of wind changes seasonally, it is sufficient to produce enough wind power during the year. According to Muchiri (2007), average wind speeds usually change from 2m/s to 8.5 m/s (Muchiri, 2007). Although wind speed fluctuates significantly from one season to the next and during the year, the northern region has the highest average wind speed of 17 m/s in July while low wind speed values occur in most regions of southern Somalia (Muchiri, 2007).

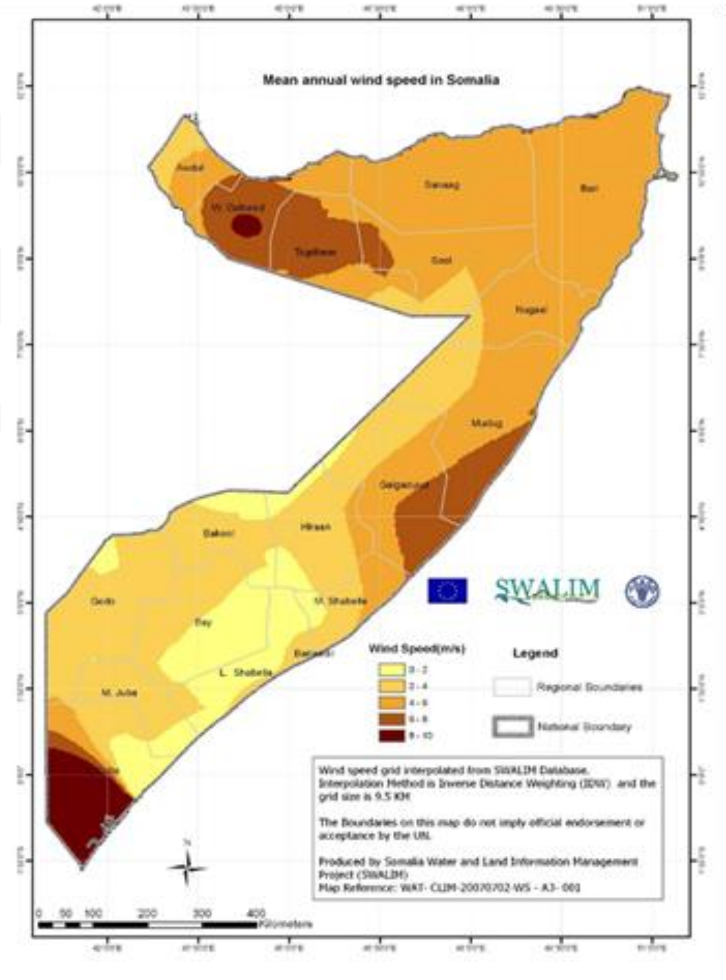

Figure 5. 1 Mean Wind Speed In Somalia(Muchiri, 2007)

Figure 5.1 shows the temporal distribution of wind speed in Somalia. Wind speed is highest throughout the southwestern monsoon, which extends from June to July. According to the graph above, the northern winds of the cities of Iscusiban, Berbera Hargeisa are much powerful than in the southern cities kismayo, luuq and

Mogadishu, particularly during the Haggai season which is between July-September. On average, the lowest wind speed values happen in April and October / November in the country, corresponding with the peaks of the two rainy seasons Gu and Deyr respectively (Muchiri, 2007).

VAISALA Global Wind Dataset provides average annual wind speed at 80 meters above ground. Average values are based on over 10 years of hourly data generated by advanced computer model simulations ((VAISALA, 2018)).

Figure 5.2 below shows VAISALA Somalia Wind Dataset 5km onshore wind speed at 80m above the ground.

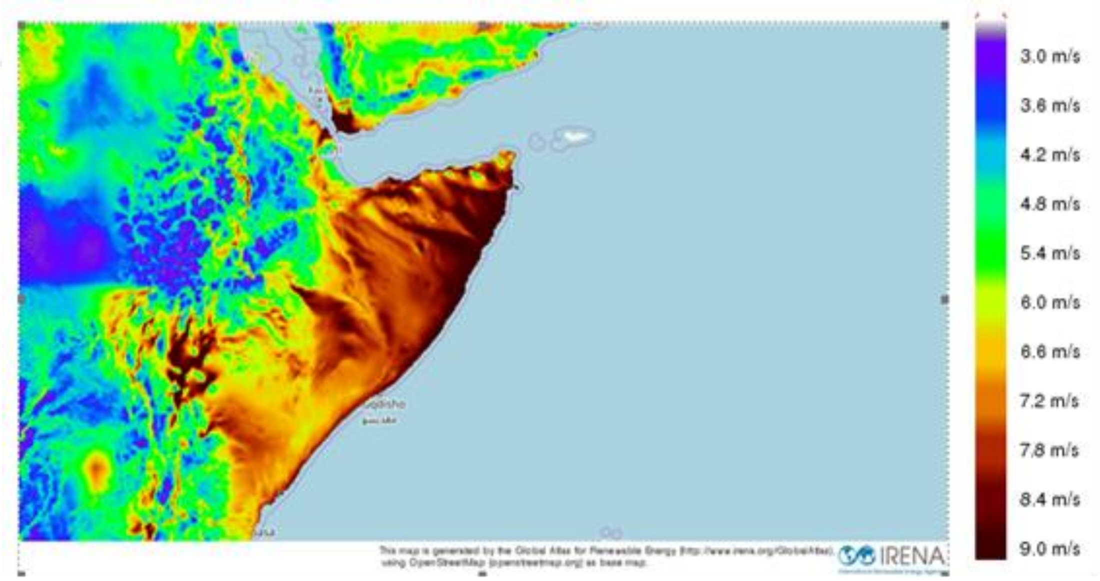

Figure 5. 2 Onshore wind speed at 80m above the ground (VAISALA, 2018)

5.1. Previous Studies

Pallabazzer & Gabow (1991) presented the results of wind speed analysis in Somalia. They found that the 85% of the country has wind resource that suitable for power production (Pallabazzer & Gabow, 1991). They identified and characterized two regions of different wind speed. And also they presented and discussed the wind-distribution features on 11 stations, together with the regional maps of the intensity of the wind and power of the wind .

Somali Ministry of Transport (SMT) installed 19 aeronautical stations in the country. Even though Somalia is mostly a flat country where some territorial extrapolation of data is permitted, 19 data points are a little sample to use to obtain information of the wind speed distribution on an area of bigger than 600.000 km^2. Some of the SMT data were doubtful and unreliable; uncertain information's were accepted from other circumstances about instrument collocation and altitude (Pallabazzer & Gabow, 1991).

Somali Ministry of Transport (SMT) installed 19 aeronautical stations in the country. Even though Somalia is mostly a flat country where some territorial extrapolation of data is allowed, 19 data points are a small sample to use to get knowledge of the wind energy distribution on territory more than 600.000 km^2. Some of the SMT data are irregular and unreliable; uncertain information's were gotten from other cases about instrument collocation and elevation.

Make allowance for these constraints of the SMT data, Somali National University (SNU) conducted a research program on wind speed pattern and exploitation with the help of the government of Italia in 1983. Pallabazzer and Gabow (1991) presented the result of A 5-year wind speed study result was presented in the research. The study has given significant results considering the wind speed potential in the country by classifying the wind speed pattern in different sites. 11 anemometer stations which Two wind-cup monthly mechanical anemographs, one propeller self-generating electric anemograph, and nine wind cup counter anemometers were installed in southern Somalia during 1983-1984 for the research. SNU staff made a manual reading of the recording document of the anemometer allowing up to 10 minutes of resolution (Pallabazzer & Gabow, 1991).

The Ffintoli's climatic study was the source of well-organized wind data on Somalia: 12 well-scattered station with wind-cup anemometers at 2 m of height above the ground were in installed in the country (Pallabazzer & Gabow, 1991). The Ffintoli's climatic study gathers and analyzes wind direction and speed of the wind data recorded for about 20 years. About the historical data of the aeronautical sites, they are addressed by the records of the Somali Ministry of Transport (SMT), usually like 5 or 8 data/ day, for years from 2 to 26 years, depending on the beginning of the site. Some of the SMT sites were considered in the research of SNU (Pallabazzer & Gabow, 1991).

The general regime of wind speeds throughout the year is that of moderate winds, on average from 3 to 11 m / s for the different stations. Winds are generally lighter during the transition months.

5.2. Assessment of wind energy potential

Pallabazzer and Gabow (1991) pointed out that the wind speed is sufficient enough in Somalia, particularly along the shoreline, to provide the people with primary power demands. It was also observed that wind consistency was relatively similar across the country. Their study calculated mean cubic and linear average wind speeds based on anemometer data obtained from government weather sites in the 1980s.

Figure 5.2 shows the monthly mean wind speed in Somalia measured at an altitude of 50m above the ground.

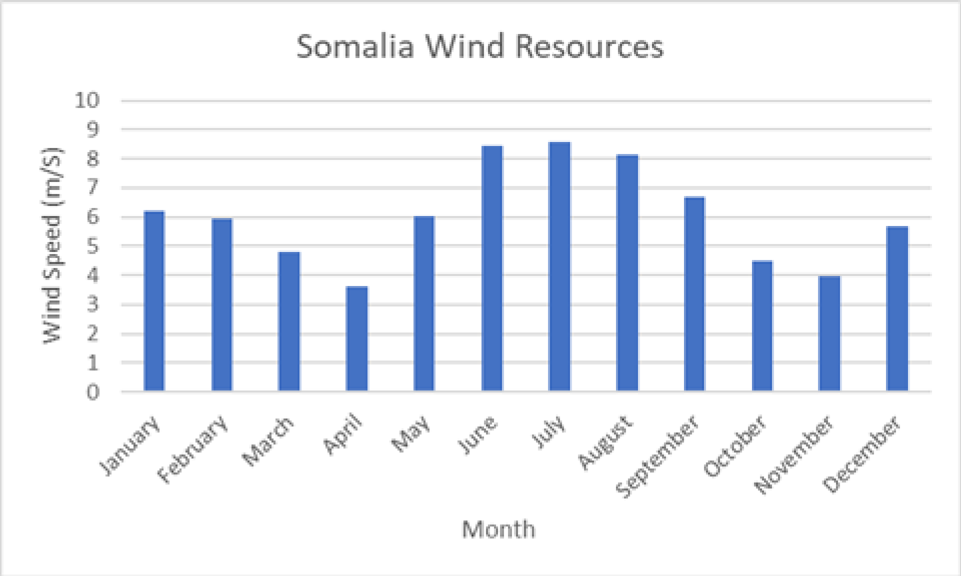

Figure 5. 3 Monthly averaged wind speed of Somalia.

It can be seen that the highest measured wind speed is between June and September, with a monthly mean speed higher than 8 m / s in July, while it is the lowest in April. These data on wind speed in Somalia show that wind energy can be used to produce enough power in most of the months of the year to replace current diesel plants.

5.3. Site Selection

Under site election, the main goal was to study the sites that having the biggest wind speed potential of the country. Figure 5.4 below shows wind speed map of Somalia at 50m hub height. This map is published by the World Bank Group, funded by ESMAP, and prepared by DTU and Vortex.

Under site selection, the primary objective was to filter the sites having highest wind potential a significant portion of the habitable parts of the country. Figure 5.4 below shows wind speed map of Somalia at 50m hub height. This map is published by the World Bank Group, funded by ESMAP, and prepared by DTU and Vortex (DTU, 2017).

Site selection was based wind power potential map published by the Global Wind Atlas alongside The World Bank, in partnership with the Technical University of Denmark (DTU Wind Energy) and Vortex. The Global Wind Atlas presents a high-resolution wind climatology at 50, 100, 200m hub altitudes above the surface for the globe (onshore and 30 km offshore) (DTU, 2017).

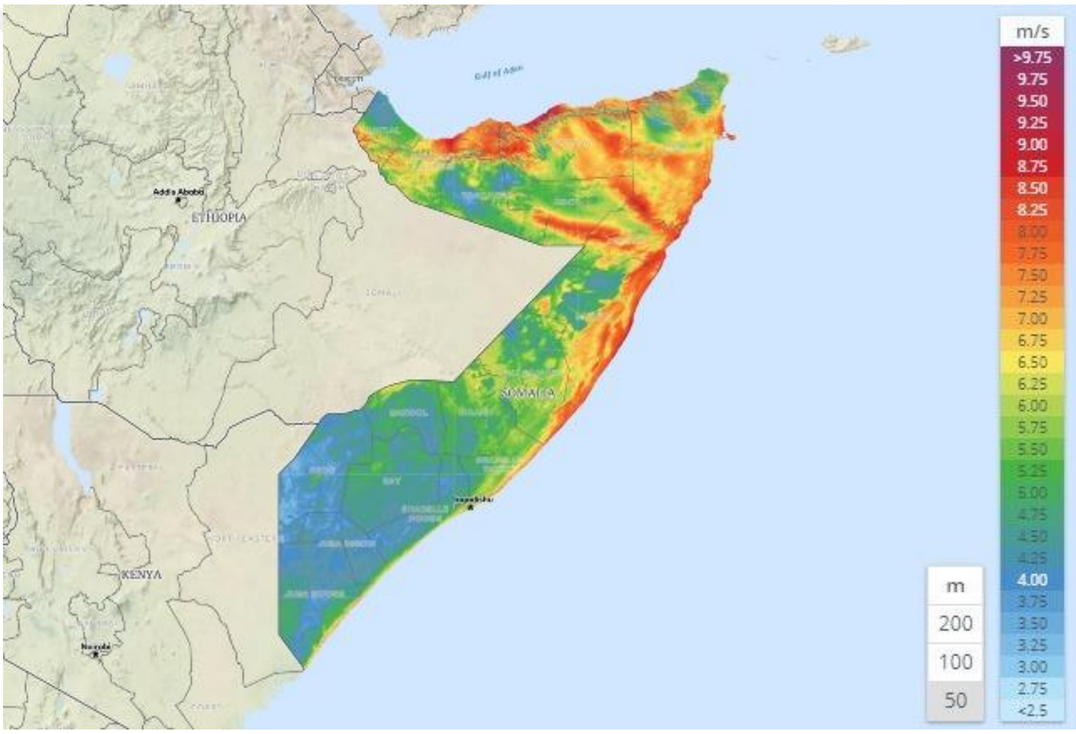

Figure 5. 4 wind speed map of Somalia at 50m hub height (DTU, 2017)

The four selected regions are following;

- Mogadishu
- Hargeisa
- Kismayo
- Bosaso

5.3.1.1. Wind Energy in Mogadishu

Mogadishu, the largest and most populous city in Somalia, is located in the coastal region of Banaadir, in the Indian Ocean, with a population of more than 2.5 million.

Mogadishu, the capital and most populous city of Somalia, is Located in the coastal Banaadir region on the Indian Ocean with a population of more than 2.5 million residents. Wind speed data used for this analysis are downloaded from NASA Surface meteorology and solar energy database (NASA, 2018). Mean monthly values of wind speed at 50 m above ground level in Mogadishu over a period of more than 10 years (July 1983-June 1993) are shown in Table 5.1 and Figure 5.5.

Table 5.1. Average wind speed per month of Mogadishu at 50 m altitude(NASA, 2018)

Month	Wind Speed (m/s)
January	6.22
February	6.18
March	4.56
April	3.58
May	5.46
June	6.99
July	7.26
August	7.19
September	6.34
October	4.6
November	3.77
December	5.43
Annual Average	**5.632**

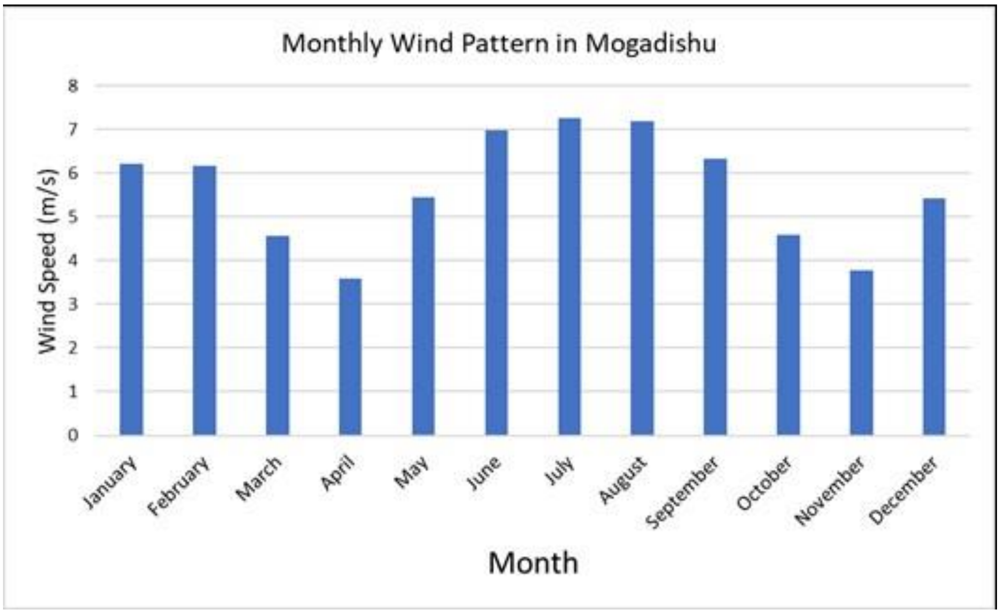

Figure 5. 5 Monthly wind speed in Mogadishu

It can be observed from the above Table 5.1 and Figure 5.5 that the lower wind speeds happen within March to April and October to November whereas the speed of winds is usually higher during May to September and during December to February.

According to the above figures in Mogadıshu, the highest estimated mean monthly wind speed is 7.26 m/s that can be seen in July, while a minimum value of 3.58 can be observed in April; The annual average wind speed is 5.63 m/s.

The most important characteristics are therefore very persistent monsoon winds, from southwest through the midpoint of the year, and from the northeast at the start of the year with relatively long transition periods between monsoons, of about two months each. Although not very calm, the winds are generally light to moderate.

5.3.1.2. Solar Energy Potential in Mogadishu

Average solar radiation and temperature for Mogadishu are displayed in Table 5.2. A graphical image of the monthly mean solar energy of Mogadishu is presented in Figure 5.6.

Table 5.2. Monthly mean solar radiation potential in Mogadishu

Month	Daily radiation (kWh/m^2/day)	clearness Index
January	6.09	0.619
February	6.63	0.647
March	6.55	0.625
April	5.75	0.559
May	5.44	0.553
June	5.08	0.533
July	5	0.519
August	5.41	0.539
September	5.8	0.561
October	5.39	0.526
November	5.31	0.537
December	5.51	0.57
Avarege	**5.663**	0.520

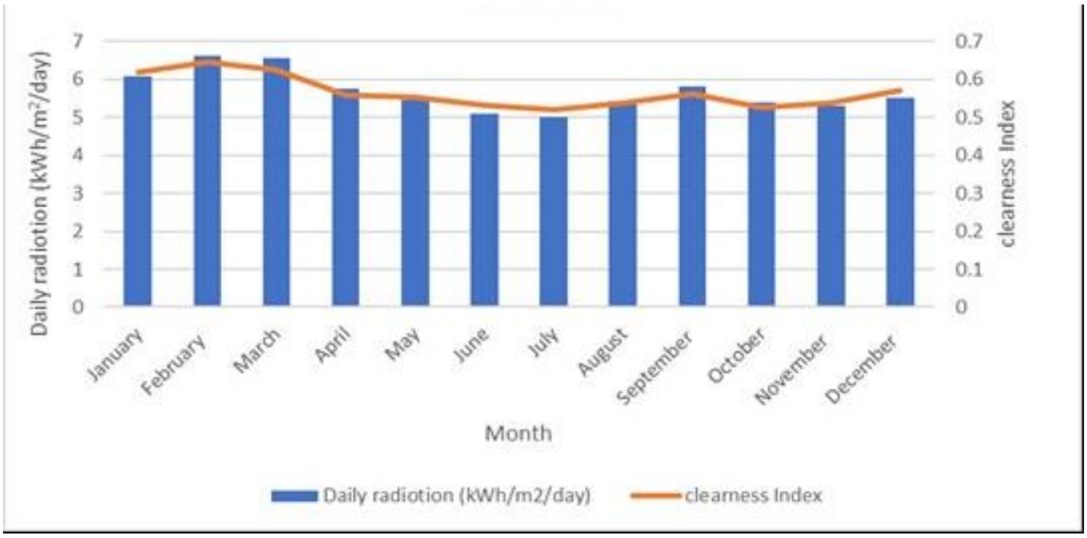

Figure 5. 6 Monthly solar radiation potential in Mogadishu

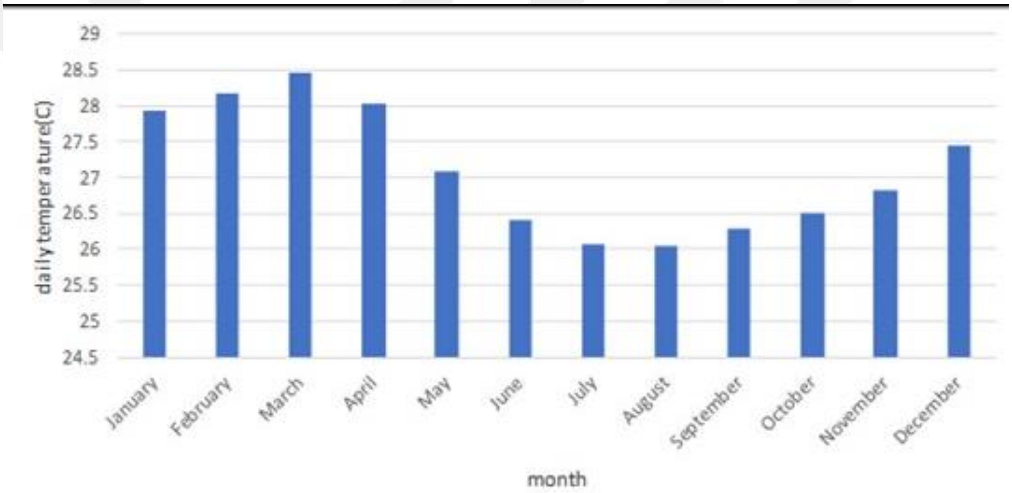

Figure 5. 7 Average temperature in Mogadishu

The measured solar radiation has the highest value of 6.55 kWh/m^2 /day in March, the lowest value of 5 kWh/m^2 /day is in July, and an annual mean of 5.663 kWh/m^2 /day while the mean clearness index from the Selected site is 0.520.

5.3.2.1. Wind Energy in Hargeisa

Excellent wind speed exists in regions round Hargeisa on the northwest of Somalia. the speed of the wind is more powerful towards the inner land of the north than near the sea, because of the great mass which covers the region. Measured wind speed data from NASA Surface meteorology and solar energy database website evaluated a 10 year at 50m in Hargeisa is applied for the study.

Mean monthly wind speed at 50m height in Hargeisa area is presented in Table 5.3 below, whereas Figure 5.8 provides the graphical illustration of the monthly mean wind speed fluctuation.

Table 5.3. Monthly mean solar radiation in hargeysa

Month	Wind Speed (m/s)
January	5.760
February	5.290
March	4.460
April	3.280
May	4.300
June	7.390
July	8.180
August	7.500
September	5.650
October	3.780
November	4.620
December	5.360
Average	**5.464**

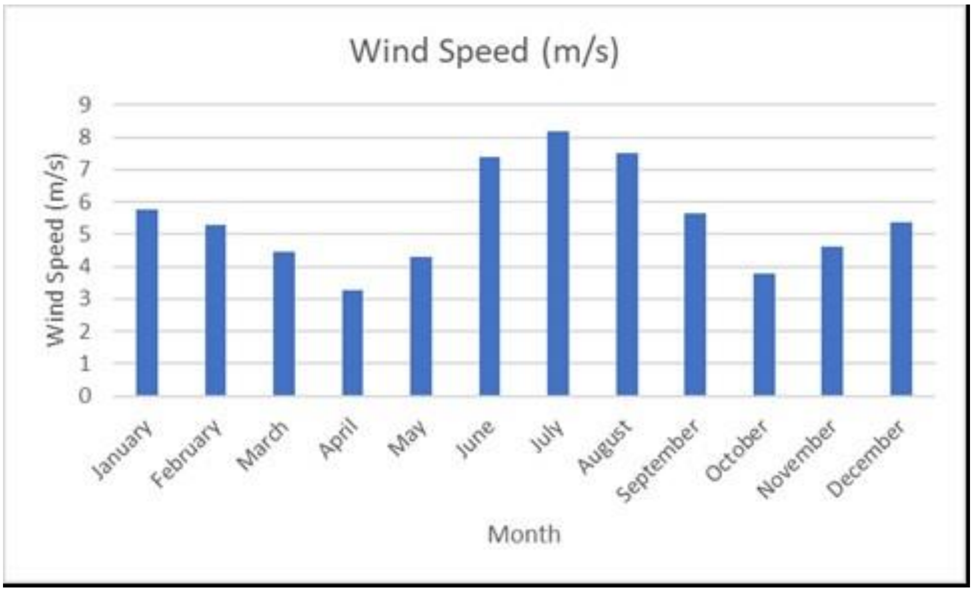

Figure 5. 8. Monthly wind model in Hargeisa

It can be observed from Table 5.3 and Figure 5.8, it can be seen that the higher wind speeds happen during June to September and December to February while whereas the speed of winds is usually lower from March to May and during October to November.

According to the above Figure 5.6 in Above, the highest evaluated wind speed is during the season from June to September achieving a monthly mean wind speed of higher than 8 m/s in July, whereas it is weakest in April.

Estimated mean monthly wind speed is 8.16 m/s that can be seen in July, while a minimum value of 3.28 can be observed in April; The annual mean wind speed is 5.464 m/s.

5.3.2.2 Solar Energy Potential in Hargeisa

Average solar radiation and temperature of hargeysa is shown in Table 5.4 and Figure 5.9.

Table 5.4. Monthly average solar radiation in Hargeisa

Month	Daily radiotion (kWh/m2/day)	clearness Index
January	5.37	0.601
February	6.03	0.628
March	6.39	0.624
April	6.22	0.592
May	6.38	0.614
June	6.34	0.619
July	6.26	0.61
August	6.33	0.609
September	6.29	0.612
October	5.82	0.597
November	5.59	0.617
December	5.16	0.594
Average	**6.015**	**0.60975**

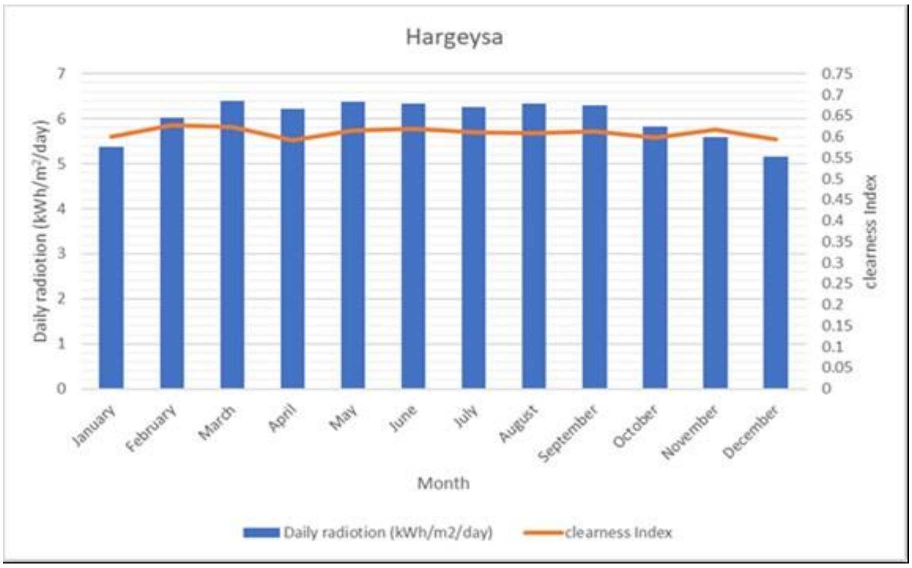

Figure 5. 9. Average solar radiation of Hargeisa

The measured solar radiation in Figure 5.9 and Table 5.4 has a maximum value of 6.55 kWh/m^2 /day in Marh, the lowest value of 5 kWh/m^2/day is in July , and an annual mean of 5.663 kWh/m^2 /day. The mean clearness index from the this site is 0.520.

5.3.3.1. Wind Energy Potential in Bosaso and Kismayo

Average monthly wind speed at 50m height for Kismayo and Bosaso cities is listed in the Table 5.5 below, while Figure 5.10 and 5.11 presents the of the monthly variation of mean wind speed.

Table 5.5: Monthly mean wind speed of Bosaso and Kismayo cities at 50m altitude above the ground

	Kismayo	Bosaso
Month	Wind Speed (m/s)	Wind Speed (m/s)
January	5.280	7.090
February	5.420	6.230
March	4.250	5.280
April	3.960	4.360
May	5.270	4.800
June	6.490	10.170
July	6.780	12.520
August	6.780	11.850
September	6.200	7.090
October	5.080	4.560
November	4.050	5.550
December	4.570	6.790
Average	5.344	7.191

It can be seen that the highest determined wind speed in Kismayo is during the period from June to September approaching a monthly mean wind speed of higher than 6 m/s and it is the lowest in April with 3.96m/s while highest evaluated wind speed in Bosaso is higher than 12 in July and lowest in October which is 4.5 m/s. The annual mean wind speed in Bosaso is 7.2 m/s which is moderate wind speed whereas the mean annual wind speed in Kismayo is 5.34 m/s.

Monthly wind speed variation of Bosaso and kismayo is presented in Figure 5.10 and 5.11 below.

Figure 5. 10 Average wind speed of Bosaso

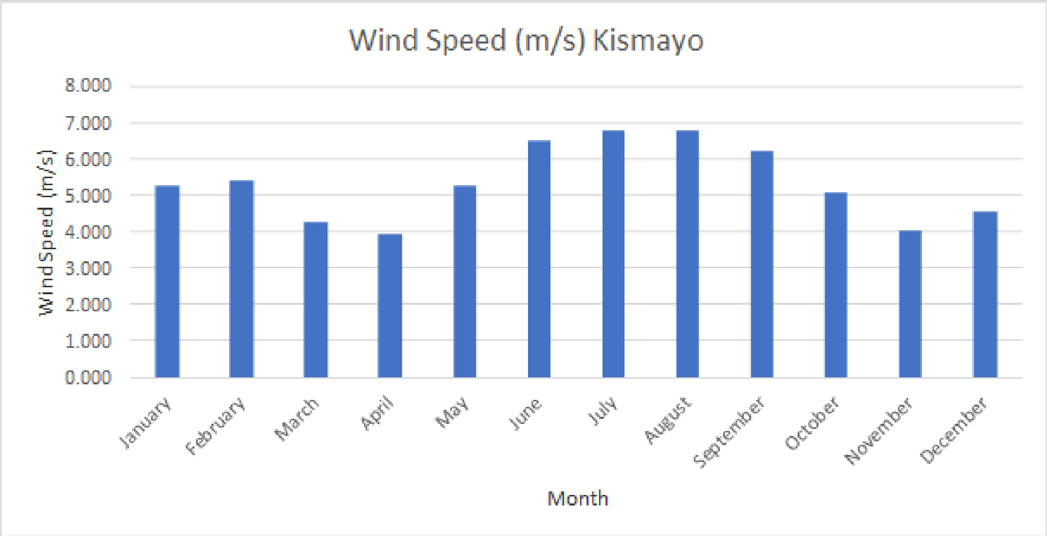

Figure 5. 11 Average wind speed of Bosaso

5.3.3.2. Solar Energy Potential in Bosaso and Kismayo

The Table 5.6 below displays the monthly solar radiation and clearness index of Bosaso and Kismayo cities.

Table 5.6. Monthly mean solar radiation and clearness index of Bosaso and Kismayo cities

	Bosaso		Kismayo	
Month	Daily radiation (kWh/m2/day)	clearness Index	Daily radiation (kWh/m2/day)	clearness Index
January	6.030	0.692	6.010	0.595
February	6.770	0.717	6.370	0.612
March	7.410	0.729	6.170	0.587
April	7.510	0.713	5.410	0.531
May	7.330	0.698	5.240	0.545
June	6.770	0.652	4.860	0.524
July	6.650	0.64	5.100	0.543
August	6.870	0.657	5.390	0.545
September	7.180	0.701	5.670	0.549
October	6.960	0.724	5.700	0.549
November	6.160	0.696	5.460	0.539
December	5.770	0.682	5.690	0.572
Average	**6.784**	**0.694**	**5.589**	**0.558**

The average annual daily radiation of Bosaso is 6.784 kWh/m^2/day while Kismayo city is 5.589 kWh/m^2/day. The average clearness index of Kısmayo and Bosaso are 0.520 and 0.5 Respectively.

6. FEASIBILITY STUDY OF THE HYBRID SYSTEM

The concept of hybrid energy generation is a system of producing and using electrical power of more than one source of energy as part of a combined system. The Sources of power production can be traditional sources such as oil, natural gas, coal, or unconventional, like solar, wind, hydro, biomass either stand-alone or connected to the grid.

As part of this thesis, an off-grid solar-wind combination system for electricity generation to a small load is proposed. Figure 6.1 illustrates a typical stand-alone wind-solar hybrid system. The system combines solar photovoltaic panels that produce electricity in DC and wind turbines, which can produce electricity in DC or AC And (power conditioning) To associate these sources of electricity to a load and battery bank. combined wind turbines and photovoltaic solar panels provide higher reliability than any of them because the power supply to the community cannot entirely rely on one of these sources alone.

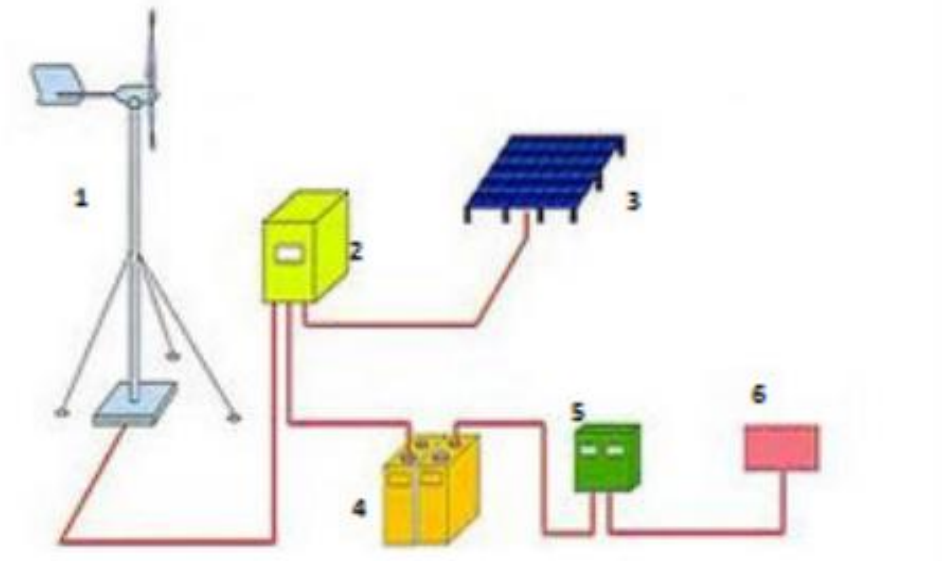

Figure 6. 1 Stand-alone hybrid system schematic configuration

It is believable that a combined wind-solar system has several benefits. When the resources of solar and wind energy generation are utilized together, reliability is enhanced, and the power supply of the system is improved; the deficiency of one type of power, an alternative power would be ready to continue the supply the power, and, consequently, the capacity of the storage system of the battery can be decreased. Other benefits of the hybrid system include system stability, lower maintenance requirements and Contribution to the reduction of pollution emissions

Wind energy and solar energy are very irregular sources of electricity production. The time intervals in that the variations happen to cover various time ranges, from seconds to years. These changes can be divided into periodic fluctuations (diurnal or yearly variations) and non-periodic fluctuations linked to the change of the weather (Tong, 2010).

Throughout a day, the sunlight is high whereas the wind is light. during the night, the wind is increased because of the significant variations of the temperature over the surface of the ground. The investigations and analysis data of solar-wind combination energy methods have determined that the best connection of the solar-wind hybrid arrangement occur within 0.70 and 0.75 of solar power to load ratio with the reduced price of the life cycle. For all load needs, the leveled cost of energy for the solar-wind hybrid system is always cheaper than that of separate solar or wind system.

6.1 The Model and the Hybrid Setup with HOMER

The Hybrid Optimization Model for Electric Renewables (HOMER) is a computer program developed by the National Renewable Energy Laboratory (NREL) that can assist configure, simulate, evaluate, and optimize multiple design selections from different systems (Energy, 2018). It can be used to design several systems: off-grid or grid-connected, isolated or dispersed generation and traditional or renewable technologies.

The model inside the software helps to predict the layout of decentralized systems and can combine conventional and alternative technologies: solar photovoltaic, wind, gasoline or diesel, biofuel, micro-turbines, small hydropower, thermoelectric, fuel cell, and battery bank. The software contains information on websites that supply data resources, like the speed of the wind and solar energy and more data resources of energy elements like generators, solar panel, wind turbines, storage system.

The Homer software can be applied to evaluate a large number of alternatives to identify the cheapest cost combination of components that match the load demand, based on a daily analysis of the input variables, like solar radiation and wind speed that is capable of supplying the electricity demand to a specific community in an optimal way. HOMER also provides a primary comparative analysis of the different electrification options and predicts the results of changes in load parameters, as well as the environmental impact and potential greenhouse gas emissions.

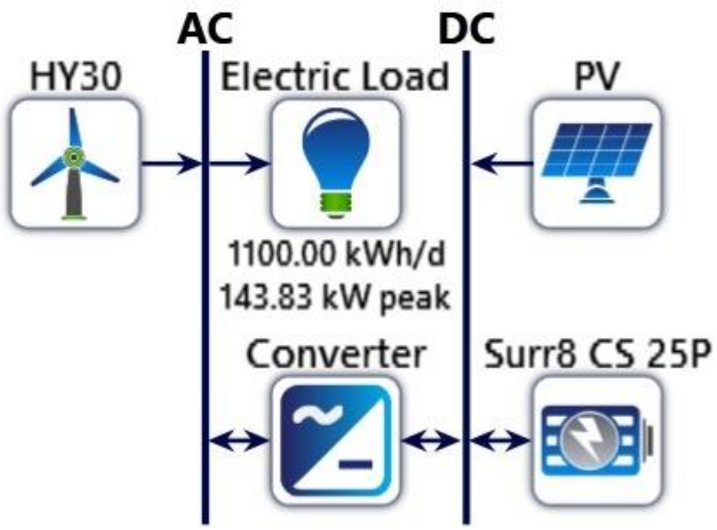

Figure 6. 2 Configuration of standalone hybrid solar-wind system in HOMER

In order to use the homer, input that specifies technology alternatives, resource availability and component costs are provided to the software. HOMER applies these variables to simulate different system arrangements or combinations of components and produces a list of possible results arrangements ordered by net present cost(Energy, 2018).

The Stand-Alone Solar wind combination arrangement includes solar panels, wind turbines, batteries, and converters. The model is applied as a device to perform the investigation. Figure 6.2 presents the arrangement of the isolated hybrid energy setup. The software needs an input variable in order to study the system. Those variables are illustrated below in detail.

6.2 Location Selection

The purpose of the study is to study and design an independent wind-solar hybrid energy production method that generates electricity demand at a small load. As presented in the previous chapter, the potential resources of solar and wind energy of different geographical regions were analyzed, and a detailed investigation of four selected places has been carried out in the previous chapters.

Wind speeds in Somalia are, almost everywhere, light to moderate. Only on the north coast are strong winds a significant feature affecting people activities. The general pattern of wind speeds throughout the year, is that of moderate winds, averaging between 3 to 11 m/s for the different locations. Over the year, the winds are the strongest round Hargeisa, with an average speed of more than 10 m/s. Rather less strong winds occur over the rest of the northern areas and the eastern half of the Central Regions. There is a gradient in Central and Southern Regions from east to west, with the lightest winds in the country occurring in Bakool, Gedo and the western parts of Hiraan, Galgadud and Mudug.

For the modeling of the solar-wind combined energy system proposed in this thesis, the Mogadishu site was chosen, which is situated in the Banadir coast of the Indian ocean. It is assumed that the location of the community would be in the suburbs to assure that the wind speed and solar radiation of the location would not be a major disadvantage for installation.

6.3. Load

One of the most critical steps in designing a hybrid system is deciding on the load demand of the system. Table 6.1 shows the electrical load requirement of a model community of about 100 families, with an average of 7 family members in each. The most important utilization of energy in these houses are essentially lighting, water pump, refrigeration and entertainment. Moreover, in addition to these primary uses, there are other likely uses of electricity in the community, such as the use of washing machines, irons and some electronic devices.

The water pump has an estimated rating power of 5 kW, with a pumping potential of 4m^3/h. The pump provides 20 m^3/day for the 100 households (200 liters per house). The total consumption of power by the pumps is estimated to be 20 kWh/day for the houses.

Table 6.1 load description of the House

Load Usage	Quantity	Hours	Power(WATT)	KWh Consumtion
Lighting	8	8	20	1.28
Water Pump	1	4	50	0.20
TV	1	10	150	1.50
Washing machine	1	2	450	0.90
Refrigetor	1	24	120	2.88
Iron	1	1	1000	1.00
Computer	2	2	100	0.40
Phone Charger	3	2	50	0.30
Other Electronics	1	5	500	2.50
Daily Consumption of one household				**10.96**

The mean power consumption of the model of the community is 1100 kWh/day with a peak demand of 143.8 kW. Thus, the predicted average data of energy demand was entered as input data in the Homer software, for characterization of the electricity demand of the particular community in consideration. The lifetime of the project is expected to be about 20 years.

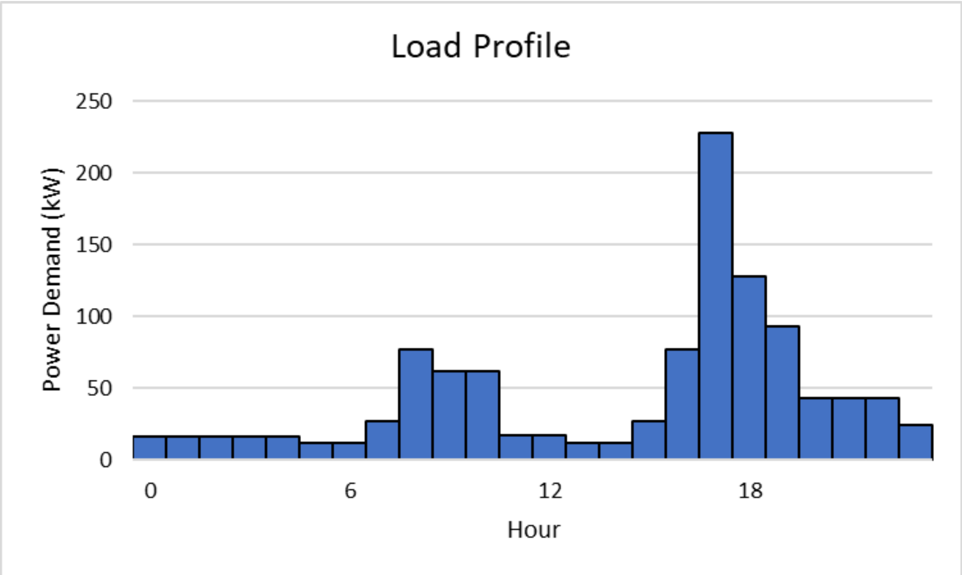

Figure 6. 3 Daily load profile of the community

6.3. Wind Data

For this study wind data collected at 50 m height was used as wind resource input data in HOMER. Data resources are obtained from NASA. Figure 6.4 shows the monthly mean wind speed measured for Mogadishu. The mean wind speed varies from 3.77 m/s to 7.26m/s with an annual mean of 5.632m/s.

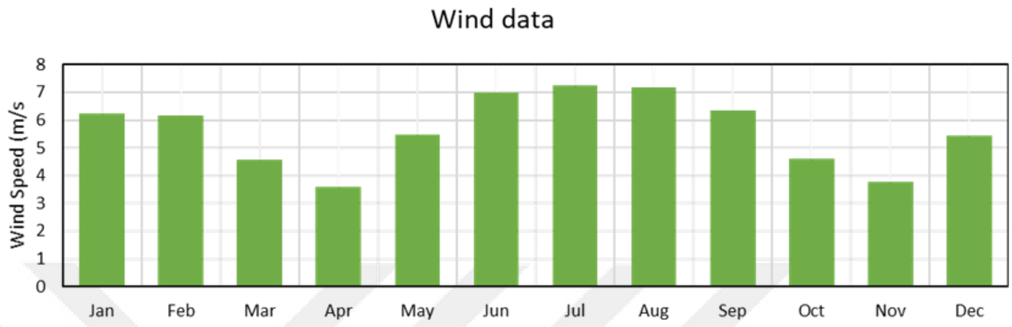

Figure 6. 4 Monthly mean wind speed

6.4. Solar Radiation Data

Solar radiation data shows the amount of global solar energy that the surface of the earth receives in a typical year. The monthly solar radiation and clearness index given by HOMER software is displayed in Figure 6.5 below.

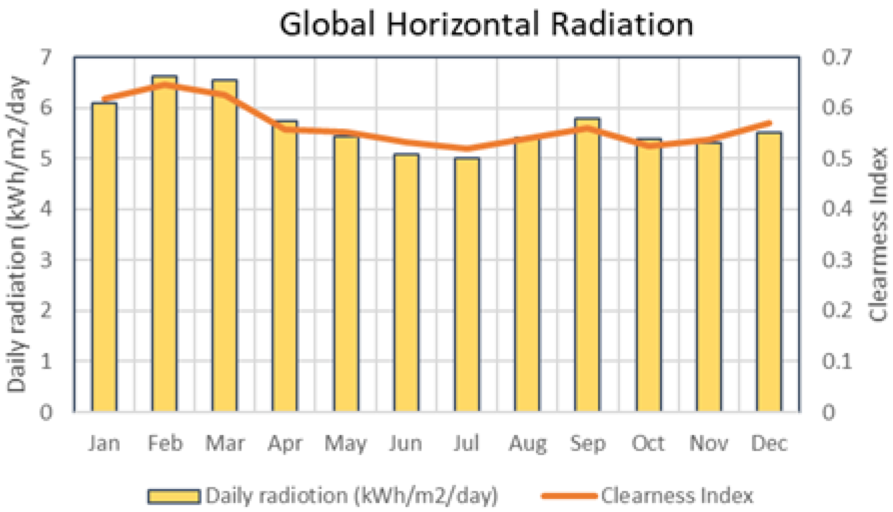

Figure 6. 5 monthly averaged solar radiation and clearness index

The mean daily radiation varies from 5.08 kWh /m^2/day to 6.63 kWh /m^2/day, with an annual mean of 5.66 kWh /m^2 / day. The mean clearness index is 0.57.

6.5. Wind Turbine

Wind turbine with 30kW Ac rated power was selected for the design in order to use the low wind speed efficiently. The capital cost of one turbine is estimated around $15000. The replacement value is considered to be the equal to the capital cost, with an evaluated yearly operating and maintenance (O&M) costs of $300/yr. The considered maintenance costs for current wind turbines are in the range of 1.5% to 2% of the cost of the turbine per year.

The data taken from the suppliers and wind turbine features were entered into HOMER, and Figure below presents the power curve of the 30kw wind turbine. Additionally, the hub of the machine is considered to be at the altitude of 25m and the lifetime of the wind turbine was designed for 20 years.

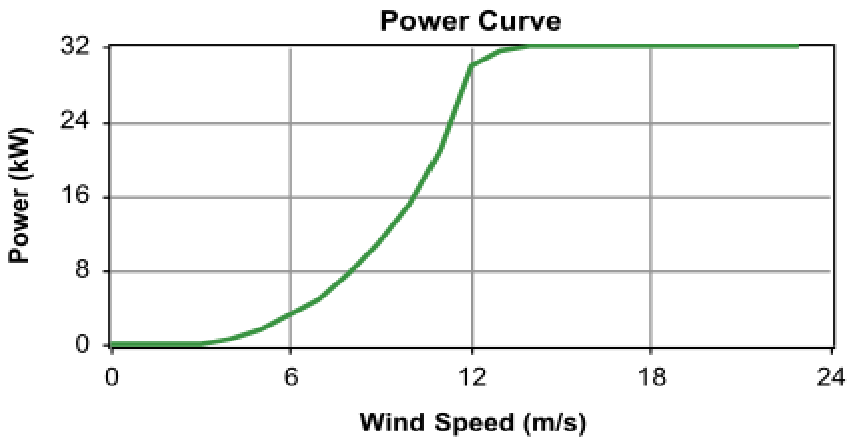

Figure 6. 6 The power curve of the 30 kW wind turbine

6.6. Solar PV Modules

For the proposed system, 300 Wp polycrystalline solar modules was selected. Estimated setup cost of 1kw solar panel system will be 1500 $ With a similar replacement cost and the O&M cost of total investment cost is considered nearly zero. A derating factor of 90% is used to the power generation from every panel for a lifetime of 20 years

6.7. Storage System

The storage system applied in this combination setup is the Surrette 8CS25P batteries. The selected battery has a capacity of 8 V and 800 Ah and has a lifetime of

1300 kWh per battery. HOMER simulations provide the required number of batteries to meet the storage demand. Minimum state of charge of the battery is assumed to be 40%. The round-trip efficiency (RTE) of the storage is modeled to possess a steady performance of between 80-85%. The cost of one battery is estimated to be $2200 and the replacement cost was taken at the same price. The O&M cost is estimated to be small and therefore was fixed to 0.

6.8. Converter

A converter is needed to change DC to AC or AC to DC. Several converter sizes of 5 kW with installation costs of $ 2,000 were considered in the HOMER software for the designed system. And the replacement cost was taken at the same price. The O&M cost is estimated to be small and therefore was fixed to 0. The inverter and rectifier efficiencies are assumed to have efficiencies of 0.9 and 0.85 for this study.

7. RESULTS AND CONCLUSIONS

Hybrid optimization model for electric renewables (HOMER) version 3.12 is used for the optimization model design process for evaluating the best selection for sizing the hybrid system. The collected results of the modeled solar-wind hybrid energy production system are shown and discussed in this chapter.

7.1 Results Obtained in the Simulations

HOMER simulates the performance of a system by performing power balance estimates at each time interval of the year. For every time step, Homer matches the electrical need during this time step to the power that the setup can provide during this step. Then determines the energy streams to and from every element of the arrangement. HOMER also determines, at each time step, whether the batteries should be charged or discharged.

HOMER makes these power balance predictions for every system arrangement that needed to be analyzed. It then finds if an arrangement is possible, (i.e., if it can fit the power requirement under the specifications that has been defined), and evaluate the expense of building and running the system over the life cycle of the design. The system cost calculations evaluate for costs like capital, replacement, operation and maintenance, fuel, and interest (Energy, 2018). After simulating all of the available system arrangements, HOMER presents a table of arrangements ordered by net present cost (NPC), sometimes called life-cycle cost, that can be used to compare system combination choices.

The NPC of a system is the present value of all the prices the system acquires over its design life cycle, minus the present value of all the revenue it gets over its lifetime. HOMER Optimizer analyzes the process of finding the least expensive system and speeds up the search for the optimal system over a range of sensitivity values, especially if the range is wide. It also facilitates the identification and comparison of different system designs.

The generated list is formed in two forms; a categorized form; where particularly the minimum cost system arrangement is regarded for every model of a system and in an overall form in which the highest ranked system arrangements are recorded based on their net present cost (NPC).

Table 7.1 shown below summarizes the categorized configurations of a list of the feasible configurations of system components for electricity generation.

Table 7.1 HOMER Simulation Categorized Results

PV (kW)	HY30	Surr8 CS 25P	Converter (kW)	Dispatch	NPC ($)	COE ($)	Initial capital ($)	Ren Frac (%)
179	13	134	124	CC	73,927.70	0 .16	768,346.20	100
	36	219	134	CC	1,206,069.00	0.23	1,018,152.00	100
406		253	136	CC	1,255,918.00	0.24	1,155,471.00	100

The first row in Table 7.1 above shows that 13 wind turbines, a 179-kW photovoltaic module and 134 batteries with a 124-kW converter provide the most cost-effective system design. This combination has a COE of $ 0.16 / kWh and an NPC value of $ 873,927.70. The Wind turbine-battery-Converter setup is the second-best cost-effective arrangement with NPC of $1,206,069 and COE of 0.23 $/kWh, and it contains 36 wind turbine, 219 batteries with a 134-kW converter and. There is another system in row 3 containing 406 photovoltaic module, 235 batteries, and 136 kW Converter having about a total NPC of $1,244,918 and CEO of 0.24 $/kWh.

7.2 Financial Evaluation and technical

It can be seen that the hybrid system1 offers low costs of Operation &Maintenance(O&M), Cost of Electricity (COE), and net present cost (NPC) compared to the other systems of isolated wind or solar systems alone. Table7.2. below shows the percentage of electricity generation from each of the system components.

Table 7.2. Electrical energy production for the categorized results

	System 1-Pv-WindTurbine		System 2-PV		System 3-WindTurbine	
Production	kWh/year	%	kWh/year	%	kWh/year	%
PV array	297,975.00	31.20	672,065.00	100.00	0.00	0
Wind turbine	654,009.00	68.80	0.00	0.00	181,101.00	100
Total	951,984.00	100.00	672,065.00	100.00	181,101.00	100
NPC	$873,928		$1,255,918		$1,206,069	
COE	$0.164		0.24		$0.23	

Total annual energy production from the combination system 1 is 951,984.00 kWh, where solar provides with 297,975.00 (31.2%) and 654,009kWh (68.5%) are received from wind. Total annual power generation system 2 is 672,065kWh are received from solar where Total annual power generation system 3 form wind turbine is 181,101. The combination of wind-solar and battery design is the best system to fit the requirement for electricity at the lowest cost. Figure 7.1 displays the monthly average energy generation of the selected hybrid arrangement.

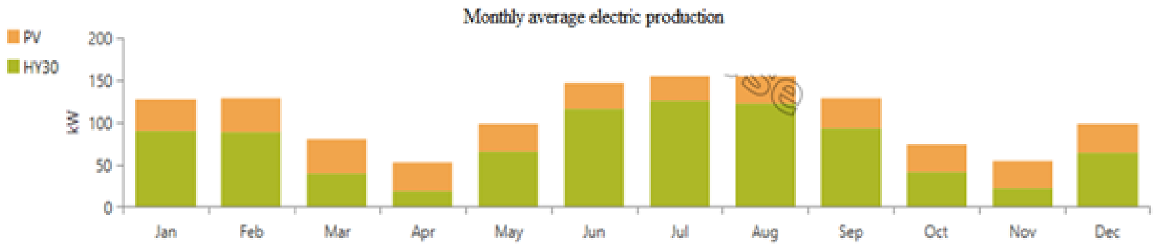

Figure 7. 1 Monthly average energy generation of the wind-solar hybrid system

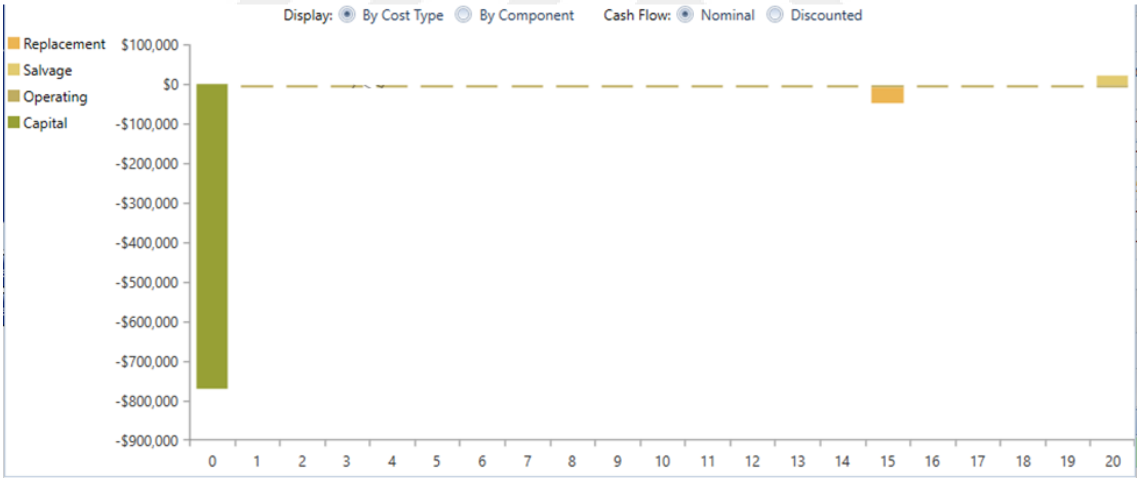

Figure 7. 2 Cash flow summary over the lifetime of the project System1

As results in Table 7.1. shows the hybrid system1 produces the highest amount of electricity over solar and wind due to the combination of two power sources. This leads to complementarity of resources in the event of lack of or low availability of resource potential or technical availability of system components. The annual electricity production which is the total value of electrical power generated by the hybrid energy system1 in one year is 952 MWh 31.2% from PV and 68.5 from the wind turbine.

Moreover, the System1 has less storage and more significant amount of excess of electricity that is lost in relation than the other systems, which leads to independence of the system at a substantially lower level. The figure below shows the excess power, unmet electric load and capacity deficiency.

Quantity	kWh/yr	%
Excess Electricity	530,355	55.8
Unmet Electric Load	11,618	2.89
Capacity Shortage	20,386	5.08

Figure 7. 3 Excess and Unmet electricity

Although the S1 has high amounts of excess electricity leading to electricity losses, it can be seen that S1 is the best option because it can meet the load at a relatively low cost.

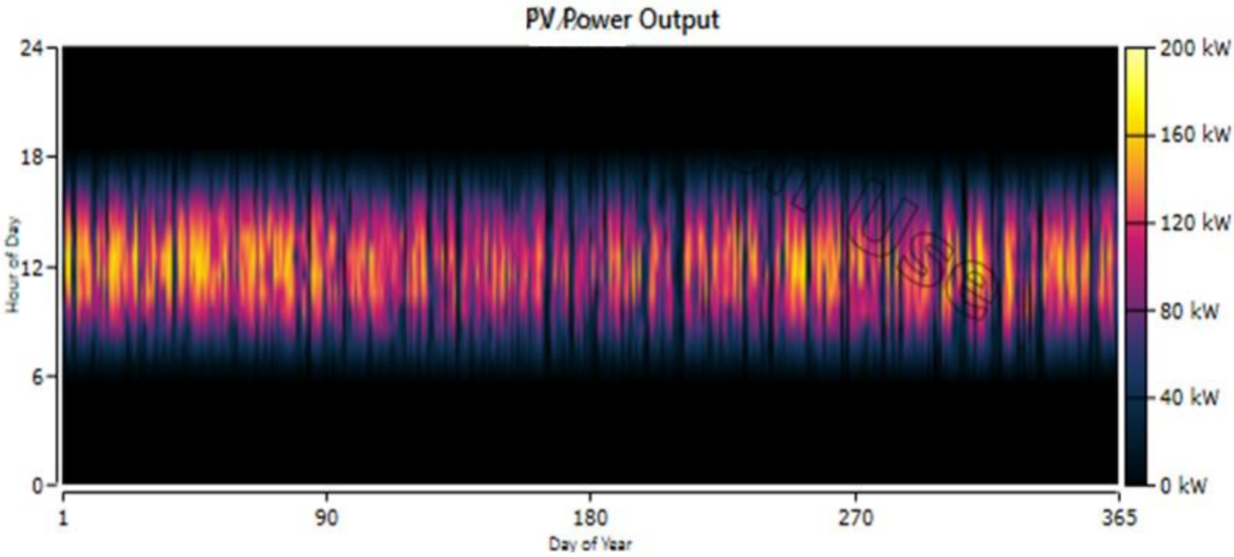

Figure 7. 4 PV Power Output

Quantity	Value	Units
Total Rated Capacity	390	kW
Mean Output	74.7	kW
Capacity Factor	19.1	%
Total Production	654,009	kWh/yr

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	390	kW
Wind Penetration	163	%
Hours of Operation	7,730	hrs/yr
Levelized Cost	0.0278	$/kWh

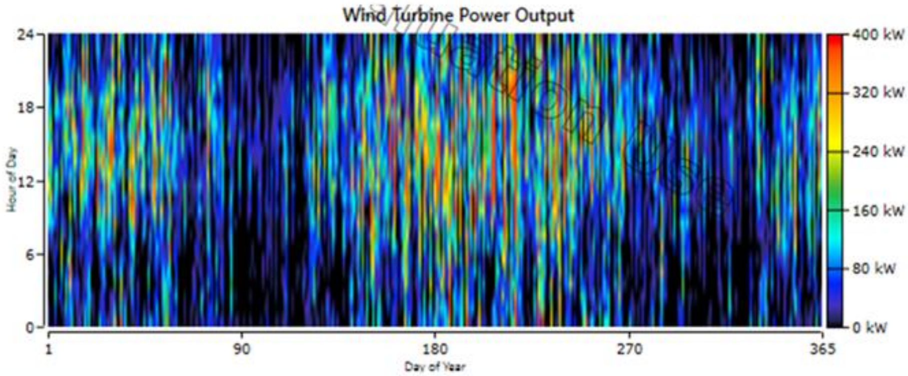

Figure 7. 5 wind turbine power output

7.3. Cost of wind energy and feasibility of a wind project

Cost of wind energy and feasibility of a wind project investments in a selected area is presented. The parameters of wind turbines and the distribution of wind speed in the region play an important role in obtaining energy. Factors of production and energy production capacity are also evaluated each year using three different wind turbines with three different zones. then, the analysis of investment costs and the economic profitability is calculated. According to the results, the most suitable and efficient turbine is determined by comparison. Table 7.3 shows technical specifications of the turbines and Figure 7.6 shows the output power curve of the turbine.

Table 7.3. Technical specifications of turbines

Wind Turbine	Hub height (m)	Rotor Diameter(m)	Rated Power (MW)	**Wind speed at hub height Bosaso**	**Wind speed at hub height** Mogadishu	**Wind speed at hub height** Hargeisa
Leitwind LTW80-1500kW	80	80.3	1.5	7.68	6.01	5.84
Enercon E-92/2350kW	84	92	2.35	7.73	6.05	5.88
Leitwind LTW101-3000kW	97	101	3	7.89	6.18	6

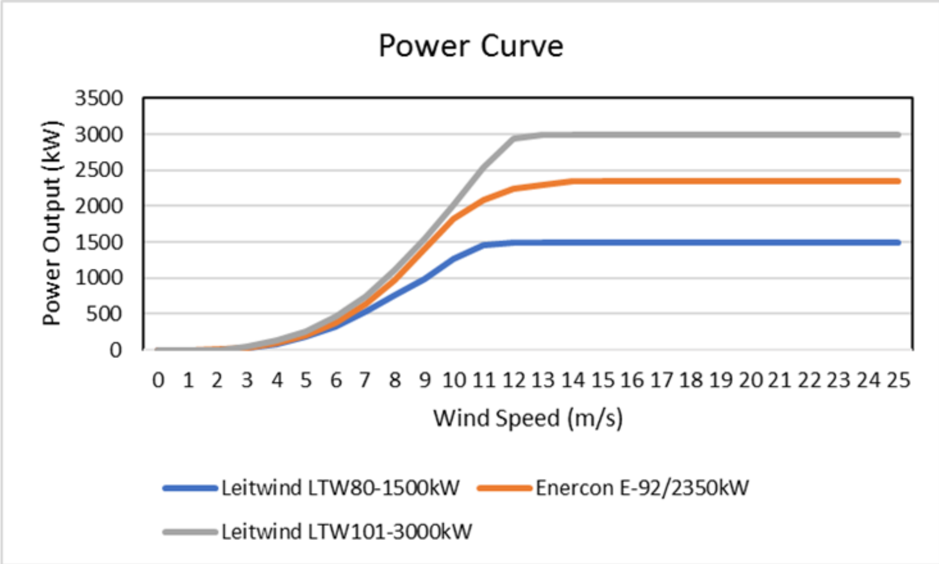

Figure 7. 6 Output power curve of the turbines

The amount of power collected from turbines and capacity factors are determined by using technical specifications of chosen turbines and the annual data of the selected cities. The capacity factors and amount of power of three different turbines at three sites is shown is Table 7.4

Table 7.4. Total electricity generated and capacity factors of selected turbines at three locations

	Mogadishu		**Hargeisa**		**Bosaso**	
	Annual Energy Output (MWh/yr)	Capacity factor (%)	Annual Energy Output (MWh/yr)	Capacity factor (%)	Annual Energy Output (MWh/yr)	Capacity factor (%)
Leitwind LTW80-1500kW	4,039.22	30.7	3,814.27	29	6,058.26	46.1
Enercon E-92/2350kW	5,568.31	27	5,232.42	25.4	8,670.79	42
Leitwind LTW101-3000kW	6,878.13	26	6,444.34	24.5	10,815.13	41.2

Three costs; construction and installation cost, O&M cost, and wind turbine cost of energy, were examined for the evaluation of the generation cost of the wind power conversion system. An estimated cost of the wind turbines Investment is shown in Table 7.5. In wind energy systems, the total cost consists of wind turbines (70-75%), construction and installation cost (20-25%), maintenance and operation cost (2-3%), and other costs that may arise during investment (3%).

Table 7.5. Cost Analysis of Wind Investment

	Cost of wind turbine	Installation Cost	O&M Cost	Total Cost
Leitwind LTW80-1500kW	$ 2,400,000.00	$ 720,000.00	$ 48,000.00	$ 3,120,000.00
Enercon E-92/2350kW	$ 3,150,000.00	$ 945,000.00	$ 63,000.00	$ 4,095,000.00
Leitwind LTW101-3000kW	$ 3,400,000.00	$ 1,020,000.00	$ 680,000.00	$ 4,420,000.00

It is expected to sell electricity produced from wind turbines to the market. Therefore, an annual yield of produced electricity is determined by considering that 1 kWh electricity will be sold from 8.5 cents. Table 7.6, shows the power and capacity factors.

Table 7.6. Cost Analysis Results of Turbines

	Mogadishu		Hargeisa		Bosaso	
Turbine	Pay-back Period (Year)	Profit ($)	Pay-back Period (Year)	Profit ($)	Pay-back Period (Year)	Profit ($)
Leitwind LTW80-1500kW	10.56	$4,263,331.88	11.3	$3,785,313.13	6.68	$8,553,791.88
Enercon E-92/2350kW	9.98	$6,162,648.13	10.73	$5,448,901.00	6.08	$12,755,437.25
Leitwind LTW101-3000kW	8.56	$8,496,030.50	9.21	$7,574,218.25	5.19	$16,862,144.88

7.4. Conclusion

This thesis gives an idea of the energy status of Somalia and the feasibility of renewable energy in the country. Somalia's wind speed and solar power have been found to have an economically viable potential for electricity generation. Northern and central along the shoreline are very suitable for the production of wind and solar energy to satisfy the primary energy needs of the population.

This analysis also investigates the possibilities for providing the demand of electricity to a hypothetical community in Mogadishu using wind-solar hybrid power system. The results of the evaluation conducted on the accessibility of power sources in the investigated region presents assuring data for the implementation of the suggested design, as the annual mean potential is about 5.63 m/s for the speed of the wind data and 5.13 kWh/m^2/day for the solar radiation data, respectively. The wind speed, daily radiation and clearness index used in this analysis is based on NASA wind resource data. The data was generated using HOMER Pro which uses NASA satellite data. The daily profile data is based on the community's estimated electrical load demand. Generally, community load profiles peak in the evening. It is essential to try to get a reasonable estimate of the maximum load as this will affect the size of the system.

Using the HOMER software, the feasibility analysis was investigation to find the most suitable system for the electrification of the hypothetical community, combining two energy sources solar and wind.

However, after a significant analysis of these options, it was concluded that the hybrid combination was more technically and economically feasible due to the cost of the lowest electricity generation (0.16 $/kWh) compared to the other two choices (0.23 $/kWh for solar-only and 0.24 $/kWh for wind-only) and also require less battery energy storage.

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CV

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EDUCATION

		Year
High School	: Mamur High School	2007-2011
B.Sc.	: Mevlana University,Mechatronics Eng.	2012-2016
M.Sc.	: Selçuk University, Mechanical Eng.	2016-2018

WORK EXPERIENCE

LANGUAGE SKILLS:

Somali: Fluent
English: Advanced
Turkish: Intermediate
Computer Skills:
MS Office, MATLAB, C Programing, Solidworks

Appendix

Appendix -1 Overall Optimization Results Tables in HOMER

PV (kW)	WT30	Surr8 CS 25P	Converter (kW)	Dispatch	NPC ($)	COE ($)	Initial capital ($)	Ren Frac (%)
179	13	134	124	CC	873927.7	0.163791	768346.2	100
179	13	134	124	LF	873927.7	0.163791	768346.2	100
179	13	134	124	LF	873927.7	0.163791	768346.2	100
183	13	131	123	LF	874127.3	0.163828	768446.6	100
183	13	131	123	CC	874127.3	0.163828	768446.6	100
183	13	131	123	CC	874127.3	0.163828	768446.6	100
178	13	135	124	LF	874187.5	0.163836	768610.8	100
178	13	135	124	CC	874187.5	0.163836	768610.8	100
177	13	136	123	LF	874744.1	0.163906	769244.5	100
177	13	136	123	CC	874744.1	0.163906	769244.5	100
177	13	136	123	CC	874744.1	0.163906	769244.5	100
179	13	135	121	LF	875159.4	0.163952	769662	100
179	13	135	121	CC	875159.4	0.163952	769662	100
182	13	133	126	LF	878175.8	0.164492	772111.9	100
182	13	133	126	CC	878175.8	0.164492	772111.9	100
182	13	133	126	LF	878175.8	0.164492	772111.9	100
182	13	133	126	CC	878175.8	0.164492	772111.9	100
185	13	131	125	CC	878208.2	0.164506	772087.8	100
185	13	131	125	LF	878208.2	0.164506	772087.8	100
167	14	137	121	LF	878527.4	0.164593	770305.1	100
167	14	137	121	LF	878527.4	0.164593	770305.1	100
156	14	150	117	CC	887787.4	0.166255	779512.3	100
156	14	150	117	CC	887787.4	0.166255	779512.3	100
165	14	142	124	LF	887854	0.166144	778936	100
165	14	142	124	CC	887854	0.166144	778936	100
165	14	142	124	LF	887854	0.166144	778936	100
156	14	150	117	CC	887787.4	0.166255	779512.3	100
156	14	150	117	CC	887787.4	0.166255	779512.3	100
165	14	142	124	LF	887854	0.166144	778936	100
165	14	142	124	CC	887854	0.166144	778936	100
165	14	142	124	LF	887854	0.166144	778936	100
183	14	150	124	CC	933877.8	0.173452	821453.9	100
175	14	157	122	CC	935462	0.173793	823268	100
175	14	157	122	LF	935462	0.173793	823268	100
175	14	157	122	LF	935462	0.173793	823268	100
175	14	157	122	CC	935462	0.173793	823268	100
226	13	130	111	CC	937823.4	0.174462	827297.9	100
226	13	130	111	LF	937823.4	0.174462	827297.9	100

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226	13	130	111	LF	937823.4	0.174462	827297.9	100
226	13	130	111	CC	937823.4	0.174462	827297.9	100
219	13	137	102	LF	938439.9	0.174274	828552.8	100
219	13	137	102	CC	938439.9	0.174274	828552.8	100
219	13	137	102	LF	938439.9	0.174274	828552.8	100
219	13	137	102	CC	938439.9	0.174274	828552.8	100
204	15	154	118	LF	994221.3	0.183449	874682.2	100
204	15	154	118	CC	994221.3	0.183449	874682.2	100
204	15	154	118	CC	994221.3	0.183449	874682.2	100
275	12	130	100	CC	995004.1	0.184596	882733	100
184	19	150	144	CC	1038012	0.191319	903450	100
184	19	150	144	CC	1038012	0.191319	903450	100
275	12	148	126	LF	1043416	0.192232	926675	100
275	12	148	126	CC	1043416	0.192232	926675	100
275	12	148	126	LF	1043416	0.192232	926675	100
342	7	143	139	LF	1051306	0.195227	945655.8	100
342	7	143	139	LF	1051306	0.195227	945655.8	100
342	7	143	139	CC	1051306	0.195227	945655.8	100
342	7	143	139	CC	1051306	0.195227	945655.8	100
184	19	150	180	CC	1051542	0.193812	914250	100
184	19	150	180	LF	1051542	0.193812	914250	100
184	19	150	180	LF	1051542	0.193812	914250	100
264	15	147	111	CC	1074597	0.197486	948326.8	100
264	15	147	111	CC	1074597	0.197486	948326.8	100
288	14	128	168	LF	1074993	0.198637	947904.6	100
288	14	128	168	LF	1074993	0.198637	947904.6	100
288	14	128	168	CC	1074993	0.198637	947904.6	100
288	14	128	168	CC	1074993	0.198637	947904.6	100
275	12	169	109	CC	1081855	0.198507	963537.8	100
275	12	169	109	LF	1081855	0.198507	963537.8	100
245	15	172	98	LF	1091435	0.200102	965400	100
245	15	172	98	CC	1091435	0.200102	965400	100
367	12	100	144	LF	1097793	0.205964	973700	100
367	12	100	144	LF	1097793	0.205964	973700	100
367	12	100	144	CC	1097793	0.205964	973700	100
367	10	150	180	LF	1179954	0.216668	1054500	100
367	10	150	180	LF	1179954	0.216668	1054500	100
367	10	150	180	CC	1179954	0.216668	1054500	100
367	10	150	180	CC	1179954	0.216668	1054500	100
	36	219	134	CC	1206069	0.228321	1018152	100
	36	219	134	LF	1206069	0.228321	1018152	100
	36	219	134	LF	1206069	0.228321	1018152	100
	36	219	134	CC	1206069	0.228321	1018152	100

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	36	219	136	LF	1206848	0.228456	1018774	100
	36	219	136	CC	1206848	0.228456	1018774	100
	36	221	144	CC	1214306	0.229731	1025316	100
	37	210	160	LF	1215911	0.230097	1023109	100
	37	210	160	CC	1215911	0.230097	1023109	100
	37	210	160	LF	1215911	0.230097	1023109	100
	37	210	160	CC	1215911	0.230097	1023109	100
	37	214	142	CC	1217695	0.230309	1025710	100
	37	214	142	LF	1217695	0.230309	1025710	100
	37	214	142	LF	1217695	0.230309	1025710	100
	37	214	142	CC	1217695	0.230309	1025710	100
367	19	100	108	LF	1218003	0.225877	1067900	100
367	19	100	108	LF	1218003	0.225877	1067900	100
367	19	100	108	CC	1218003	0.225877	1067900	100
367	19	100	108	CC	1218003	0.225877	1067900	100
	37	215	140	LF	1218869	0.2305	1026941	100
	37	215	140	CC	1218869	0.2305	1026941	100
	37	215	140	LF	1218869	0.2305	1026941	100
	37	215	140	CC	1218869	0.2305	1026941	100
	36	224	140	CC	1218893	0.230493	1029860	100
	36	224	140	LF	1218893	0.230493	1029860	100
	36	224	140	LF	1218893	0.230493	1029860	100
184	31	150	108	CC	1253750	0.229376	1072650	100
184	31	150	108	LF	1253750	0.229376	1072650	100
184	31	150	108	LF	1253750	0.229376	1072650	100
184	31	150	108	CC	1253750	0.229376	1072650	100
406		253	136	LF	1255918	0.236597	1155471	100
406		253	136	CC	1255918	0.236597	1155471	100
406		253	136	LF	1255918	0.236597	1155471	100
406		253	136	CC	1255918	0.236597	1155471	100
403		256	135	LF	1256618	0.236703	1156277	100
403		256	135	LF	1256618	0.236703	1156277	100
403		256	135	CC	1256618	0.236703	1156277	100
403		256	135	CC	1256618	0.236703	1156277	100
413		248	135	LF	1256667	0.236716	1155974	100
413		248	135	LF	1256667	0.236716	1155974	100
413		248	135	CC	1256667	0.236716	1155974	100
413		248	135	CC	1256667	0.236716	1155974	100
406		254	131	LF	1257257	0.236738	1156958	100
406		254	131	LF	1257257	0.236738	1156958	100
406		254	131	CC	1257257	0.236738	1156958	100
	37	240	143	LF	1273386	0.23976	1077816	100
	37	240	143	CC	1273386	0.23976	1077816	100

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	37	240	143	LF	1273386	0.23976	1077816	100
	37	240	143	CC	1273386	0.23976	1077816	100
378		285	122	CC	1273432	0.239387	1173479	100
378		285	122	LF	1273432	0.239387	1173479	100
378		285	122	LF	1273432	0.239387	1173479	100
378		285	122	CC	1273432	0.239387	1173479	100
431		243	131	LF	1273859	0.239388	1171692	100
431		243	131	LF	1273859	0.239388	1171692	100
431		243	131	CC	1273859	0.239388	1171692	100
431		243	131	CC	1273859	0.239388	1171692	100
420		251	136	LF	1274374	0.239416	1172268	100
1101	37	300	144	LF	3204252	0.583163	2849700	100
1101	37	300	144	CC	3204252	0.583163	2849700	100
1101	37	300	216	LF	3231311	0.588087	2871300	100
1101	37	300	216	LF	3231311	0.588087	2871300	100
1101	37	300	216	CC	3231311	0.588087	2871300	100
1101	37	300	216	CC	3231311	0.588087	2871300	100
	36	224	139.5343	LF	1218893	0.230493	1029860	100
	36	224	139.5343	CC	1218893	0.230493	1029860	100
	36	221	157.1361	LF	1219098	0.230582	1029141	100
	36	221	157.1361	LF	1219098	0.230582	1029141	100
	36	221	157.1361	CC	1219098	0.230582	1029141	100
	36	221	157.1361	CC	1219098	0.230582	1029141	100
	35	229	164.3068	CC	1219782	0.230735	1032292	100
	35	229	164.3068	LF	1219782	0.230735	1032292	100
	35	229	164.3068	LF	1219782	0.230735	1032292	100
	35	229	164.3068	CC	1219782	0.230735	1032292	100
	36	225	136.2179	CC	1219784	0.230637	1030865	100
	36	225	136.2179	LF	1219784	0.230637	1030865	100
	36	225	136.2179	LF	1219784	0.230637	1030865	100
	36	225	136.2179	CC	1219784	0.230637	1030865	100
	36	226	134.4455	LF	1221255	0.230884	1032334	100
	36	226	134.4455	LF	1221255	0.230884	1032334	100
	36	226	134.4455	CC	1221255	0.230884	1032334	100
	36	226	134.4455	CC	1221255	0.230884	1032334	100
	34	236	180.6924	CC	1221792	0.231225	1036208	100
	34	236	180.6924	LF	1221792	0.231225	1036208	100
	34	236	180.6924	LF	1221792	0.231225	1036208	100
	34	236	180.6924	CC	1221792	0.231225	1036208	100
	37	218	133.0078	LF	1222725	0.23114	1030902	100
	37	218	133.0078	LF	1222725	0.23114	1030902	100
	37	218	133.0078	CC	1222725	0.23114	1030902	100
	37	218	133.0078	CC	1222725	0.23114	1030902	100
	37	216	144.428	LF	1222743	0.231164	1030328	100

Appendix -1 Con..

	37	216	144.428	CC	1222743	0.231164	1030328	100
	37	216	144.428	CC	1222743	0.231164	1030328	100
	37	215	153.0314	CC	1223840	0.231388	1030909	100
	37	215	153.0314	LF	1223840	0.231388	1030909	100
	37	215	153.0314	LF	1223840	0.231388	1030909	100
	37	215	153.0314	CC	1223840	0.231388	1030909	100
	37	218	139.5882	LF	1225198	0.231564	1032876	100
	37	218	139.5882	CC	1225198	0.231564	1032876	100
	37	218	139.5882	LF	1225198	0.231564	1032876	100
	37	218	139.5882	CC	1225198	0.231564	1032876	100
	37	218	141.7794	LF	1226022	0.231707	1033534	100
	37	218	141.7794	CC	1226022	0.231707	1033534	100
	37	218	141.7794	LF	1226022	0.231707	1033534	100
	37	218	141.7794	CC	1226022	0.231707	1033534	100
	36	227	144.4922	CC	1227167	0.2319	1037348	100
	36	227	144.4922	LF	1227167	0.2319	1037348	100
	36	227	144.4922	LF	1227167	0.2319	1037348	100
	36	227	144.4922	CC	1227167	0.2319	1037348	100
	36	226	151.4506	LF	1227645	0.231997	1037435	100
	36	226	151.4506	CC	1227645	0.231997	1037435	100
	36	226	151.4506	LF	1227645	0.231997	1037435	100
	36	226	151.4506	CC	1227645	0.231997	1037435	100
	37	220	137.3011	CC	1228612	0.232135	1036190	100
	37	220	137.3011	LF	1228612	0.232135	1036190	100
	37	220	137.3011	LF	1228612	0.232135	1036190	100
	37	220	137.3011	CC	1228612	0.232135	1036190	100
	36	229	137.111	LF	1228667	0.232144	1039133	100
	36	229	137.111	LF	1228667	0.232144	1039133	100
	36	229	137.111	CC	1228667	0.232144	1039133	100
	36	229	137.111	CC	1228667	0.232144	1039133	100
	37	219	143.5217	LF	1228813	0.232181	1036057	100
	37	219	143.5217	CC	1228813	0.232181	1036057	100
	37	219	143.5217	LF	1228813	0.232181	1036057	100
	37	219	143.5217	CC	1228813	0.232181	1036057	100
	35	236	150.6227	CC	1229597	0.232365	1042187	100
	35	236	150.6227	LF	1229597	0.232365	1042187	100
	35	236	150.6227	LF	1229597	0.232365	1042187	100
	35	236	150.6227	CC	1229597	0.232365	1042187	100
	33	256	144	LF	1231634	0.232985	1050200	100
	33	256	144	LF	1231634	0.232985	1050200	100
	33	256	144	CC	1231634	0.232985	1050200	100
	33	256	144	CC	1231634	0.232985	1050200	100
	36	234	118.2273	LF	1232255	0.232795	1043468	100