T.C.
ISTANBUL AYDIN UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

INVESTIGATION OF HYBRID ENERGY SYSTEMS IN SELECTING PART OF AFGHANISTAN

MASTER'S THESIS

Mosab MOHAMMADI

Department of Electrical & Electronic Engineering
Electrical and Electronics Engineering Program

FEB, 2021

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ONAY FORMU

DECLARATION

I hereby declare that all information in this thesis document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results, which are not original to this thesis.

Mosab MOHAMMADI

FOREWORD

I would like to express my sincere gratitude to my supervisor Prof.Dr.Mehmet Emin Tacer for his valuable assistance and comments given to completing thesis work.
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ABSTRACT

Electricity is one of the most important factor for a country to develop. Human life need for energy resources has always been a fundamental issue in human life. gaining an infinite source of energy has long been a human dream and he has always looking in his imagination the source of infinite power that can be available to him at all times and places.

By growing of human civilization, plants, especially trees (wood) and then coal, oil and gas, entered the energy market, but for reasons such as: increasing energy needs, limited fossil resources and environmental pollution caused by burning and extinction of the toxic gases (which cause respiratory problems, increased air temperature and extensive climate change) experts and scientists have decided to use clean energy such as solar, wind, geothermal, hydrogen, etc. Renewable energy is an infinite source of energy and can avoid the dangers and challenges instead of limited fossil fuels. This has led countries to consider the use of other energies in nature, especially renewable energy. Renewable energy includes a variety of sources of natural and available energy. given that these energies do not have an ideal pink, but their use reduces the consumption of petroleum products and job creation and reduces environmental pollution.

Afghanistan is a country which have been seen many years of wars, cause of that most of the population of Afghanistan they cannot have electricity power from grid. Most of the people are living in decentralized zones. using of renewable energy in Afghanistan is a solution for energy problems of decentralized zone. And will have good prospect for Afghanistan true developing. Studies have shown that the development of renewable energy use can play a significant role in increasing the security of the country's energy system. In this thesis I will do study on existing capacity of renewable energy in Afghanistan, estimating consumption in the case study area by using questioner form that fulfilled by local people which are living in that area, feasibility study of the hybrid system in the selected area and optimization of system by using multitask decision method.

So on this thesis it is focused on the proper investigation of HYBRID energy systems in selecting part of Afghanistan in decentralized zone.

Also to gain the aim of the thesis, it is consist of a discussion about hybrid renewable power system, Afghanistan power condition and renewable energy sources and solution for estimation of power consumption in decentralized zones which can have different condition than each other, and finally the result is given.

Keywords: *Afghanistan, Renewable Energy, Hybrid power system, Solar, wind, Homer Software.*

AFGANİSTAN'DA HİBRİT ENERJİ SİSTEMLERİ

ÖZET

Elektrik, bir ülkenin gelişmesi için en önemli faktörlerden biridir. İnsan hayatının enerji kaynaklarına olan ihtiyacı, insan hayatında her zaman temel bir konu olmuştur. sonsuz bir enerji kaynağı kazanmak uzun zamandır bir insan rüyası olmuştur ve her zaman, her zaman ve her yerde erişebileceği sonsuz gücün kaynağına her zaman kendi hayal gücüne bakmıştır.

İnsan uygarlığının büyümesiyle bitkiler, özellikle ağaçlar (odun) ve ardından kömür, petrol ve gaz enerji pazarına girdi, ancak şu nedenlerle: artan enerji ihtiyaçları, sınırlı fosil kaynakları ve zehirli maddelerin yanması ve yok olmasının neden olduğu çevre kirliliği. gazlar (solunum problemlerine, hava sıcaklığının artmasına ve kapsamlı iklim değişikliğine neden olan) uzmanlar ve bilim adamları güneş, rüzgar, jeotermal, hidrojen vb. gibi temiz enerji kullanmaya karar verdiler. Yenilenebilir enerji sonsuz bir enerji kaynağıdır ve tehlikeleri önleyebilir ve sınırlı fosil yakıtlar yerine kullanabılır. Bu ülkeleri doğadaki diğer enerjilerin, özellikle de yenilenebilir enerjinin kullanımını düşünmeye yöneltmiştir. Yenilenebilir enerji, çeşitli doğal ve kullanılabilir enerji kaynaklarını içerir. bu enerjilerin tsm ideal enerjı değil, ancak kullanımlarının petrol ürünlerinin tüketimini ve iş yaratımını azalttığı ve çevre kirliliğini azalttığı düşünüldüğünde.

Afganistan yıllarca süren savaşlar görmüş bir ülkedir, bu sebele Afganistan nüfusunun çoğunun şebekeden elektrik enerjisine sahip değildir. İnsanların çoğu merkezi olmayan bölgelerde yaşıyor. Afganistan'da yenilenebilir enerjinin kullanılması, merkezden uzak bölgelerinin enerji sorunları için bir çözümdür. Ve Afganistan'ın gerçek anlamda gelişmesi için iyi bir beklenti olacak. Arıştırmalar yenilenebilir enerji kullanımının geliştirilmesinin, ülkenin enerji sisteminin güvenliğini artırmada önemli bir rol oynayabileceğini göstermiştir. Bu tezde Afganistan'daki mevcut yenilenebilir enerji kapasitesi, o bölgede yaşayan yerel halkın doldurduğu sorgulayıcı formu kullanarak vaka çalışması alanındaki tüketimi tahmin etme, seçilen bölgedeki hibrit sistemin fizibilite çalışması ve çoklu görev karar yöntemini kullanarak sistemin optimizasyonu.

Bu nedenle, bu tezde, merkezden uzak bölgede Afganistan'ın bir bölümünü seçerken HİBRİT enerji sistemlerinin doğru bir şekilde araştırılmasına odaklanmıştır.

Ayrıca tezin amacına ulaşmak için, hibrit yenilenebilir enerji sistemi, Afganistan güç durumu ve yenilenebilir enerji kaynakları hakkında bir tartışma ve birbirinden farklı koşullara sahip olabilen merkezden uzak bölgelerdeki güç tüketiminin tahmin edilmesi ve son olarak sonuç verilir.

Anahtar Kelimeler: *Afganistan, Yenilenebilir Enerji, Hibrit güç sistemi, Güneş, rüzgar, Homer Yazılımı.*

1. INTRODUCTION

1.1 Background

In today's world, having access to energy sources for the long run is one of the strategic goals of the countries all over the world. Looking deep into the infrastructural needs of any country, a foundational need for energy is considered for development. Life quality, income rates, industrial development and most of the other factors that decide the human condition in today's world are linked to the level of access to energy sources. In this regard, renewable energy [RE] is considered vital for enhancing life quality for humankind. With the current technology, and considering the geographical situation of Afghanistan, it is safe to say that "Afghanistan is a land of renewable energy source's opportunity." [1] In this path, the importance of energy sources is highly vital for developing countries and the countries which are setting their strategic development plans for long term. Industrial growth of these growing economics are dependent on satisfaction of electricity demands. Sustainable economic growth, which is the concern of most of the countries in 21st century needs revolution in their electricity supply infrastructure as the core and driving engine. [2] Afghanistan traditionally have the concern for extending access to electricity. Considering the technological development of the country, in the last decades the aim of providing the country with electricity was mostly through extending utility grids. Afghanistan owns a mountainous geography with having a large number of rural inhabitants. Naturally these factors make electrification of the country through utility grids costly and extremely hard. This is while the country owns sufficient renewable sources of energy. Comparing to the costly transmission of electricity via long distanced grid systems and through the hilly regions, renewable sources like wind and solar are more viable options. Figure 1-1, compares the utility grid and PV power schemes by capital cost[3]. Public grid extension cost escalates with distance than standalone hybrid systems.

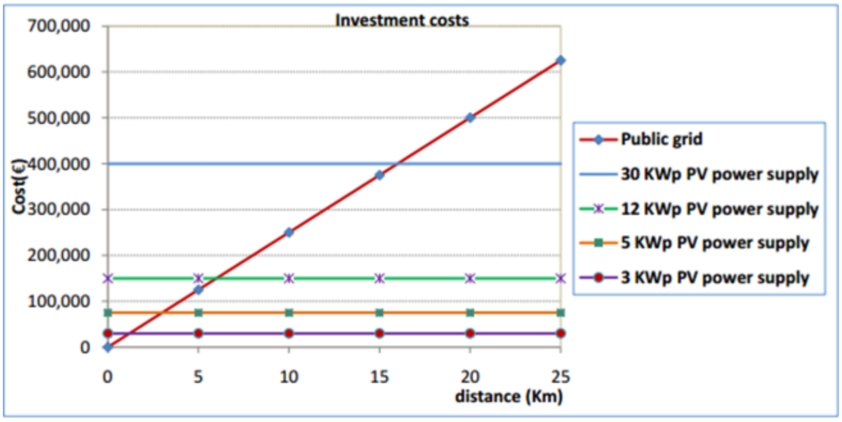


Figure 1-1 Comparison of Utility Grid and PV Power Schemes by Capital Cost [3]

Over this concern, the government of Afghanistan employed the growth and transformation plan strategy in which the state aimed to enhance the living condition and targeted to become a middle income nation by 2030[5]. This target is deemed achievable through industrial development and mechanization of agriculture. For this purpose, having a reliable and sustainable supply of electricity is a major requirement. This aim could achieve some goals as increasing the employment rate, providing better condition of living for rural inhabitants and eventually reaching positive social transformation. Therefore, the prominent challenge is to supply sustainable energy without waiting for time consuming and costly grid extension and fossil-based power plants. Considering the fact that Afghanistan is not gifted with huge oil reserves like middle-eastern countries as of this study, the country owns sufficient water sources that with some efforts can satisfy the electricity demands of the country. At this point of time, the core attention of the country is on hydropower constructions due to its availability and low generation cost. However, sometimes the fluctuation of rainfall causes the insufficiency in reservoir during the low rainy season which can eventually be a threat to the core of idea of full concentration on hydropower generation. Therefore, formulation of a sustainable mode of energy generation has to be executed after calculating all resources at stake and extensive evaluations. Facing this reality, the country can use its potential sources like solar, geothermal and wind sources to support the hydropower and grid systems. The renewable sources are echo-friendly, non-polluting and inexhaustible. This in turn means investing on needs of today and the future of the country.

Taking all the mentioned points into account, the renewable energy can decide the future of supplying energy in general and meeting electricity demands of

Afghanistan in particular. The cost efficiency of supply to scattered rural inhabitants of the country is one major benefit that could be fulfilled.

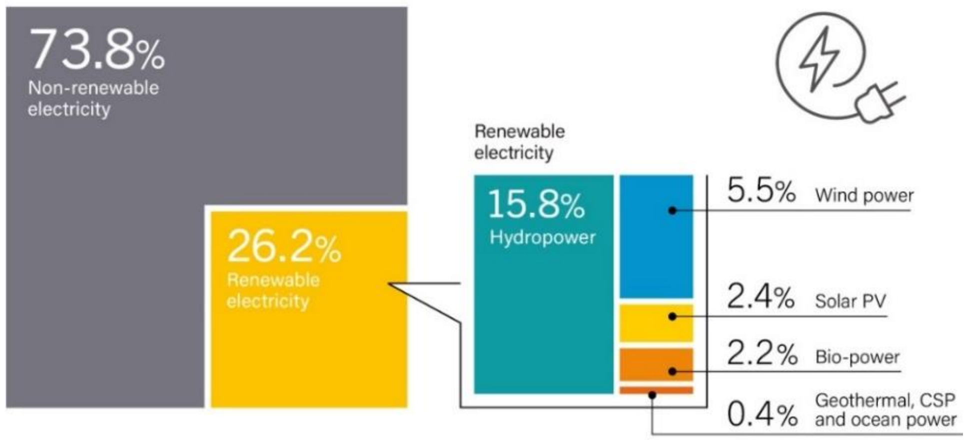
1.2 Thesis Layout

Chapter one is introduction to thesis which is the background of renewable energy, the motivation and problem statement, moreover thesis layout, methodology of the study, specific objective, the proposed area of study. Chapter two reviews the hybrid power system there advantages and disadvantages. Chapter three presents the Energy sector in Afghanistan that consist the Energy supply and demand in Afghanistan, Renewable Energy capacity in Afghanistan. Chapter four will give the information about our case study and methodology to estimate the Energy supply in that area. Chapter five gives methodology for design of standalone hybrid system. Chapter six explains simulation of the hybrid system which incorporates methodology and finally there will be a conclusion to our study in Afghanistan.

1.3 Thesis Significance

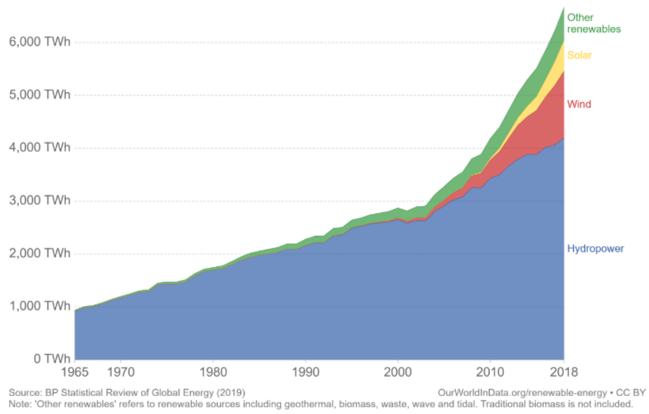
The world we are living has significantly changed in different aspects. The human condition in philosophical meaning of the term has changed and human kind has developed expectancies for welfare and easy living environment. The industrial and technological developments have provided humans with quality, speed and easiness for daily living tasks. Communication technology and mechanization has reformed all the aspect of life for humans including government, education, healthcare, transport, agriculture and etc. Smartphones, internet and online sphere has revised the meaning and methods of providing civil services and human and social relations. Unlike the last century, access to internet in 21st century is vital need. This is while in some part of the world humans are struggling for simple living standards. To catch up with these changes, and to enhance the living condition in such an environment, having sufficient energy sources and developing infrastructure for it is a major task. In Afghanistan, majority of population is living with no access to electricity. At the same time, the country is aiming for enhancing the economy and standard of livings in the long run. As per estimations, the country would have 7500 MW demand of electricity by 2032 [9]. This is while the potential energy production capacity of the country is 23,000 MW of hydropower, 67,000 MW of wind power and 222,000 MW of solar power [10]. Raising the production level to the full capacity would not only fulfill the demands inside the country but also would provide the country an income source via exporting energy. A 10-60% annual growth in worldwide renewable energy capacity has been observed since the end of 2004 [6]. Concerns over climate change and global warming raised significant concerns and alerted citizens and policy makers. Developing technologies for enhancing the production and consumption of renewable energy became the main agenda of states and many multinational corporations. However, despite all these efforts, the global portion of renewable energy with accounting 26.2% by 2018 is not significantly raised, [7]. The figure 1-2 illustrates it.

Figure 1-2 Estimated renewable energy share of global electricity production 2018[7]



The flowing figure shows the global growth rate of renewable energy. [8]

Figure 1-3 renewable energy generation. 1965 to 2018 [8]



The above figures show the growth of renewable energy in the world. Which Afghanistan share is nothing in this amount?

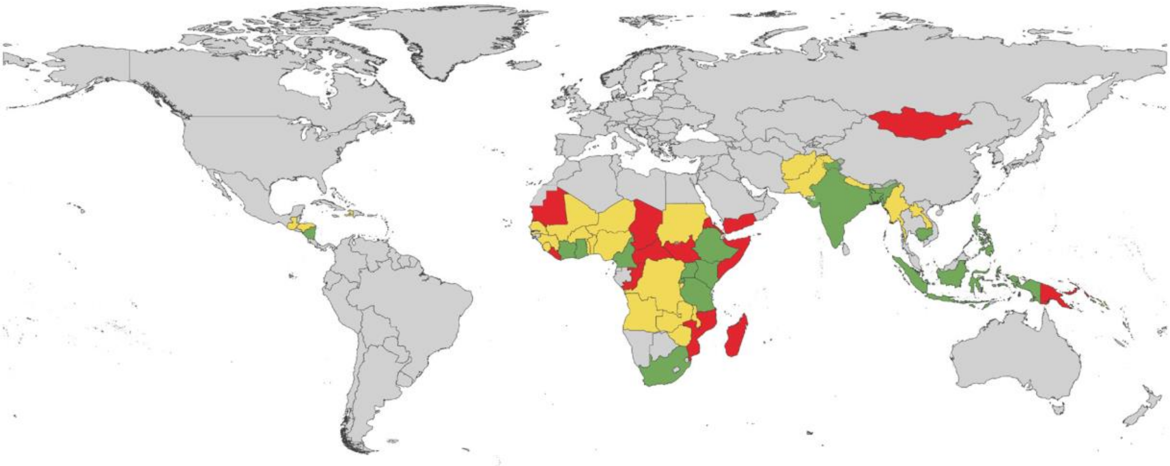
In this thesis the potential of renewable energy in Afghanistan will be study and suggested method will be a way to use this potential and to make people use their own potential of energy and to not pay electricity to other countries which can be a way true economic development in Afghanistan.[11]

1.4 Problem Statement

As an accepted principle, one of the key factors to industrialization of a country is cheap and reliable electricity [12]. This important factor also plays a key role in enhancing economy, raising employment rate, providing welfare and improving living conditions of communities. With all these benefits, there are countries in world which are struggling with shortage of supply. Unfortunately for Afghanistan as well, the available reports show a 30-38% of household's access to electricity [13].

Figure 1-4 Map: Rise Electricity Access Scores By Country, 2017[13]

Red ≤ 33%   33%<yellow<67%   green≥%



The policy makers in each country have to focus on facilitating the people's access to electricity by designing the short term and long term plans and strategies. The policy makers in Afghanistan mostly relied on import of electricity mostly from neighboring countries as a quick fix. Since 2001, when Afghanistan opened up to the world and established the new government from scratch with the help of international community, this policy started. As per Asian Development Bank report, almost 80% of Afghanistan electrical energy is being imported [14]. This policy in turn caused several outcomes among which the heavy economic burden is the most important. Not to mention, this quick fix also resulted in cash flow from the country, and the demining the concrete efforts for future self-sufficiency. This excessive investment on import of power has been raised by many experts. Realizing the fact that Afghanistan owns enough potential energy resources, it is a matter importance to focus on sustainable energy generation from domestic sources.

In this regard, this thesis discusses the current issues in energy sector of Afghanistan in decentralized zones and evaluates the long term solutions with concentration on self-sufficiency of the country through renewable energy sources. It will discuss the importance of, and highlights the methods of exploiting the energy resources in Afghanistan.

1.5 Specific Objectives

The major aim of this thesis is to design an off grid hybrid renewable energy system that could be cost-efficient for a country like Afghanistan. Besides this aim, the specific objectives of the thesis can be listed as follow.

- Reviewing renewable energies
- Reviewing hybrid power plants
- Reviewing the Power system condition in Afghanistan
- Reviewing the estimated renewable energy resources in Afghanistan
- Reviewing challenges and issues for the renewable power system in Afghanistan
- To find and suggest a solution for optimization of power system in area that are far from grid in Afghanistan.
- Reviewing the characteristics of the measured climatic raw data sources [wind speed and solar radiation] of the case study village
- Estimating electricity loads required for domestic uses, commercial sectors [flour milling machine] and community services like, primary school and health clinic were determined.
- designing the hybrid system to be applied to rural areas via wind turbines, solar PV, diesel generator, battery storage and converter.
- Comparing hybrid power price with current grid connected power price.
- Outlines conclusions and recommendations

1.6 Methodology

A hybrid energy system is composed of different components to utilize divers renewable sources such as wind, solar, diesel generator, invertors, and batteries. Designing the best hybrid energy component combination for a proposed site is dependent on several criteria like trade-off between cost, sustainability, maturity of technology, efficiency and minimum use of diesel fuel. For the propose of this study, the following step by step methodology is adhered.

- A literature review on hybrid systems applicable for rural areas
- The different hybrid configuration topologies were studied
- A review of energy condition in Afghanistan, issues and challenges.
- Choose area as case study and finding its climate data by using HOMER software.
- Electricity load demand for single household is calculated and accordingly the load required for total households residing at the selected site is also estimated.
- Electricity load demand for the necessary social places [clinic/school/etc] is estimated
- The cost data for each of the power system components has been thoroughly searched from different websites and publications. Obviously, different manufacturing companies upcoming with different costs into the market for the same product making the cost range difficult.
- Feasibility study of different renewable energy sources in selected part of Afghanistan.
- Cost optimizing design of Hybrid power plant with different system suggestion by using homer software.
- Comparing hybrid power price with existing grid connected power price.
- A multitask decision making Model has been used to choose a system with different influencing factors in decentralized zones.
- Using Microsoft office excel to do the decision making calculations.

1.7 Boundaries

Through the course of study some limits were identified and specific assumptions have been taken for the actualization of the paper.

- The energy source estimation is a general estimation which for precise designing it is needed to have precise information of energy sources in local areas.
- The security problem which will not let to do precise survey of local data.
- Not availability of recent information of Afghanistan power and energy condition.

- Due to national security problem, the information is not sharing with researcher and research must done by the NGOs.

2. HYBRID RENEWABLE ENERGY SYSTEM

2.1 Introduction

In this chapter, the importance of wind and solar hybrid power plants in providing electricity to remote areas is discussed. Where there is no power supply, but due to social and urban sensitivities and needs and investments made in these areas, such as water tanks, oil reservoirs, mining sites, etc., it is necessary to provide at least the facilities there and for Physical protection and security of the place provided the necessary devices such as cameras, lighting projector lamps and information transmission system. Therefore, it requires electricity and one of the appropriate plans for electricity supply is the simultaneous use of wind energy and solar energy so that in the absence of any of them, other energy will generate electricity.

Undoubtedly, one of the main components of national security in all countries is access to energy. Problem to energy supply system means problem for all the economy in one hand, and to the living condition of society in the other hand. For this reason, countries make diversification of energy resources one of their main strategies in order to strongly avoid dependence on one or two types of energy and reduce their vulnerability to a minimum. On the other hand, the installation of distributed power generators allows large consumers to have emergency and backup power during the outages imposed by the network and increase the reliability of their power supply system. Due to the special circumstances of Afghanistan, this measure is one of the most important measures of passive defense in order to reduce vulnerability. In case of various accidents, electricity can be supplied to different sectors by relying on local resources and facilities. Sunlight is the largest source of renewable energy on Earth. Increased electricity consumption, reduced fossil fuel resources and environmental pollution are three main issues in countries' tendency toward renewable energy systems. Despite the high potential for new energy production, new energy generation can be an effective option not only for remote areas with low populations, but also economically sustainable in the long run. The wind and solar hybrid system, which is a new species in the field of renewable energy systems, includes photovoltaic arrays, wind turbines, batteries and converters.

The diversity in energy resources increases energy security. Dozens of national and international events and examples confirm this strategy. For example, detonation of inter-city electricity transmission towers in Afghanistan by insurgency every year causes power outages. In another example, the long distanced rural areas which need fuel to run electricity generators can run out of fuel while the roads are blocked during the winter, or when the fuel transportation is impossible. In such cases, if the wind and solar hybrids or biomass were being built in Afghanistan, it would be possible to provide more electricity.

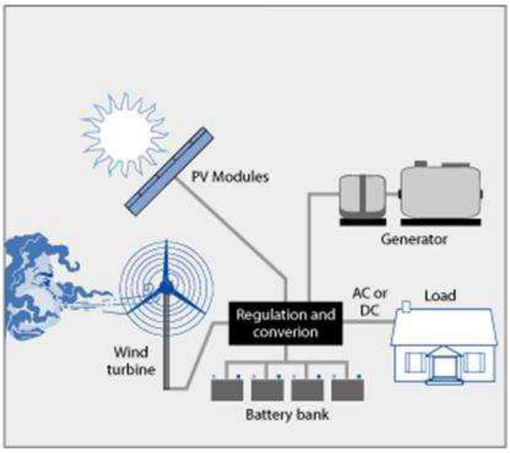
Given the importance of this issue, the cost of power outages is far higher than the cost of production. In neighboring Afghanistan, for example, if Iran's electricity is cut off for one kilowatt hour, the Iranian national economy will suffer nearly $ 8, while its cost is about eight cents. Therefore, relying solely on oil and gas is a strategic mistake. It is essential that renewable energy sources contribute more to the country's portfolio.

The terms to study hybrid renewable energy system is technical in nature and a complete discussion about that will take long so to concept discussion the hybrid renewable energy power system characteristics, thus, we will have small discussion about hybrid renewable energy systems and related studies on optimization of hybrid renewable energy system

2.2 Hybrid Power System

Hybrid power plants are used by multiple sources of renewable energy as a supplement or a combination of renewable and fossil resources and to take advantage of each to generate electrical energy[15]. In this type of power plants, the reliability factor increases due to the multiplicity of energy resources and the use of the benefits of each of them.

The energy produced by many renewable sources is expensive. In addition, they do not have enough reliability to provide the required energy at the required time and do not show the necessary stability in response to load fluctuations. Therefore, their combination with fossil fuels such as small gas and diesel power plants is very helpful in reducing energy prices, increasing their reliability and stability. For



example, if the hybrid power plant consists of a wind turbine and a diesel generator, if there is no wind or a decrease in wind rate, the diesel generators will enter the circuit and feed the load. Even when increasing the load, generators can circuit and perform load cutting operations.

Figure 2-1wind and solar hybrid power plant with an emergency power generator

Hybrid power plants are usually independent of the national grid which allows the micro grid to be disconnected from the utility grid in the case of upstream disturbances or voltage fluctuations[16] and are used in remote areas, and the following applications can be named for them:

- Mining and remote industries
- Military applications
- Villages and Islands
- Hotels and entertainment venues
- Telecommunication systems
- Agricultural farms that do not have access to city electricity

The advantages of hybrid power plants consisting of wind turbines, solar panels and diesel generators are:

- Lower repair and maintenance costs
- Reduce fossil fuel consumption
- Increase confidence
- Increasing energy production efficiency
- Reduce environmental pollution
- Support for variable loads and increase stability

2.3 Related Studies

Afghanistan grades in the bottom 5% in terms of per capita electricity consumption, with only 30% of the country’s population connected to the grid in 2015. In terms of energy mix, solar power accounts for only about 1% or 3 MW of the country’s total installed generation capacity. This is despite Afghanistan having about 220,000 MW of solar power generation potential. The Government of Afghanistan purposes to develop the country's renewable energy generation, including solar power, so it can contribute at least 5,000 MW (40% share) to the national grid by 2032 [54].

Afghanistan has the potential to produce over 222,000 MW of electricity by using solar panels [55]. In 1991, a new 72-collector solar installation was completed in Kabul at a cost of $364 million. The installation heated 40,000 liters of water to an average temperature of 60 °C around the clock. The use of solar power is becoming widespread in Afghanistan. Solar parks have been established in a number of Afghanistan cities [56]. Solar-powered street lights are seen in all Afghan cities and towns. Many villagers in rural parts of the country are also buying solar panels and using them.

The country also has the potential to produce over 66,000 MW of electricity by installing and using wind turbines.[55] The first wind farm was successfully completed in Panjshir Province in 2008, which has the potential to produce 100 kW of power.[57] The United States Agency for International Development (USAID) has teamed up with the National Renewable Energy Laboratory to develop a wind map of Herat province. They have identified approximately 158,000 MW of potential wind power.[58] Installing wind turbine farms in Herat could provide electricity to most of western Afghanistan. Smaller projects are wind pumps that already have been attached to water wells in several Herat villages, along with reservoirs for storing up to 15 cubic meters of water. The 300 KW wind farm in Herat was inaugurated in September 2017.

Afghanistan is dire need of less expensive and clean energy. While the rate of consumption is still low in rural part of the country, the renewable form of energy could fulfill the needs many low income families inhabiting in rural part of the country [53].

At the time being, there is a massive quantity of scientific works dedicated to the optimal plan of hybrid strength systems [17, 18, 19, 20]. Some of the researchers focused on the optimization of hybrid strength system's initial design. In this case the most important tasks are: mixture of assets blanketed onto the system, the preference of location, determination of appropriate conditions, discount of whole costs, reliability and fixing ecological problems for region. The fundamental difficulty is confronted while designing stand-alone hybrid structures is the uncertainty in quantity of electricity, generated by using RES. Thereby the choice of tools is normally based totally on probabilistic theory or forecasts in solar and wind output, frequently with averaging and loads of simplifications.

Some of the researches focused on optimization of modes of hybrid power system. In this case the most important duties are: agreement of consumption and technology processes, willpower of rational load modes, advent of automatic manipulates systems. The uncertainty of RES requires an introduction of back-up sources or batteries into the system, simple and reliable manage system.

One of the primary duties in designing the hybrid strength system is the dedication of a primary ratio between installed capacities of strength sources protected into the gadget [or top of the line sizing/structure of system]. This have to be made by taking into account real local weather and geographical conditions of vicinity and facets of the customer. The shape of energy machine appreciably influences performance of designing strength machine and includes many most important tasks being considered in the establishing of strength building project, such as manufacturing costs, reliability, ecological and social impacts.

This query has been regarded in many scientific works where the wide variety of RES, included in system, is wavering from one to five [21, 22, 23, 24, 17, 25].

There are many one-of-a-kind ways of putting and fixing the project of most beneficial ratio between hooked up capacities in hybrid energy system. For example, in [25] this challenge is solved through classical linear programming, in [24] – by way of equipment of convex programing, in [22] – with the aid of simulation mannequin of power system.

Some works are fixing the neighborhood electricity problems, consequently their models comprise the features of sure customer, climate and geographical prerequisites of particular place and chosen gear [23,24]. Some works are aimed to strengthen the established model [22].

Optimization standards differ as well: complete power conversion effectivity [20], reliability of power provide [23], complete charges [22,23,24,25], environmental influence [17], etc. In some of presented works the task was single-criterial [23,24], in some - multi-criterial [17,25,26].

2.4 Distributed Power Generation and Reducing Reliance to National Power Grid

Distributed electricity generation means small-scale electricity generation at the point of consumption. This production method, commonly referred to as 25 MW, allows consumers to generate the electricity they need and sell their excess electrical power to the power grid or other consumers. Today, power generation is considered one of the solutions in the electricity industry in developed countries, which reduces the reliance on long power grids. Distributed electricity generation not only does not cost more economically, but also reduces the need for storage capacity due to reduced transmission and distribution network losses, reduces the need for production storage capacity, and, if connected to the network, significantly increases the cost of electricity. It will reduce consideration. Scattered generators are very diverse, but the best types of scattering are wind power plants, small hydropower plants, wind and solar hybrids, biomass, geothermal and solar, which are not only scattered in terms of power generation, but also in terms of primary resource resources. And they don't need to use gas networks or oil transmission networks.

The existence of a national electricity network and extensive natural gas and oil transmission networks is one of the largest national assets of the country, and a major part of the development of our national economy and social welfare is due to the existence of such networks. At the same time, long networks are seriously vulnerable in spite of all their advantages. Floods, earthquakes, landslides, heavy snowfalls, hurricanes, hostilities and technical problems are some of the long list of network threats. These threats are not limited to weak countries, and countries that are advanced in terms of security, economy, and technology are also vulnerable to network damage. Extensive blackouts in the United States, Europe, and neighboring countries, including Turkey, are evidence of this fact.

On the other hand, the installation of distributed power generators allows large consumers to have emergency and backup power during the outages imposed by the network and increase the reliability of their power supply system. From the point of view of the electricity distribution network, the installation of dispersed generators can reduce the load of high-load feeders and reduce losses and increase reliability. Utilizing the above benefits requires choosing a suitable location for installing the generators, determining the appropriate capacity for them and using the necessary arrangements for a safe and secure connection of these generators. The current trend in the world is towards increasing the growth of distributed power generation compared to the growth of large power plants, as 25 to 30 percent of new power plant investments have occurred in distributed generation. Given the low efficiency and longevity of existing large power plants, it will be conceivable to get a share of the production of these power plants. In some European countries, the share of scattered production has risen to more than 60 percent.

2.5 Result

In this chapter the importance of wind and solar hybrid power plants in providing the necessary electricity to remote areas is discussed. in a place There was no power supply, but due to investments in these areas, it is necessary to provide at least the facilities there and provide the necessary equipment for the physical protection and security of the area. Therefore, it requires electricity and one of the appropriate plans for electricity supply is the simultaneous use of wind energy and solar energy so that in the absence of any of them, other energy will generate electricity.

Undoubtedly, one of the main components of national security in all countries is access to energy. Any problems in the energy supply system will cause widespread disruption and damage in all economic and social sectors. For this reason, countries make diversification of energy resources one of their main strategies to strongly avoid dependence on one or two types of energy and minimize their vulnerabilities. Therefore, relying solely on oil and gas is a strategic mistake and it is necessary for renewable energy sources to have a greater share in the country's basket.

The existence of a global electricity grid, despite all its advantages, is seriously vulnerable. Floods, earthquakes, landslides, hurricanes, and technical problems are some of the longest-running list of network threats. These threats are not limited to weak countries, and countries that are advanced in terms of security, economy and technology are also vulnerable to network damage.

On the other hand, the installation of distributed power generators allows large consumers to have emergency and backup power during the outages imposed by the network and increase the reliability of their power supply system. Given the situation in Afghanistan, this measure is one of the most important measures of passive defense to reduce vulnerability. With the realization of this goal, the country will have the facilities that in case of various accidents, the electricity of different sectors can be provided by relying on local resources and facilities.

The use of other energies in nature, especially solar energy, wind and waves, geothermal energy, which has been studied as so-called renewable energy, and currently several solar, wind and renewable energy plants on a small scale and Big ones are working all over the world, but adapting these energy sources to the current level of global energy consumption is still fraught with problems that have been explored and solved by a large volume of scientific research in recent decades.

3. THE SECTOR OF ENERGY IN AFGHANISTAN

In the last two decades, the war torn Afghanistan could not enhance its capacity of delivering the necessary power supply needed for the country and with all the undertaken efforts, it could not catch up with the world standards in facing the energy demands [27]. This chapter is dedicated to have a review over the current electricity supply chain in the country and its projected and planned demand until 2032, which is within the countries plans [28]. Considering this, there will be a review of planned means to satisfy the demand. Lastly, the potential of the country for renewable energy, as a mean to raise up the standards and to satisfy the demands, is evaluated.

3.1 Existing Electricity Supply

The power supply system of Afghanistan, relatively old in it is infrastructure, constituted from grid-based systems, mini-grids and stand-alone facilities. Majority of the infrastructures are built during the last two decades, that supposedly should be new with consideration worldwide standards. Hence, this assumption may be not so valid due to the hasty developmental plans. Living Conditions Survey's [ALCS] findings show that 89 percent of the households in the country have had access to electricity over 2013-2014. The shown percentage accumulates a 29.7 percent share for the grid system. However, considering the rural-urban spectrum, this percentage can fluctuate. So, in explaining this fluctuation, Table 3.1 is drawn to illustrate the primary source of supply for rural areas and urban areas as well as their access to electricity. What is obvious from the numbers in the table is that the urban households are the major beneficiaries of grid supply while rural households receive a relatively small portion of it [28].

% of Households	National	Rural	Urban
Access to electricity			
Yes	89.0	85.9	98.6
No	11.0	14.1	1.4
Source of Electricity			
Grid	**29.7**	**10.9**	**88.8**
Government Generator	0.7	0.2	2.2
Private Generator – Engine	0.8	0.7	1.0
Private Generator – Hydro	1.2	1.5	0.1
Community Generator – Engine	0.4	0.5	0.3
Community Generator – Hydro	7.4	9.7	0.1
Solar	46.4	57.9	10.2
Wind	0.4	0.6	0.1
Battery	11.6	14.3	3.3

3.1.1 Grid Based Electricity

In Afghanistan, the responsibility of grid based systems are giving to Da Afghanistan Breshna Sherkat [DABSS]. The state owned DABSS was originally started its mission under the framework of Ministry of Energy and Water, which in 2009 acquired its autonomy by splitting from the ministries organizational complex. DABSS's original scope of work was concluded in transmission and distribution [T&D] of electricity but recent public administration strategies of the country let DABSS to show its intensive involvement in investments for development of T&D capacities.

Since Afghanistan fulfils its electricity requirement through importing, the source of these imports are considered as an important factor in all related analysis. Mostly the imports are done from close neighbors of the country to make it cost efficient for use [29]. 3,767 GWh, which constitutes an estimated 80 percent of total grid supply. Uzbekistan as key source provided 1,284 GWh, closely followed by Turkmenistan with a share of 1,184 GWh. Iran's share is 827 GWh and Tajikistan, less among all, supplied 471 GWh. Figure 3.1 illustrates the overall share of each source in total grid electricity supply of Afghanistan. Not to mention, the domestic power generation with 1,007 GWh amount acquires lowest share which, almost entirely [96 percent], are provide from hydro power plants.

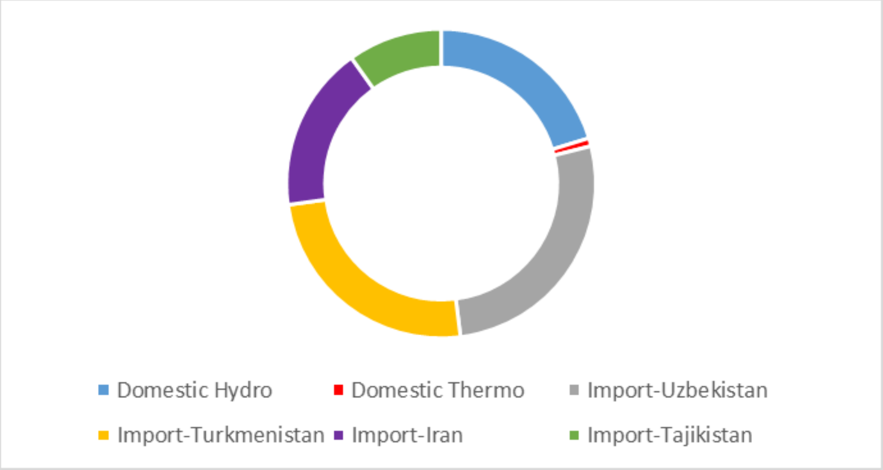


Figure 3-1 Grid Electricity Supply of Afghanistan, 2015-16 [30]

3.1.2 Transmission Network

The transmission system of the country is constituted from isolated grid system that makes it fairly fragmented. This fragmentation is majorly due to plurality of sources from which electricity is imported which in turn ended up with different results. One of the results is the establishment of several independent power systems in the country which asynchronously. Each of these power systems are synchronized with the system of source country and operate separately from each other. Only in the west part of Afghanistan, where the contracted countries to import electricity are the immediate neighbors, Turkmenistan and Iran, could eventually end up with some level of synchronization. The unthoughtful aim of fast development which access to electricity was a major factor of it, drew the path for the infrastructure of the country that now became the blue print for all future infrastructure building plans. Asynchronous supplies eventually resulted in demolishing the ability to interconnect and to enhance the security of supplies. The future expansion of the power network in a standard rational way will definitely be affected by the undertaken policies.

3.1.3 Off-Grid System

Considering ALCS report, off-grid systems are including solar power, mostly solar home systems [SHS], and micro hydro systems. The National Solidarity Program [NSP] has taken the charge of developing 5,000 separate micro hydro projects. The solar potential, except for 1MW plant in Bamyan province, has not been considered in large scale projects. This while under the NSP, a significant number of small scale projects, which counts for 8,300, are constructed. Adding to that, the database of Rural Energy Department of Ministry of Energy and Water shows a total number of 5,194 renewable energy projects. This figure includes 2,450 solar-based initiatives [the procurement of solar panels, as well as solar warm water systems, solar pumps and invividual clinic, school, and mosque systems] [31].

3.2 Current Electricity Consumption

For Afghanistan's economic development a fast increase in demands for electricity is quite normal and projectable. With some level of industrialization and mechanization in different sectors, the raise in electricity demand pattern can multiply over a short period of time. The present supply, as in Table 2.1, provides 86% percent of rural households and 99% of urban households with access to electricity via different means. Among that, 89% of homes in urban areas are supplied via grid-based system. From the total grid-based supply of 4,773 GWh, 3,767GWh are imported. Hydropower amounts for 967GHw and thermal power amouts for 39 GWh. The imported electricity cannot coup with the increasing demand. Unless the amount of import are raised and the domestic electric generation multiplied, the system will suffer from frequent interruptions in providing service. [32]

3.3 Projected Electricity Demand

Acknowledging the shortage of energy as a major weakness and meeting the electricity demand as a challenge the government of Afghanistan aimed for projecting the future needs. In this regard, Afghanistan Power Sector Master Plan [APSMP], a conclusive document that was initially prepared to predict the energy supply for Afghanistan, was created. This document used the pattern of consumption in 2011 as workable basis and provided three options of gross energy, net energy and peak demand supply. Energy supplied to clients which in short conceptualized as net supply indicates an average rise of 9.8% from 2.8GWh in 2012 to 15.909GWh in 2032. The power delivered which is conceptualized as gross demand indicates an average raise of 7.8% from 4,000 GWh in 2012 to 18,400 GWh in 2032. Figure 2.3 shows the predicted gross and net electricity consumption.

Peak demand in this regard would raise an average of 8.6% per year from 600 MW in 2012 to 3.502MW in 2032. The rise in peak load is mildly smaller than the rise in total supply due to a predicted rise over the forecast period in the median load factor.

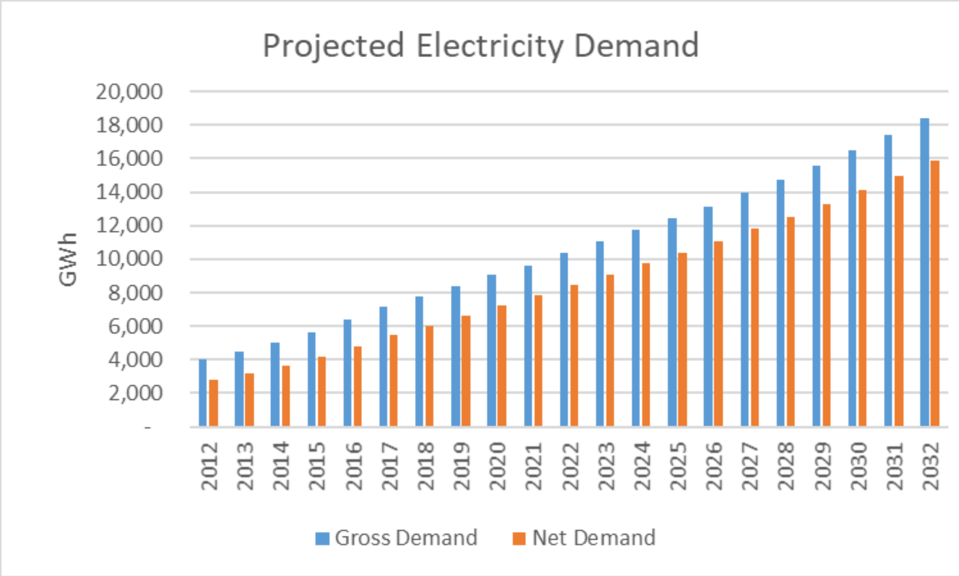


Figure 3-2 Afghanistan Projected Electricity Demand [2012 – 2032, Base Case] [28**]**

3.4 Renewable Energy Potential

Unlike most of the countries in the world Afghanistan is considered one of the untouched countries in resources sector. The country has highly important renewable energy resources and vast fossil fuel reserves. However, as it is a major concern in National Development Strategy of Afghanistan [ANDS], the accurate data on this matter is not yet available [32]. Henceforth, we concentrate mainly on renewable energy potential, since it is possibly the quickest way to supply fragmented rural population with electricity and heating fuel. It worth mentioning that in Afghanistan the largest portion of the population is the rural population. What we undertake here is not to undermine the national grid system, nor we are looking to completely disregard the fossil fuel reserves of the country. According to latest study undertook by American geologists, an approximate of 1.6 billion barrels of crude oil and something aroung 0.5 billion bareels of petroleum are reserves beneath the soil of the country [33]. The projected undiscovered natural gas reserve of the country is estimated at 444 billion cubic meters, which is in northern region of the country mostly Amu Darya Basin [33]. The power Sector Master Plan also reports an estimate of 73 million tons of coal reserves and 35,000 tons of production in 2008.

Nevertheless, considering the economy of the country, the low operating costs, installation time and technical simplicity makes the grid connections, fossil-fired power stations, stand-alone, off-grid or small island grid, solar, micro-hydro power

[MHP] and wind power systems more viable options [34,35]. Since 2001, approximately 5,000 RE projects most of which solar an MHP with potential capability of 50 MW are finished or under construction [27].

With all developments in field of renewable energy in Afghanistan, there are some major obstacles that challenges it. The spectrum of these obstacles starts with inconsistency in policies, poor stakeholder’s coordination, continues with shortage in technical capacity and weak grid infrastructure, to more global issues like climate change [36]. Although, the Afghanistan’s National Renewable Energy Policy [ANREP] defines a target of up to 95% of renewable power for the country.

3.4.1 Hydro [All Scales]

The mountainous geography of Afghanistan can possibly challenge the country for building grid systems, but it provides a major opportunity in hydropower production. The hydropower production potential of the country is forecasted to be 23,000 MW with large participation from big dams [3]. Right now, the present established capacity is amounted only for 254 MW, which relatively seasonal water and estimated to capacitate less than 40% [27]. The hydropower production involves the older huge hydroelectric power stations along with new installed MHP. The newly installed MHPs have been built under the supervision of Ministry of Rural Rehabilitation and Development [MRRD]. Since 2005, this ministry has put its efforts to construct vast number of MHPs via National Solidarity Program [NSP], which is donor-supported. The MHPs are anticipated to provide 7% of the population with electricity after fully operationalized [35].

3.4.2 Solar

Sun is considered as the life the universe. Countries and international organizations all over the world are realigning their policies to utilize this vast source of energy in human’s service. Afghanistan is considered as a land of "sunbelt" [38]. The climate in Afghanistan has its uniqueness by reaching the sunny days of Africa at one time and the cold winters of Russia at another. However, due to the vast land of the country it can differ from one region to another. In Afghanistan, “the annual average Global Horizontal Irradiance [GHI] is 1.935 kWh / m2/day and the national average seasonal maximum and minimum is 7.84 kWh / m2/day and 2.38 kWh / m2/day” [34]. GHI summer peaks reach about 9.0 kWh / m2/day in some western and southern provinces. The US National Renewable Energy Laboratory [NREL] preliminary estimates suggests approximately 220,000 MW of the country's solar potential [36]. In another study, Anwarzai and Nagasaka [39] calculate the total annual generation potential at 146,982 GWh, comprising 140,982 GWh of Photovoltaic [PV] and 6,000 GWh of Concentrating Solar Power [CSP] technologies, using Multi-Criteria Decision Analysis [MCDA] and Geographical Information System [GIS]. Figures 2a and 2b use the scoped-down capacity values of the latter [39], not the initial NREL values [36].

3.4.3 Wind

In Afghanistan, there are big waste regions with promising wind energy potential. A study conducted by MEW's Renewable Energy Department estimates the wind's energy potential at around 67,000 MW [40], while NREL estimates the potential at 158,000 MW [41]. The latter study, which produced high-resolution wind resource maps using advanced modeling and analysis techniques, classifies 5 percent [31,600 Km2] of total land area in Afghanistan [650,000 Km2] as "class 4 +" offering' good-to-excellent' potential for useful applications. The main wind resource regions are situated in Nimroz, Farah, Herat's western provinces, and Balkh and Takhar's southeastern provinces. The wind corridors in the south and near Qalat, Gadamsar, Walakhor, Golestan and Gorzanak in the main and southern areas are close Jabalsaraj, Sarobi, and Tirgari. The same research adds that for off-grid apps, 12 percent of the complete region of the country has excellent potential, "class 3." In Figures 2a and 2b, as even the more conservative value of [40] far outstrips projections of national power demand, we use this. Other surveys are also accessible: Tetra Tech, contracted by ADB in 2009, used the NREL research map and information to define economically feasible wind energy manufacturing sites using GIS with other accessible information [42]. This identified two sites in Kabul, three sites in Heart and five sites in Mazar-e-Sharif with the best current potential, taking into account several factors, including security issues. Another study found an annual output potential of 342,521 GWh for Afghanistan [39].

3.4.4 Geothermal

The primary axis of the Hindu Kush Mountains are situated in active geothermal systems [43]. Low to medium geothermal sites in the form of hot springs and noticeable heat leakage with ground manifestations are common throughout the nation, but the potential of geothermal energy reserves has not been explored. Saba et al. [2004] believe that the geothermal energy potential in Afghanistan is "huge" and that its use in electrical and non-electrical applications is "feasible" and "realistic." The Renewable Energy Policy of the country recognizes the geothermal potential and notes that there are 70 "places" and three large feasible areas [30]. The Inter-Ministerial Energy Commission estimates the potential at around 3,500 MW and indicates that power plants with a generating capacity of 5 to 20 MW can be constructed at each location [29]. The Rural Renewable Energy Policy of the country proposes direct use of geothermal energy applications in industries such as food processing, fruit drying, refrigeration, hatchery and farming, carpet and wool processing, recreation and tourism [31].

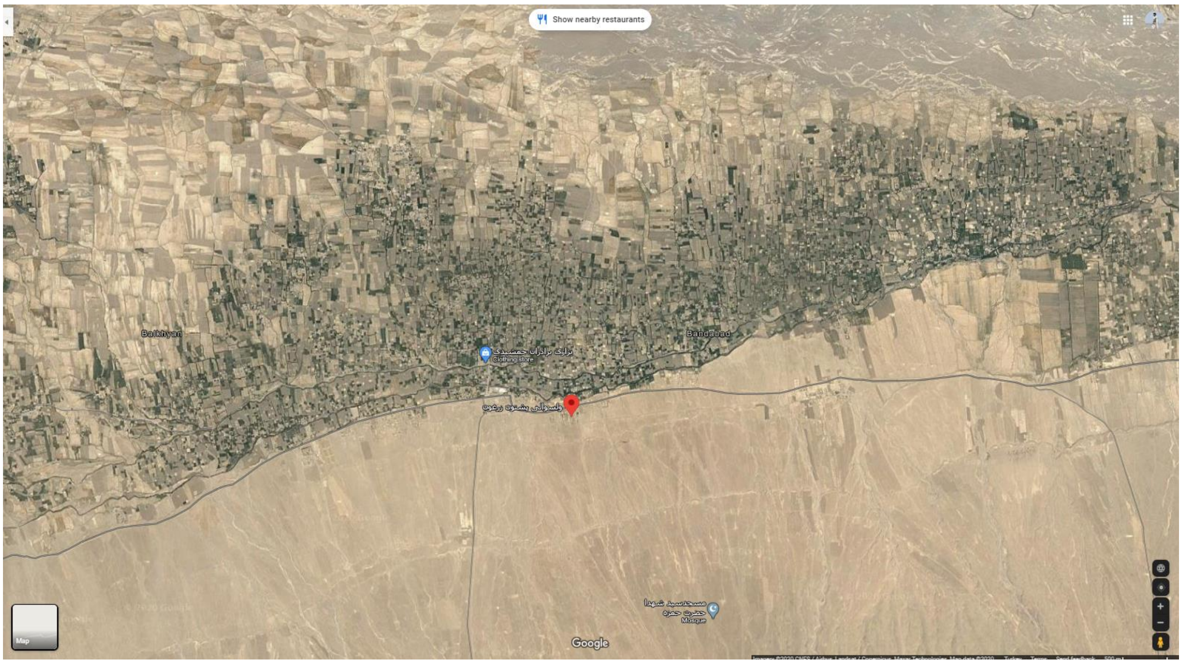
3.4.5 Biomass

Use of strong biomass is common practice in the country particularly in rural parts. Comparing to urban areas, rural areas comprise a vast part of the country in which biomass is used for heating and cooking, which amounts to 90 percent of overall power usage in some areas [44]. Although using firewood, shrubs and dung is the very option for rural population, in addition to health problems enhances level of desertification in vulnerable country to effects of climate change. New technologies that integrated higher energy efficiency such as biogas, electricity, building insulation and cooking tools and machines can be effective in reduction of this problem. A widely known and cited research on the prospective evaluation of biomass resource in the country was conducted by NREL [44] The authors provide an estimated 134 GWh of annual electrical energy from only Municipal Solid Waste [MSW] using GIS technology and statistical analysis on agricultural, environmental and socioeconomic data. They also estimate that it is possible to install around 896,000 small biogas plants using cattle manure, with the potential to provide clean energy to 26 percent of the population. For economic and climatic reasons, the study does not see forest resources and crop residues as good energy production options. The National Renewable Energy Policy of Afghanistan estimated that 4000 MW of energy could be produced from biomass resources, including 3090 MW of agricultural waste, 840 MW of animal waste, and 91 MW of solid waste [MSW] [30]. Again, for Figures 2a and 2b, in this case by NREL, we take the lower value.

4. CASE STUDY [ELECTRICITY LOAD ESTIMATION OF THE VILLAGE]

Our case study in this thesis is Pashtun Zarqoon district, which is placed in the western side of Afghanistan in Herat province, the main area is the center of Pashtun zarqoon district which is sounded by other villages that are all far away from the grid with the following coordinate 34.226431, 62.689328.

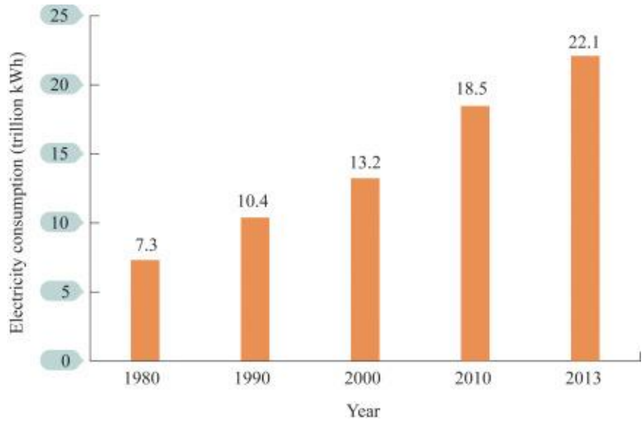
Figure 4-1 Pashtun zarqoon district



4.1 Electricity Consumption

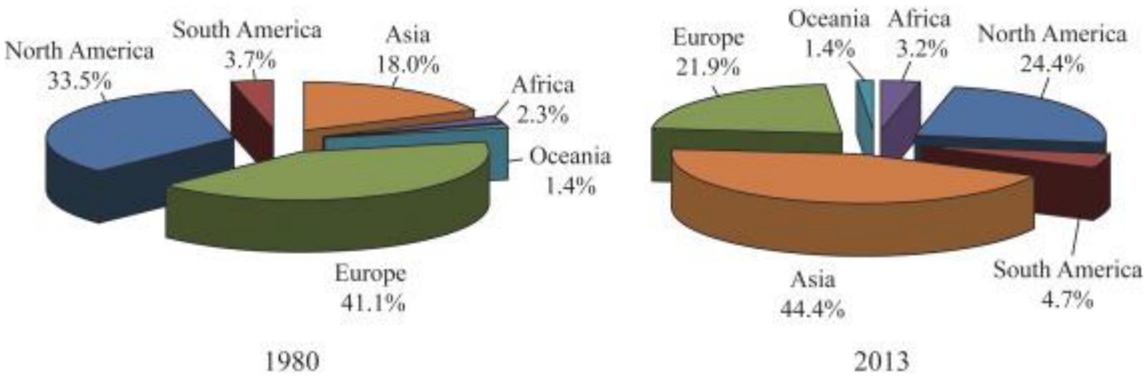
Electricity consumption rate has rapidly inclined almost faster than energy production globally. Considering the time period between 1980 and 2013, level of consumption rose up from 7300 TWh to 22,100 TWh globally. By twenty first century, the consumption rate increased even faster by an average annual increase of 3.4% which is 1.2 percent higher than average annual growth of energy consumption. As Afghanistan is a developing country, estimation for the hole country needs in-dept researches and depends in many different condition unique to it. This study aims to design an off grid power plant, so we will just employ the annual rate of 3.4% which is annual growth rate of countries that they passed their developing years.

Figure 4-2 Global Electricity Consumption During 1980–2013 [45].



New emerging economies in Asia and Central and South America, like China, India, Brazil, have experienced a significant change in their consumption rate comparing to the developed countries. The consumption rate of Asia, central and South America, and Africa in 2013 was 9820, 1050, 710 TWh respectively, which comparing to 1980 have experienced a 5.8, 2.4 and 2.3 times increase respectively. This is while North America and Europe had respectively experienced 87% and 148% increase, which shows far lower than new emerging economies mention before. [45]

Figure 4-3 Change in the Share of Each Continent's Electricity Consumption in World Total 1980–2013[45]



4.2 Methodology for Estimating the Electric Consumption in Off Grid Area

Afghanistan and especially the area this thesis which I choose it as case study experience summer and winter seasons as extreme cases, the electricity consumption vary almost the mentioned sessions[46]. In this thesis the electric load demand of the village community is divided in to the following major categories:

- household/domestic sector which includes of [lighting, TV, Radio, and baking appliances]
- street lights
- Commercial loads [flour milling machine]
- Public institutions and social service
- Agriculture
- Miscellaneous

The total electric load estimated for the listed appliances above were summed up to get the required load to be supplied by the system. Despite of the present situation is below the poverty line, Peak operation hours of the appliances have been proposed based on the current living condition of the community and the current growth trend of the country. It is very obvious that the load factor in a rural community is lower than urban areas; therefore, by have a social survey in area and asking 50 household between the total 1100 household which are living in the area. I got a average of daily necessary consumption for the selected villages and so as we mentioned we will take 3.4% growth rate which is the average growth rate of the world in 33 years from 1980 to 2013 [45].

4.3 Estimation of Village Load

For the estimation of demand of village we will consider the following loads for a normal life with average quality of life in rural area in Afghanistan that are Domestic load for 1100 household each house hold with average of 6 family members in Afghanistan, street lights with 200 lights for the whole 10km of main streets in the selected area, commercial purpose that can have 50 shops for the selected area, public institutions with 4 school, 10 mosque and 1 clinic, agriculture and all other miscellaneous loads for the whole area for a range of 20year.

The load will estimate for 3 different weather condition, first for spring and fall, second for summer and the third one for the winter.

4.3.1 Domestic Load

In an individual residence house in rural area the electricity demand for a average life can be estimate for 5 LED Lamps each one 15watts, 1 TV 50watts, 1 Refrigerator 75watts, 1 Radio 20watts, 1 computer 100watt, 3 cell phone charger each one 5watt, water pump 500watt and washing machine 750watt for fall and spring and for two other session we have to add cooling system 500 watt and warming systems 1000watts.

Table 4-1 Domestic load Hourly demand table for [spring and fall]

devices	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Television								50	50	50					50	50	50	50	50	50	50	50	50	
Radio								20	20	20			20	20	20									
Lights																		75	75	75	75	75	75	
Cell phone								15											15	15				
Computer										100	100								100	100				
Water pump								500																
Refrigerator	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Washing Ma.										750	750													
Total (watt)	75	75	75	75	75	75	75	660	145	995	925	75	95	95	145	125	125	200	315	315	200	200	200	75
total (kWh)	0,075	0,075	0,075	0,075	0,075	0,075	0,075	0,660	0,145	0,995	0,925	0,075	0,095	0,095	0,145	0,125	0,125	0,200	0,315	0,315	0,200	0,200	0,200	0,075
total for 1100 houshold	82,5	82,5	82,5	82,5	82,5	82,5	82,5	726	159,5	1094,5	1017,5	82,5	104,5	104,5	159,5	137,5	137,5	220	346,5	346,5	220	220	220	82,5

Table 4-2 Domestic load Hourly demand table for [summer]

devices	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Television								50	50	50					50	50	50	50	50	50	50	50	50	
Radio								20	20	20			20	20	20									
Lights																		75	75	75	75	75	75	
Cell phone								15											15	15				
Computer										100	100								100	100				
Water pump								500																
cooling										500	500	500	500	500	500	500	500	500	500	500	500	500	500	
Refrigerator	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Washing Ma.										750	750													
Total (watt)	75	75	75	75	75	75	75	660	145	1505	1425	575	595	595	645	625	625	700	815	815	700	700	700	75
total (kWh)	0,075	0,075	0,075	0,075	0,075	0,075	0,075	0,660	0,145	1,505	1,425	0,575	0,595	0,595	0,645	0,625	0,625	0,700	0,815	0,815	0,700	0,700	0,700	0,075
total for 1100 houshold	82,5	82,5	82,5	82,5	82,5	82,5	82,5	726	159,5	1655,5	1567,5	632,5	654,5	654,5	709,5	687,5	687,5	770	896,5	896,5	770	770	770	82,5

Table 4-3 Domestic load Hourly demand table for [winter]

devices	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Television								50	50	50					50	50	50	50	50	50	50	50	50	
Radio								20	20	20			20	20	20									
Lights																		75	75	75	75	75	75	
Cell phone								15											15	15				
Computer										100	100								100	100				
Water pump								500																
warming						1000	1000	1000	1000	1000	1000	1000					1000	1000	1000	1000	1000	1000	1000	
Refrigerator	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Washing Ma.										750	750													
Total (watt)	75	75	75	75	75	1075	1075	1660	1145	1995	1925	1075	95	95	###	###	1125	1200	1315	1315	1200	1200	1200	75
total (kWh)	0,075	0,075	0,075	0,075	0,075	1,075	1,075	1,660	1,145	1,995	1,925	1,075	0,095	0,095	0,145	0,125	1,125	1,200	1,315	1,315	1,200	1,200	1,200	0,075
total for 1100 houshold	82,5	82,5	82,5	82,5	82,5	1182,5	1182,5	1826	1259,5	2194,5	2117,5	1182,5	104,5	104,5	159,5	137,5	1237,5	1320	1446,5	1446,5	1320	1320	1320	82,5

4.3.2 Street Lights

As it is necessary for the security purpose and for quality of life in each country we will consume street lights for villages, in our case study area, we have about a total 10 km of main streets that is in all sides that we need to install a light in each 50m that totally we have to install 200 street light, all the lights will use 6 hours per day from 7PM to 1AM and in all season we will use the same time of using.

Table 4-4 Electric Load Consumption for streetlights

devices	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
street lights	20000																			20000	20000	20000	20000	20000
Total (watt)	20000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20000	20000	20000	20000	20000
total (kWh)	20,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	20,000	20,000	20,000	20,000	20,000

As it seem we have daily usage of 120 kWh and peak load of 20kW for street lights in all seasons.

4.3.3 Commercial Load

It is necessary for each area to have shops and commercial places for facing the people's need in the mentioned area in this area totally we consider 50 different shops that is working in that area, normally in Afghanistan shops are working form 8 am to 8 pm 12 hours daily and cause of security problem there are no commercial load in the night shift.

Table 4-5 Electric Load for commercial purpose

places	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
shops									5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000				
Total (watt)	0	0	0	0	0	0	0	0	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	0	0	0	0
total (kWh)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	0,000	0,000	0,000	0,000

As there are just small shops in the selected area there will be just a average demand of 100 watt hourly for each shop for light and refrigerator and we can use the same data foe all days of the year cause in the shops in the rural areas they are using the same electrical devices in all session of the year.

4.3.4 Public Institutions and Social Service

In this filed we have to estimate the load for social services like mosques, clinics and public institutions that is consist of schools in the area, in our area there are 4 schools, 10 mosque and 1 health clinic for servicing people that load for all of them is daily loads all of the social service and public institutions are close in the night shift. Average load for one school is 1000 watt for each school a 200watt for each mosque and just for lighting purpose, and 2000 watt for clinics.

Table 4-6 Electric Load for public institutions and social service

places	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
mosques																	2000	2000	2000	2000	2000	2000		
schools									4000	4000	4000	4000	4000	4000	4000	4000	4000	4000						
health clinic									2000	2000	2000	2000	2000	2000	2000	2000								
Total (watt)	0	0	0	0	0	0	0	0	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	2000	2000	2000	2000	0	0

The load for public institution for all the seasons of the year is the same

4.3.5 Agriculture

For agriculture the only necessary thing is using water pumps in the villages in Afghanistan, and normally people watering there fields in day from 8 o'clock to 8 o'clock in the night and in according to raining capacity it can starts from the first days of spring and it can continue tell the last days of fall session. And normally people watering there fields in a order that is described by the government for people then we can consume 10000watts for 10 hours in each day

Table 4-7 Electric Load for agriculture for spring and summer

places	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
watering									10000	10000	10000	10000	10000	10000	10000	10000	10000	10000						
Total (watt)	0	0	0	0	0	0	0	0	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	0	0	0	0	0	0
total (kWh)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	0,000	0,000	0,000	0,000	0,000	0,000

The load for agriculture is the same for spring summer and fall and for winter there is no load for agriculture purpose in the rural area cause there is raining in the area and no need to watering the fields by water pumps .

4.3.6 Miscellaneous

This one is for all other miscellaneous that we did not consume or emergency loads that can daily use or extra loads, and we will assume average load of extra 5000watt for each hour for all the seasons.

Table 4-8 Electric Load for miscellaneous loads

places	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
miscellaneous	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Total (watt)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
total (kWh)	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000

4.3.7 Estimation of Total Hourly Loads in Village for Different Seasons

Table 4-9 Estimation of total hourly loads for spring and fall

devices	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
domestic	82,5	82,5	82,5	82,5	82,5	82,5	82,5	726	159,5	1094,5	1017,5	82,5	104,5	104,5	159,5	137,5	137,5	220	346,5	346,5	220	220	220	82,5
street lights	20,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	20,000	20,000	20,000	20,000	20,000
commercial	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	0,000	0,000	0,000	0,000
public institutions	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	2,000	2,000	2,000	2,000	0,000	0,000
agriculture	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	0,000	0,000	0,000	0,000	0,000	0,000
miscellaneous	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Total (kWh)	107,5	87,5	87,5	87,5	87,5	87,5	87,5	731	185,5	1120,5	1043,5	108,5	130,5	130,5	185,5	163,5	163,5	246	358,5	378,5	247	247	245	107,5

Table 4-10 Estimation of total hourly loads for summer

devices	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
domestic	82.5	82.5	82.5	82.5	82.5	82.5	82.5	726	159.5	1655.5	1567.5	632.5	654.5	654.5	709.5	687.5	687.5	770	896.5	896.5	770	770	770	82.5
street lights	20.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	20.000	20.000	20.000	20.000	20.000
commercial	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	0.000	0.000	0.000	0.000
public institutions	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	2.000	2.000	2.000	2.000	0.000	0.000
agriculture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	0.000	0.000	0.000	0.000	0.000	0.000
miscellaneous	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Total (kWh)	107.5	87.5	87.5	87.5	87.5	87.5	87.5	731	185.5	1681.5	1593.5	658.5	680.5	680.5	735.5	713.5	713.5	796	908.5	928.5	797	797	795	107.5

Table 4-11 Estimation of total hourly loads for winter

devices	hourly demand table																							
	AM												PM											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
domestic	82,5	82,5	82,5	82,5	82,5	1182,5	1182,5	1826	1259,5	2194,5	2117,5	1182,5	104,5	104,5	159,5	137,5	1237,5	1320	1446,5	1446,5	1320	1320	1320	82,5
street lights	20,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	20,000	20,000	20,000	20,000	20,000
commercial	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	0,000	0,000	0,000	0,000
public institutions	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	2,000	2,000	2,000	2,000	0,000	0,000
agriculture	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
miscellaneous	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Total (kWh)	107,5	87,5	87,5	87,5	87,5	1187,5	1187,5	1831	1275,5	2210,5	2133,5	1198,5	120,5	120,5	175,5	153,5	1253,5	1336	1458,5	1478,5	1347	1347	1345	107,5

Table 4-12 Estimation of hourly loads for different seasons

devices	hourly demand table																							
	AM												PM											
time	00:01	01:02	02:03	03:04	04:05	05:06	06:07	07:08	08:09	09:10	10:11	11:12	12:13	13:14	14:15	15:16	16:17	17:18	18:19	19:20	20:21	21:22	22:23	23:24
spring and fall	107,5	87,5	87,5	87,5	87,5	87,5	87,5	731	185,5	1120,5	1043,5	108,5	130,5	130,5	185,5	163,5	163,5	246	358,5	378,5	247	247	245	107,5
summer	107,5	87,5	87,5	87,5	87,5	87,5	87,5	731	185,5	1681,5	1593,5	658,5	680,5	680,5	735,5	713,5	713,5	796	908,5	928,5	797	797	795	107,5
winter	107,5	87,5	87,5	87,5	87,5	1187,5	1187,5	1831	1275,5	2210,5	2133,5	1198,5	120,5	120,5	175,5	153,5	1253,5	1336	1458,5	1478,5	1347	1347	1345	107,5

Figure 4-4 Estimation of load demand in different months

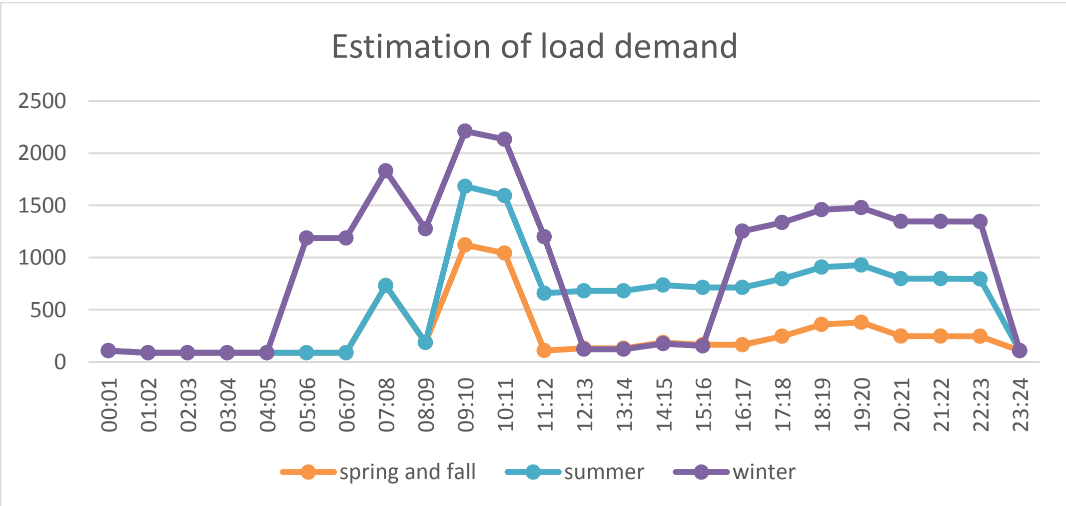
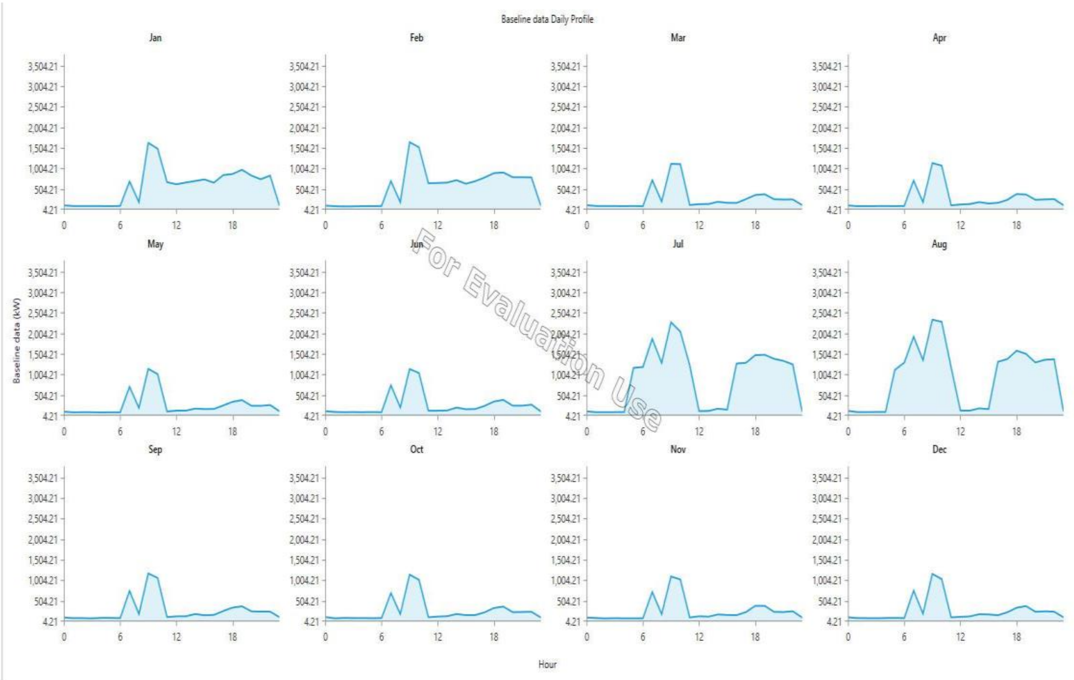


Figure 4-5 Monthly demand Graphs



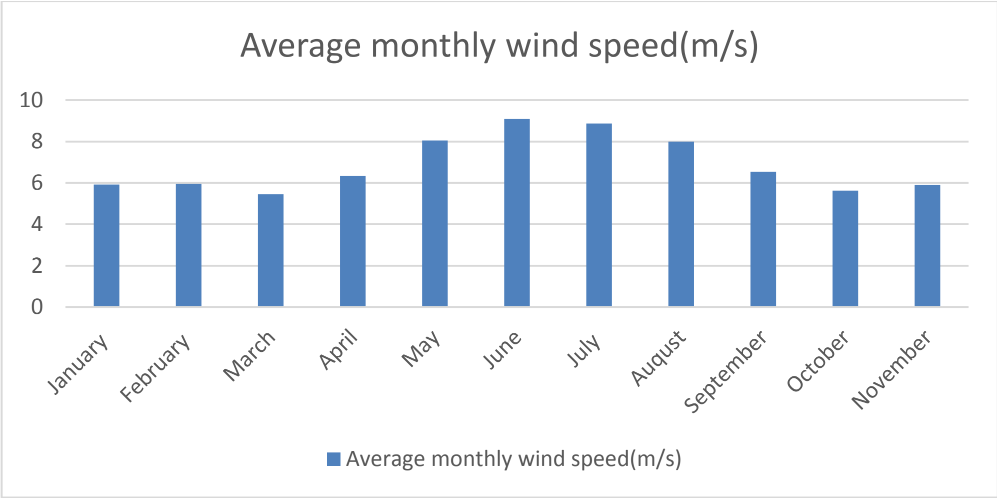
4.4 Wind Speed in Pashtoon Zarqoon

All data about wind condition our selected area [34.226431, 62.689328] is taken from the HOMER software. HOMER software is currently the best application for optimizing hybrid power system and data inside the HOMER software is downloaded from NASA surface meteorology and solar energy database. Wind speed is measured 50m above the surface of the earth, monthly averaged values over a period of 10 year from july 1983 to june 1993.

Table 4-13 average monthly wind speed [47]

Months	Jan	Feb	Mar	April	May	June	July	August	Sep	Oct	Nov	Dec
Average speed[m/s]	5.71	5.92	5.95	5.45	6.33	8.050	9.09	8.87	8	6.54	5.63	5.9

Figure 4-6 average monthly wind speed [47]



4.5 Solar Radiation in Pashtoon Zarqoon

As the wind speed all data for solar global horizontal irradiance [GHI] data in our selected area [34^o 7.8'N, 62^o 58.2'N] is downloaded from the HOMER. data inside the HOMER software is downloaded from NASA surface meteorology and solar energy database and it is monthly averaged values over a period of 22 year from july 1983 to june 2005

Table 4-14 average solar radiation and clearness index [47]

Months	Jan	Feb	Mar	April	May	June	July	August	Sep	Oct	Nov	Dec
Clearness Index	0.529	0.533	0.549	0.573	0.611	0.635	0.628	0.638	0.654	0.635	0.578	0.525
Daily Radiation [kWh/m^2/day]	2.77	3.62	4.57	5.73	6.78	7.31	7.090	6.62	5.8	4.48	3.190	2.53

Figure 4-7 average monthly clearness index [47]

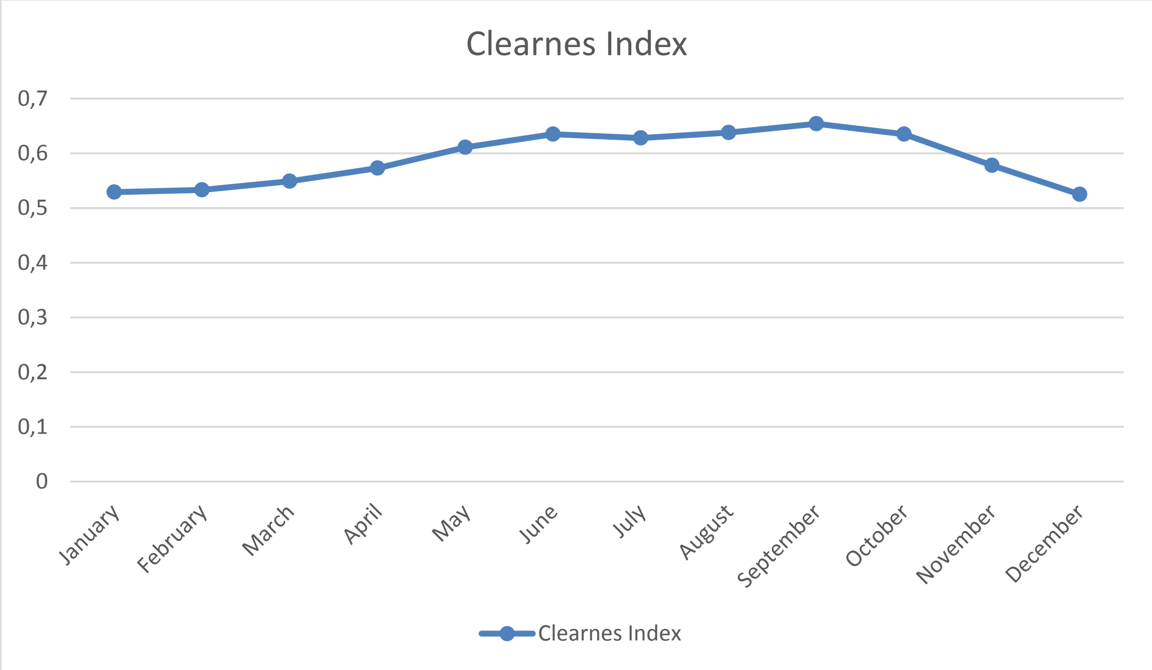
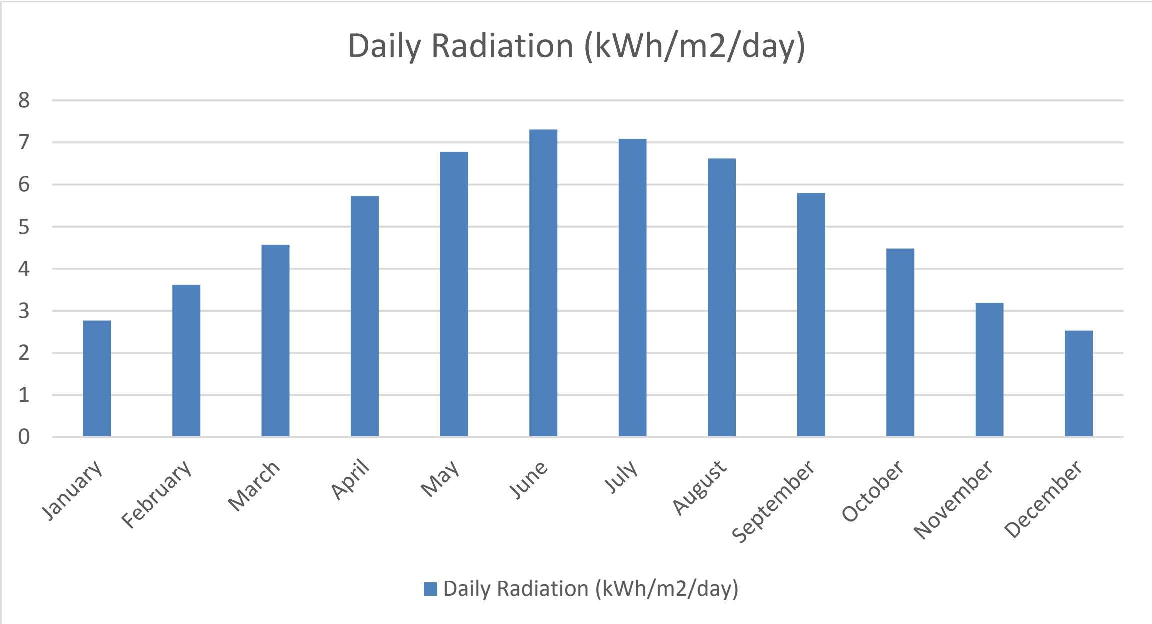


Figure 4-8 average daily solar radiation in different months [47]



Note: Due to unavailability of local data for solar radiation and wind speed, The data for both of them is downloaded to HOMER software from NASA surface meteorology and solar energy database which solar radiation is taken over a period of 22 year from july 1983 to june 2005and wind speed is taken over a period of 10 year from july 1983 to june 1993 and as this data is taken over a long period of time, both can be used for designing purpose[47].

5. DESIGN CRITERIA FOR STAND-ALONE HYBRID POWER SYSTEMS

Hybrid stand-alone systems can be employed for the power supply decentralization using their relatively good economic and technical features.

The selection of a proper hybrid power system needs an assessment approach of different aspects and criteria such as economic and technical aspects and environmental and social considerations. In the following section, the considerable aspects, their influences on the decision making, and an assessment approach to evaluate these aspects are presented.

5.1 Feasibility Study of the Project

Evaluation of important aspects in the design of a power system significantly depends on the decision-maker's point of view. Different decision-makers prioritize different aspects. The role of the decision-maker should be clarified at the beginning of the project. Usually, the design of a power system can be influenced by the decision of three groups; government, private sector, and inhabitants. The government may consider the regulation, environmental, and public efficiency of the power system as priorities, however, the private investor will focus the performance of the system, cost, and the economic and technical issues. On the other hand, the inhabitants as the user of the system will consider the aspect such as the electricity price and the risk of power interruptions.

As was mentioned the first step in the development of a power system is determining the decision-makers and their roles in the project. The second step is to perform a feasibility evaluation of the project. This should be implemented in the three branches; technical feasibility study, funding feasibility, and the legislation.

After decision makers decided, a feasibility study for the project should be started. The feasibility study is divided into three phases: technical feasibility; funding feasibility; and legislation. Each of these phases are discussed in detail in following paragraphs. In decision making, all the existing power sources utilized for combination of a decentralized power supply, like wind, solar, micro-hydro, biomass, hydrogen, diesel and etc. are being evaluated.

5.1.1 Technical Feasibility

The technical feasibility of a power system project is evaluated based on the number of parameters. The basic data for consideration of the type of decentralized power supply is the technical characteristics of the power source. One can evaluate the feasibility of a power system considering the technical characteristics of power source together with the geographical and site restrictions and determine the efficiency of a proposed generation unit.

The feasibility of the project depends on the type of power source. For a solar power plant, the average daily son radiation is the critical aspect, while for a wind turbine the average wind speed should be considered. For the micro hydropower plant, the minimum speed and flow rate of water steam are considered, however, the feasibility of a geothermal energy plant is evaluated based on the access of the required sources in the region.

Table 5.1 present the different criteria that should be considered for the different power sources during the feasibility evaluation. This table shows that for the wind the annual speed average of the wind should be larger than the minimum required speed to rotate the turbine.

Table 5-1 Evaluating the technical feasibility of technologies

Technology	condition
Wind	$V_{turb\_max} \geq V_{avar} \geq V_{turb\_min}$ ----------------------5.1
Solar	$I \geq I_{min}$ --5.2
Hydro	$Q \geq Q_{min}$ -------------------------------------- 5.3
Diesel	$D \geq D_a$ --------------------------------------- 5.4

Which V_{aver} = average wind speed V_{turb_max} = maximum wind speed for turbine

V_{turb_min} = minimum wind speed for turbine I = average daily solar radiation

I_{min} = Minimum solar radiation Q = water discharge

Q_{min} = Minimum needed water discharge for turbine D = needed amount of diesel

D_a = Available amount of diesel

In addition to the power source characteristics, the technical competence of the system designer should be considered in the feasibility evaluation. The ability of the designer to construct the system according to the provided technology is an important issue that will influence the power system development. The ability of the designers should be evaluated based on their existing projects to find their capacity in terms of engineering skills and experiences.

5.1.2 Funding Budget Feasibility

The funding feasibility of a project focuses on the study of the capability of the project to receive funds and budget from the government or private investors. In addition to these two funders, the project might be funded by the bank loan.

For the power supply projects, the bank loan can be a critical investment. Before receiving a loan, the capability of loan repaying should be considered and a long-term selling agreement with the power utilizer needs to be guaranteed.

The project funding can be insured by the funding agreement with the investor or with the credit's approval by the banking institution.

5.1.3 Legislation

In addition to the technical and funding feasibility, government legislation on the power system design and installation is crucial to be considered.

The legislation may include some governmental restrictions such as forbiddance of some generation units, restriction on the related to the usage of land plan or limitation of the installation of power units such as the height of the unit, safety aspects, and the noise.

5.2 Cost Optimizing/Electricity Price

The cost of electricity produced by a generator is usually can be indicated by the Leveled Cost of Energy [LCOE]. LCOE is calculated as the ratio of all expected costs of the system to the lifetime expected outcomes of the system [kWh]. The lifetime costs of a power system consist of its construction, financing, fuel, maintenance, taxes, and insurances. [49]

$$LCOE = \frac{Costs}{W} \qquad 5.8$$

Where

LCOE = Leveled Cost of Energy

Costs = total costs of power plants

W = total amount of produced electrical energy

<u>Data for evaluation:</u>

In addition to the design and construction of the system, the equipment's costs, the loans from the bank or investors, the possible rent prices, the fuel price, and other factors should be determined.

The outcomes of the system are obtained based on the minimum price of the electricity and earnings from the system's operation. In this thesis we used the concept of electricity price implemented by the HOMER software for the economic evaluation of the system.

5.3 Multi Objective Evaluation of Other Influencing Factors

The efficiency of a power system is evaluated based on the four effect parameters:

- Technical
- Economical
- Environmental
- Social

A hybrid system consists of many power units which are different from each other. To consider the high diversity of its power features and other influencing factors, we use the multi-goal decision-making approach.

We consider the four mentioned criteria to perform a qualitative and quantitative evaluation of the system. The quantitative evaluation will be performed based on the indicators which are obtained or calculated from the existing statistical data. However, the qualitative indicators are the review scores obtained from the opinion of decision-makers and experts.

5.3.1 Technical Criteria

The technical criteria are related to the characteristics and performance of the system, as well as the operational aspects.

In this thesis hybrid system is evaluating technically base on the following parameters:

5.3.1.1 Power Efficiency

The power efficiency of the system is one of the most important aspects that should be considered during the evaluation of the hybrid system. The power efficiency of a system presents the efficiency of the system to provide a needed level of power consumption. For the hybrid system, the power efficiency is related to many factors such as solar radiation, wind model, and the ratio between the system capacity and design sophistication.

The energy efficiency is calculated as the ratio between the real power output and the nominal power output. The overall efficiency of the system is the maximum input by every source in the system:

$$\eta = \frac{P_{real}}{P_{nom}} \quad 5.5$$

where η is power efficiency, P_{real} is the real power output which is obtained as average power output in a measuring time interval, and P_{nom} is the nominal power output provided by the manufacturer.

5.3.1.2 System's Reliability

The other crucial factor in the evaluation of a power system is the reliability of the system. The reliability of a system presents its capability to sufficiently function under specific conditions. This is an important factor especially for the systems which is dealing with unstable sources as RES.

The reliability of a system is divided into model reliability and scheme reliability. The model reliability discusses the possible modes when the generation cannot cover demands, while the scheme reliability is related to the possible deficits that may occur due to the break-down of a system's art.

There are some indices to evaluate the reliability of a power system. Some of the most applied indices are LPSP [loss of power supply probability], LOLP [loss-of-load probability], LOLH [Loss of Load Hours], SPL [System Performance Level], SAIFI [System Average Interruption Frequency Index], the number or frequency of breakdowns, average recovery time and many others.

As an example, the LOLP can be present as the probability that demand will exceed supply. [48]

$$LOLP = P[S<D] \quad 5.6$$

This equation shows the probability that demand will exceed supply

<u>Data for evaluation:</u>

The expected D[demand] and S[supply] data are required for the evaluation of the power system. Using these data, the LOLP can be obtained directly by the calculation of all possible combinations of forced outages.

5.3.1.3 Construction Risks

In the technical evaluation of the power system, we should consider the risk related to the construction of the power units. This risk is related to the possible technology shortages due to wrong information from the manufacturer, risk related to design errors, and risks due to unpredictable changes in environmental conditions that may cause instrumental damages.

The qualitative evaluation of the construction risks can be achieved by the probability of damage and or deterioration of system performance from the high probability scored 3 to low probability scored 1:

$P = \{1,2,3\}$

where

1- low probability

2- medium probability

3- high probability

Data for evaluation:

For construction evaluation, the existing data from the previous project, and information from the consultants and experts can be used.

5.3.1.4 Possibility of Undersupplying Fuel

For the power system working based on fuel consumption, the on-time delivery of the fuel on the site is the other factor that should be considered. The probability of delay on the fuel providing and the probability of fuel undersupply is an evaluation criterion for these types of the power system.

For such a power system the energy source is defined as secure if the fuel for the consumption of electricity generators can be obtained on time and enough. Providing the fuel resources for the countries which are dependent on fuel importing is a critical issue that faces to potential risks such as fluctuating of international market price and fuel disruption due to possible geopolitical disturbances.

Data for evaluation:

Probability of fuel undersupply is evaluated quantitatively by the statistical calculation:

$$P_S < P_E \tag{5.7}$$

Where P_S is supplied fuel and P_E exist amount of fuel

Or qualitatively by using consultation of companies or experts:

P={1,2,3}

1- low probability

2- medium probability

3- high probability

5.3.2 Economical Criteria

Economical efficiency system is the most important aspect of the design of a hybrid power system. The economical efficiency can be defined as the ratio between the economical outcomes of a project and the costs that spent to reach these outcomes. The higher value of outcomes and fewer costs, the more efficient the power system is.

The efficiency of a power system can be evaluated by many factors. For the designer the minimization of investment and production cost is the most important factor, however, later the maximum revenues obtained from the electricity sale can be the most important factor.

Mostly, the economic evaluation of the power system performed based on the Leveled Cost of energy or electricity price.

5.3.2.1 Business risk

The other important factor that should be considered in the evaluation of a power system is business risk. A power system project can face risks like any other project due to business uncertainties. The business risk may influence the project due to many factors such as tax growth, subsidies cancel, equipment prices growth, guaranties not paid.

The project can be evaluated base on the business risks by qualitative assessment:

P= {1;2;3}

where

1. low risk
2. medium risk
3. high risk

<u>Data for evaluation:</u>

The business risk is evaluated by the data obtained from the power system and economical experts and consultants.

5.3.2.2 The Complexity of Administrative Issues

The complexity of administrative issues related to the project implementation also should be considered in the economical evaluation of the power system project.

A qualitative evaluation can be used for this criterion:

P= {1;2;3}

Where

1. low complexity
2. medium complexity
3. high complexity

<u>Data for evaluation:</u>

The related administrative data are obtained from the governmental rules and regulations.

5.3.3 Environmental Criteria

With raises of attention to the environmental aspects and global warming issue in recent years, the influence of power systems on environmental conditions is currently one of the most important factors in the decision making process. The power generations have many environmental impacts such as pollution, greenhouse gases, climate changes, and the influence of the local ecosystem. The environmental impacts should be evaluated compared to different solutions of a power system.

5.3.3.1 GHG Emissions

Greenhouse gases are greatly increasing the rate of global warming. When sunlight strikes the Earth's surface, some of the light reflected to space as heat. Greenhouse gases which are existed in the atmosphere absorb and trap this heat and prevent it to be transferred to space. Over time, the amount of solar energy that is coming to the Earth should be almost the same as the amount of radiation sent back to space to keep a roughly constant temperature on the Earth's surface. However, the greenhouse gases reducing the reflected energy and increase the temperature of the Earth's surface. Among these gases:

- Carbon dioxide [CO2]: enters the atmosphere through burning fossil fuels [coal, natural gas, and oil], solid waste, trees, and wood products, and also as a result of certain chemical reactions [e.g., manufacture of cement].
- Methane [CH4]: is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other

agricultural practices and by the decay of organic waste in municipal solid waste landfills.

- ➢ Nitrous oxide [N_2O]: is emitted during agricultural and industrial activities, as well as during the combustion of fossil fuels and solid waste.
- ➢ Fluorinated gases: Hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes [50].

Between the power system, only the generator with fossil fuel operation is producing CO_2. PV and wind technologies do not have any GHG emissions during the operation.

The average amount of CO_2 emissions over a year can be calculated by multiplying the annual produced electricity[W,kWh] by the average annual emissions for a certain power system[q, kg/MWh].

$$Q(CO2) = qCO2 * W \quad \text{5.9}$$

Where

Q[CO2] = Total CO2 Emission

qCO2 = CO2 emission based on the existed standard value per kWh

W = total Power produced by the system

<u>Data for evaluation:</u>

We evaluate the CO2 emission based on the existed standard value per kWh electricity generation obtained from the literature: 545 kg/kWh [51]. The amount of produced GHG during electricity production depends on the generator's load and it should be considered in the evaluation.

5.3.3.2 Other Emissions

In addition to the GHG there are some other unnatural pollutions which are produced during the power system operation:

Sulfur dioxides: Between the power system pollution is SO_2 which can cause harm and breathing difficulty for the people especially for the children, elderly people, and people with heart or lung disease. SO_2 contributes to the formation of acid rain, ground-level ozone [smog], and particulate matter pollution.

Particulate Matter [PM]: Particles produced from the power operation influence the health of the people living for long time exposure to these particles. Smaller particles may travel deeper through the lung or even the bloodstream. Long term exposure will affect both lungs and heart.

[NOx]: The amount of emission can also be calculated by multiplying the annual produced electricity[W,kWh] by the average annual emissions for a certain power system[q, kg/MWh].

$$Q(SO2) = q(SO2) * W \quad 5.10$$

$$Q(PM) = q(PM) * W \quad 5.11$$

$$Q(NOx) = q(PNOx) * W \quad 5.12$$

Where

Q[SO2] = Total SO2 Emission

q [SO2] = SO2 emission based on the existed standard value per kWh

Q[PM] = Total PM Emission

q [PM] = SO2 emission based on the existed standard value per kWh

Q[NOx] = Total NOx Emission

q [NOx] = NOx emission based on the existed standard value per kWh

W = total Power produced by the system

<u>Data for evaluation:</u>

We evaluate the pollutions based on the existed standard value per MWh electricity generation obtained from the literature: NOx:10,5 kg/MWh, SO2: 10,2 kg/MWh PM:0,35kg/MWh [51].

5.3.3.3 Influence on the Local Ecosystems

Beside the GHG emission and air pollution, the power systems have some other effects on the environment that should be evaluated. This influence on the local ecosystem may occur during the construction and operation phases of the power system, which both will be evaluated in this research.

For example, for wind power, this influence can be the loss of habitat for some species of birds and bats, noise, vibration, landscape change; for PV panels – the occupation of Agriculture earth; for diesel – noise, smell, and vibration.

A qualitative evaluation is considered for influences on the local ecosystem:

P= {0;1;2;3}

where

0. means no influence;
1. low influence;
2. 2-medium influence;
3. 3-high influence

<u>Data for evaluation:</u>

The data is usually public information.

5.3.4 Social Criteria

The power system has considerable influences on people's lives, especially those who live in the vicinity of the power plant. The social criteria include a big range of social aspects; however, we evaluate the three major aspects which are specifically influencing the decision of a power system design.

5.3.4.1 Improvement of the inhabitants' life

The power system may improve the life of inhabitants by increasing employment numbers and improving social welfare. The employment improvement is simply evaluated by the number of working places [N] provided by the power system in the power plat region.

The power systems improve social welfare by possible reduction of money outflow, increasing the social independency for the power sources, and reduce the dependency on the local policies. We evaluate social welfare based on the qualitative method:

P= {0;1;2}

where

0. means no influence;
1. low influence;
2. significant influence.

<u>Data for evaluation:</u>

To evaluate the employment improvement, we required the number of people required for system maintenance. A typical number of 2 people for a small decentralized project up to 10 kW is considered.

Considering the existed power units and fuel cost for the people the social welfare is evaluated by the amount of money for fuel which is saved by the employment of the new power system.

5.3.4.2 Consistence With the Local Policies

The governmental regulation and requirement for the need of a RES development influence the design decision and criteria. There would be some local policies such as green certificates, emission allowance, and carbon taxes which should be fulfilled. In addition to the regulations, there are some construction and design standards as well as technology's consistency which should be considered.

A qualitative evaluation can be performed:

P= {0;1;2}

0. not consistent
1. partly consistent
2. consistent

<u>Data for evaluation:</u>

The required data for the evaluation is obtained from the regulations of the local and national policies.

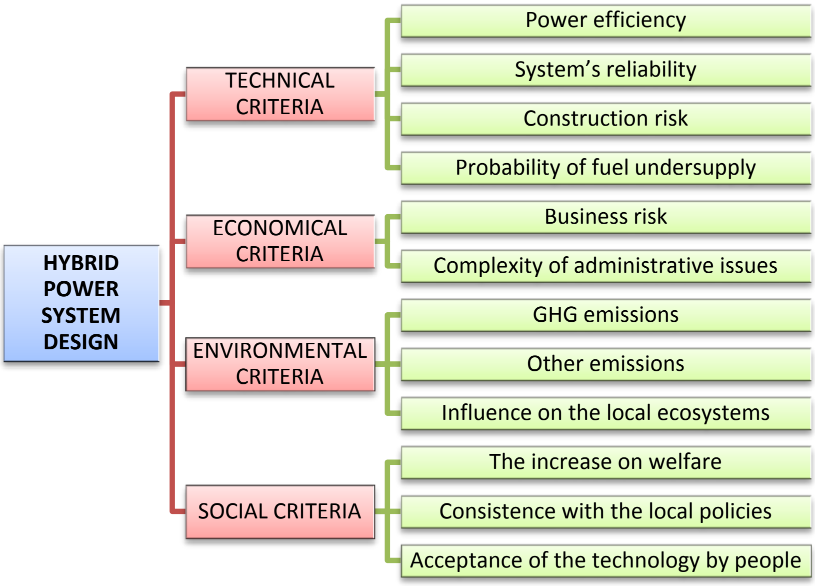
5.3.4.3 Acceptance of the Technology by People

The other factor that should be considered is the people and social responses to the power project. The people mostly tend to be conservative and not willing to pay more because of the environmental effects. It rarely occurs that people are willing to pay an additional fee for green energy. Meanwhile, the governmental requirements and regulations for ecological and environmental improvement of the power plant projects are growing yearly. It is very important that the society and the inhabitants adapted to these new regulations to accept the consequences of them. Acceptance of technology is evaluated based on the percent of habitants accepting given technology.

<u>Data for evaluation:</u>

A survey of the people and inhabitants is required to evaluate the acceptance level of technology. The given data from the peoples' response to the existed similar projects can be also used.

Figure 5-1 Criteria that is mentioned in this theses



5.4 Multi Objective Decision Making Function

In this thesis, we consider 13 different criteria for system evaluation. Different value of each criterion is considered for different technologies.

The criteria can be add or remove due the place of different power system which the application for the system, culture and everything is different. These criteria that are mentioned at the top are general necessary criteria that is needed for design of any power plants, we use the method multi-tasking decision making to decide the optimized task. Among many other existing methods, the method of global criterion has been chosen as one with the most suitable structure for the given task [52] The chosen method will be implemented in the MS Excel software to select the optimal task.

We compared the absolute values with the relative ones using the calculated maximum and minimum values for each criterion. To minimize the criteria, we divided the criterion value by the minimum possible value of this criterion among all other alternatives. for the maximization criteria conversely: the dividing the optimal value [maximum] by the value of considered criterion.

The decision-maker will determines the weights of each criterion from 0 to 100% based on the importance of each of them due to the country, need of people, culture and etc.

The objective function in the method of the global criterion is:

$$F = \sum_{n=1}^{13}[\frac{C_n}{C_{n\,max}} W_n, \frac{C_{n\,min}}{C_n} W_n] \quad 5.12$$

Where

C_n = the value of the criterion C_n

W_n % = the weight for criterion C_n

$C_{n\,max}$ = maximum value for the criterion C_n [for minimizing criteria]

$C_{n\,min}$ = minimum value for the criterion C_n [for maximizing criteria]

6. SIMULATION

6.1 Introductıon

As it is mentioned in chapter five because Afghanistan isn't a developed country and tell now facing different types of war, people are far away from technology and many other problems while starting new project in a special area there will be lots of new problem that it didn't happen in any other project or will not happen in any other projects and because we cannot have the necessary data to estimate and optimize the best solution for all criteria that is mentioned in past chapter, in this thesis and for the selected area we are going just to do the feasibility study of the project in the selected area and simulation of just three criteria that is mentioned in the past chapter for which are power efficiency, cost optimizing (minimum electricity price) and GHG emissions in the following orders:

First Part : Cost Optimizing of the system (minimum electricity price)

- **Step 1**: we well do the feasibility study for different power source that we can use in the mentioned area.
- **Step 2**: we will do the cost optimization of the system by using HOMER software and comparing of the result with the existing electricity price in Afghanistan.

Second Part: Multi Objective decision making

- **Step 3**: according to systems, which are suggested by homer software, we will do our calculation on other requested criteria; in this thesis for the selected area, we will do the calculation on following criteria according to unavailability of data in Afghanistan.
    - GHG emissions
    - power efficiency
- **Step 4**: by using method of the global criterion we will choose the appropriate system.

6.2 First Part : Cost Optimizing of the System (Minimum Electricity Price)

6.2.1 Step 1: Feasibility Assesment of Project

According to the model that mentioned in chapter 5 we will do many type of Power producing systems for the mentioned area.

We will do our study on the six different power sources which are normally available in Afghanistan (28).

- Micro hydro power sources
- Wind Power sources
- Solar radiation power sources
- Biomass power sources
- Hydrogen power sources
- Diesel generator power sources

We will do feasibility study for all of these power sources and we will do our calculation for each these power sources.

6.2.1.1 Micro Hydro Power System

In our study we will not consider the micro hydropower system because there isn't any dam in the area that is mentioned and there isn't chance of making dam in that place then we will leave not consider this option for our power system.

Result: can't be use cause of long distance between this area and closest micro hydropower source.

6.2.1.2 Wind Power Sources

To evaluate the feasibility of installing wind turbines in any area we need to do comparison between the minimum wind speed that is necessary for wind Generator that is specified by the manufacturer company of turbine which normally in the small size the minimum speed is specified 2.5-3 m/s and according to the information that we have about our area the average wind in the mentioned place is bigger than the minimum necessary wind speed.

And so on it is suggested for the area with low wind speed and high fluctuation of wind to not use the wind technology as a standalone and independent technology so on it will be more efficient to always use battery sources or to use wind turbine with hybrid power systems.

In our case study area there aren't any situation to make legalization problems that can prohibit installing wind turbines.

Result : we can use wind turbines in the selected area with hybrid power system or we can use it as a standalone system consisting battery sources.

6.2.1.3 Geothermal Power Source

Same as micro hydropower system we can't use geothermal energy sources in this area cause there isn't a study of geothermal sources in the place and closest geothermal energy source is far enough from this place to make the price too much expensive.

Result: can't be use cause of long distance between this area and closest geothermal source.

6.2.1.4 Biomass Power Source

This option needs costruction of special structures for processing the biofuel and delivery of sufficient amount of biofuel to the mentioned area that will increase the cost too much .

Result: cant be use according to the absence of structure in the place and unviability of enough source of biofuel.

6.2.1.5 Solar Energy Power Source

To estimate the feasibility of solar we need to figure out the minimum value of solar radiation in the desired area that must be more than 0.2 kWh/m2 [11]. In place that we are going to do our study the average of solar radiation in all 12 months of the year is more than 0.2kWh/m2.

And so on like wind potential there is fluctuation of solar radiation in different seasons of year and days cause of that it is suggested to use battery sources also as backup for solar system in standalone system or to use the solar system as a part of other hybrid system.

In our case study area there aren't any situation to make legalization problems that can prohibit installing solar panels.

Result: we can use solar system in the selected area with hybrid power system or we can use it as a standalone system consisting battery sources.

6.2.1.6 Diesel Generator Power Source

Nowadays diesel generators are one of the most useful power source that is running by use of diesel oil, the only reasons that can avoid us to use diesel generator in our system is unavailability of diesel in the place and the legalization problems, that in our area diesel is available and there is no legal problem.

Result: can be use as a part of hybrid system or it can be a standalone system.

The summary of our evaluation for feasibility of using different technology in the mentioned area is presented in the table below:

Table 6-1 summary of feasibility evaluation of the system

Technology	Feasibility
Wind	possible
Micro Hydro	Can't be use
Geothermal	Can't be use
Biomass	Can't be use
Solar	possible
Diesel	possible

As you can find it in the table the only power sources that are possible to use in our system is: wind, solar and diesel Energy sources.

6.2.2 STEP 2: Cost optimization using HOMER software

We will use the net present Cost model [NPC] to evaluate the project economically. To compare projects, we will use the minimum values in electricity generated by each technology or a combination of technologies. This method is good because we can compare prices with each other

Since the purpose of this dissertation is to evaluate different options for power generation options, choosing equipment for each new option is very time consuming. Therefore, it was decided to calculate investment costs using specific equipment prices [$ / kilowatts]. The method of this calculation is to use HOMER software.

The specific price of equipment is derived through the statistical data - current prices for RES equipment on the Afghanistan is not known because of this we will use data that is already exist in the HOMER software but for best calculation and to achieve the exact result we can enter the specific price for each component of the system to our system in the homer software.

After doing calculation on the HOMER the following system are suggested by the HOMER and we are going to calculate the other two option for these systems, and to do multiple choice optimization and choose the best system.

1. Wind power generator + PV panels + diesel generator + battery
2. PV panels + diesel generator + battery

3. Wind power generator + diesel generator + battery
4. Wind power generator + PV panels + battery
5. PV panels + battery
6. Wind power generator + battery

Here it is the economic result that is taken from the homer software.

Table 6-2 Economic evolution of different systems

system 6	System 5	System 4	System 3	System 2	System 1		
	295.75	164.3682253		97.703125	72.59982233	PV (kW)	archichure
31		3	6		2	G10	
			25	25	25	Gen25 (kW)	
1668	1405	1429	733	487	385	1kWh LA	
2705594	1548675	1407364	1033676	788062.7	736394.3	NPC ($)	cost
1.897974	1.086819	0.9876834	0.7249056	0.5527098	0.5164124	COE ($)	
56578.47	33487.94	36073.66	43287.02	33263.88	28228.59	Operating cost ($/yr)	
2050400	1160875	989620.6	532400	402857.8	409499.6	Initial capital ($)	
			2624	2758	2265	Hours	Gen 25
			60548.53	57179.29	48344.2	Production (kWh)	
			18694.55	17885.29	15066.59	Fuel (L)	
			1968	2068.5	1698.75	O&M Cost ($/yr)	
			18694.55	17885.29	15066.59	Fuel Cost ($/yr)	
	739375	410920.6		244257.8	181499.6	Capital Cost ($)	PV
	484864	269471.7		160178.3	119023	Prod.(kWh/yr)	
1550000		150000	300000		100000	Capital Cost ($)	G10
625628.5		60544.69	121089.4		40363.13	Prod. (kWh/yr)	
15500		1500	3000		1000	G10/O&M Cost ($)	
71.24605	60.01241	61.03753	31.30896	20.80145	16.44468	Autonomy (hr)	Battery
43956.77	59382.35	46009.27	27240.28	28235.88	21769.76	Annual Throughput (kWh/yr)	
0	0	0	0	0	0	Operating hours (hours)	
1669.334	1406.124	1430.143	733.5864	487.3896	385.308	Nominal Capacity (kWh)	
1001.601	843.6744	858.0859	440.1518	292.4337	231.1848	Usable Nominal Capacity (kWh)	
5.609783	0	0.5874202	3.476464	0.896372	0.9523649	Rectifier Mean Output (kW)	convertor
4.263735	14.04688	9.873389	2.642263	8.47512	6.107798	Inverter Mean Output (kW)	

First column architecture describes the design of each system

PV(kW) : total (kW) of PV Panels in the system

G10: number of 10kw/h wind turbines

Gen 25: is one 25kW/h diesel generator

1kW/h La: is total kW/h Latium Battery

Second column: cost

NPC : Net Present Cost

COE: Cost of Energy

6.3 Economical Comparison of Grid Connected, Stand-Alone Hybrid and Stand-Alone Diesel Generator Power Systems

The following table shows the electricity price for different existing power system in Afghanistan.(27)

No	Type of power system	COE $
1	Hybrid power system	0.5 – 1.7
2	Diesel Generator	0.2-0.4
3	Grid Connected	0.07-0.3
4	Mini Hydro power system	0.2 – 0.4

By checking the COE of each power system, we can find that hybrid power system is less economical, and the decision makers and donors must do this system for places with multi objective purposes. Which mentioned in chapter 5.

6.4 Multi Objective Decision Making

Due to unavailability of data in our area we are going to do the calculations on following two factors:

- **Green House Gas Emissions**
- **Power Efficiency**

6.4.1 Power efficiency calculation:

The power efficiency of a system presents the efficiency of the system to provide the desirable level of the power consumption. The energy efficiency is calculated as the ratio between the real power output and the nominal power output. The overall efficiency of system is the maximum input by every source in the system:

$$\eta = \frac{P_{real}}{P_{nom}} \quad 6.1$$

where, η is the power efficiency, P_{real} is the real power output which is obtained as average power output in a measuring time interval, and P_{nom} is nominal power output that provided by the manufacturer.

The following table shows the power efficiency of different systems that is driven by using of the giving formula in MS. Excel.

Table 6-3 Power Efficiency

system						Gen 25		PV	wind	hourly power production			total		power effeciency%
	PV (kW)	G10	Gen25 (kW)	1kWh LA	Conv (kW)	Hours	Production (kWh)	PV/Production (kWh/yr)	G10/Production (kWh/yr)	gen 25	pv	g10	real power	nominal power	
System 1	72.59982233	2	25	385	9999999	2265	48344.2	119023	40363.13	21.34401766	13.42768502	4.553602211	39.32530489	117.5998223	33.43993563
System 2	97.703125		25	487	9999999	2758	57179.29	160178.3		20.73215736	18.07065659	0	38.80281395	122.703125	31.62332984
System 3		6	25	733	9999999	2624	60548.53		121089.4	23.0748971	0	13.66080776	36.73570487	85	43.21847631
System 4	164.3682253	3		1429	9999999			269471.7	60544.69	0	30.40068818	6.830402753	37.23109093	194.3682253	19.15492662
System 5	295.75			1405	9999999			484864		0	54.70036101	0	54.70036101	295.75	18.49547287
system 6		31		1668	9999999				625628.5	0	0	70.58083258	70.58083258	310	22.76801051

6.4.2 CO2 Emissions Calculation:

The amount of average annual harmful emissions per MWh of produced electricity for the diesel generator is presented in the Table 6.4 [51]. This dependence is made for the most optimal way of diesel operation [70-80% of load]. Since we consider only emissions during the system's operation, it is assumed that that technologies based on PV and wind do not have any emissions so we just use the amount of power that is produced by the diesel generator.

Table 6-4 Average annual harmful emissions for diesel generator [51]

Emissions type	CO2	NOx	SO2	PM
Average annual emissions for the certain power system [kg/MWh]	545	10.5	10.2	0.35

We will multiply the amout of electricity produced by diesel generator by the specific
Emissions per kWh:

Table 6-5 Average annual harmful emissions

	archtichure			Production (kWh)	Emissions Kg				Total Emissions kg
	PV (kW)	G10	Gen25 (kW)		CO2(0.545)	Nox(0.0105)	SO2(0.0105)	PM(0.035)	
System 1	72.59982	2	25	48344.2	26347.59	507.6141	507.6141	1692.047	29054.86
System 2	97.70313		25	57179.29	31162.71	600.3825	600.3825	2001.275	34364.75
System 3		6	25	60548.53	32998.95	635.7596	635.7596	2119.199	36389.67
System 4	164.37	3			0	0	0	0	0
System 5	295.75				0	0	0	0	0
system 6		31			0	0	0	0	0

6.4.3 Choosing Appropriate System:

As we said we are going to choose the system according to more than one object that is dependent to different factors, we can add any factor that we want and as we said here in this study related to our case study and data that we can gain we are going to choose the system up on three factors by the using of the formula that we mentioned in the chapter 5.

$$F = \sum_{n=1}^{3}[\frac{C_n}{C_{n\,max}} W_n + \frac{C_{nmin}}{C_n} W_n] \quad 6.2$$

Related to this formula we will choose our system according to

1. Power efficiency
2. Minimum Electricity Price
3. Green House Gas Emissions

As mentioned in the past chapter The decision-maker will determines the weights of each criterion from 0 to 100% based on the importance of each of them due to the country, need of people, culture and etc. so will give the following weight due to the importance of each of them in the place that we are doing our study there, we will give the 50% importance to electricity Price, 30% will be for power efficiency and 20% percent will be for Green House Gas Emissions. And as it is mentioned this value will be choose by the decision maker due to condition of the each area which shows system one is the best choice for the area.

Table 6-6 shows the result of calculations that is done in excel

	archtichure				cost			value of objective function	order
	PV (kW)	G10	Gen25 (kW)	1kWh LA	Power efficiency	minimum Electricity price	Green House Gas		
System 1	72,59982233	2	25	385	33,440	0,516	29054,864	0,461	1
System 2	97,703125		25	487	31,623	0,553	34364,753	0,510	2
System 3		6	25	733	43,218	0,725	36389,667	0,520	3
System 4	164,3682253	3		1429	19,155	0,988	0,000	0,549	4
System 5	295,75			1405	18,495	1,087	0,000	0,586	5
system 6		31		1668	22,768	1,898	0,000	0,745	6

6.5 Summary and Conclusion

This study provides an introduction to the Afghanistan energy and power sector in its general view pint. It also evaluates the availability of electrical energy sector, the chronic challenges to electrical energy sector and potential renewable energy resources in Afghanistan. Based on the data cited in this study, Afghanistan is one of the richest countries of the world in terms of availability of renewable energy resources. The number of studies on irradiation and wind are limited due to difficulty in obtaining these data. This is due to couple of reasons like lack of database for solar and wind resources, reluctance on cooperating with associative academic researches in the field by officials and finally lack of sufficient funding, since such a research needs extensive funding and labor.

The research findings from the reports shows that Afghanistan is one of the countries with lowest level of access to electricity among middle-eastern countries. A low rate of population has access to electricity via grid system. The rural part of the country is widely affected with this challenge. Small scale generators are usually being used by industrial complexes, hospitals and hotels to meet their urgent needs. The infrastructure is mostly outdated and widely insufficient that needs serious attention. The tight security environment also complicates the exploration, production and transmission of energy all over the country. Therefore, the study suggests that renewable energy can be a strategic investment for the future of country and its economy. Considering the situation in Afghanistan, establishment of hybrid systems would shorten the energy gap.

Following points can be driven from this thesis:

- Nowadays electricity is one of the most important factor for developing countries.
- The foil fuel power sources is finishing one day and it is not clean and harming nature so all the world is using the renewable energy as next choice, because it is clean and renewable.
- Most of the countries are targeting to become 100% renewable power users.
- In Rural areas such as Pashtun Zarqoon district, the hybrid power systems are more efficient because in absence of one source the other source can take its place.

- Afghanistan is land of renewable sources but still they are importing power from other countries cause of decades of wars so Afghanistan can produce its needed power and also it can export if they use there renewable sources.
- Afghanistan has mostly decentralized zone which are far away from grid or cause of security problem they can’t have connection to grid so the best solution is Hybrid power system.
- Afghanistan is country with different weather condition, cause of that for estimating the future power consumption it is necessary to do local surveys in each area and estimating the power consumption.
- As Afghanistan is, a developing country and a country with different culture the yearly grow rate of power consumption in Afghanistan needs local surveys.
- A multitask optimization method is suggested for Afghanistan which the necessary task can be change due to different cultural condition of Afghanistan.
- From figure 4 that shows the monthly demand of electricity in Pashtun Zarqoon district, it can be concluded that, the electricity demand in summer and winter increased in comparison to spring and fall. Therefore, in winter because of limited sunny days, the diesel power generator system should be used to support the other systems of renewable energy.
- As per figure 4-6 the average wing speed in Pashtun Zarqoon district from June to September is more than 8 m/s, so the wing power system should be used mostly at this period to support the solar power system instead of diesel power generator system.
- Figure 4-7 and 4-8 demonstrated that clearance index and daily radiation in Pashtun Zarqoon are in a reasonable level during the whole year; therefore, it should be kept in operation all days.
- From Tables 4-5, 4-6 and 4-7 that each of them shows the demand for commercial, social and agricultural purposes, it can be concluded that from 9:00 am to 16:00 pm is the highest demand for the electricity, therefore all the systems of renewable energy generation should be compounded to each other to overcome the high demand.

Policy recommendations for government and ınvestors on energy sector:

- Wide re-evaluation and reform in energy sector is vital for the country.
- Academic researches and concrete studies in energy sector is necessary.

- Foreign investment in energy sectors should be encouraged via policies and laws.
- Conducive laws and tax exemption should be deemed for renewable energy technology.
- Development, implementation and expansion of the rural electrification program using renewable energy resources.
- Create special association to help Afghanistan people use renewable energy.
- Encourage Wind-PV hybrid systems in rural areas.
- Adapting policies to encourage domestic production of renewable energy components especially solar.
- Public awareness for encouraging production of renewable energy.
- Designing university curriculums, financing university level researches and attracting more students for this field.

REFERENCES:

[1] **Gul Ahmad Ludin , Mohammad Amin Amin , Assadullah Aminzay , and Tomonobu Senjyu**, Theoretical potential and utilization of renewable energy in Afghanistan, AIMS Energy, 5[1]: 1-19, DOI: 10.3934/energy.2017.1.1.

[2] **Wen-Cheng Lu,** Electricity Consumption and Economic Growth: Evidence from 17 Taiwanese Industries, Department of Economics and Finance, Ming Chuan University, 30 December 2016.

[3] **IRENA [2018],** Renewable Power Generation Costs in 2017, International Renewable Energy Agency, Abu Dhabi.

[4] **Subhes C. Bhattacharyya • Debajit Palit,** Mini-Grids for Rural Electrification of Developing Countries, Analysis and Case Studies from South Asia, DOI 10.1007/978-3-319-04816-1, Springer Cham Heidelberg New York Dordrecht London

[5] **WORLD BANK GROUP,** Afghanistan to 2030, www.worldbank.org/afghanistan, 2016-2017

[6] **K.R._Rao,** Wind Energy for Power Generation Meeting the Challenge of Practical Implementation, https://doi.org/10.1007/978-3-319-75134-4, Springer Nature Switzerland AG 2019

[7] **REN21 Renewable now**, Renewables 2019 Globals Status Report, Paris, France, https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf

[8] https://ourworldindata.org/renewable-energy

[9] **4. World Bank Documents**, Afghanistan Renewable Energy Development Issues and Options [2018] http://documents.worldbank.org/curated/en/352991530527393098/Afghanistan-renewable-energy-development-issues-and-options

[10] **UNECE United Nations Economic Commission for Europe,** Afghanistan Energy Sector [2016], https://www.unece.org/fileadmin/DAM/energy/se/pp/eneff/7th_IFESD_Baku_Oct.2016/ESCAP_Elec_CIS/1_W.Aria_AVG.pdf

[11] **David I. Stern, Paul J. Burke, Stephan B. Bruns,** The Impact of Electricity on Economic Development: A Macroeconomic Perspective, energy and economic growth, 19 December 2016.

[12] **Ibrahim Saliu Alley Tajudeen Egbetunde Blessing Ose Oligbi** , [2016],"Electricity supply, industrialization and economic growth: evidence from Nigeria", International Journal of Energy Sector Management, Vol. 10 Iss 4 pp. - http://dx.doi.org/10.1108/IJESM-10-2015-0005.

[13] **RISE electricity access pillar,** Regulatory Indicators For Sustainable Energy, 2018

[14] **Saadatullah Ahmadzai, Alastair McKinna,** Afghanistan electrical energy and trans-boundary water systems analyses: Challenges and opportunities, ELSEVIER, 2018

[15] **Shivarama Krishna K., Sathish Kumar K.** A review on hybrid renewable energy systems. Renewable and Sustainable Energy Reviews 2015; 52: 907–916.

[16] **Parhizi S., Lotfi H., Khodaei A., Bahramirad S.** State of the art in research on microgrids:
a review. IEEE Access 2015; 3: 890–925.

[17] **A.Arnetten, C.W.Zobel** - An optimization model for regional renewable energy development: Elsevier journal - Renewable and Sustainable Energy Reviews 16, 2012

[18] **A. Kashefi Kaviani, G.H. Riahy, SH.M. Kouhsari** - Optimal design of a reliable hydrogen-based stand-alone wind/PV generating system, considering component outages: Elsevier journal - Renewable Energy 34, 2009

[19] **V.V.Simakin, A.V.Smirnov, A.V.Tihonov, I.I.Tyuhov** – Modern system of autonomous power supply with the use of renewable energy sources: scientific magazine «Energetik» № 3, 2013

[20] **A.T.D. Perera, R.A. Attalage, K.K.C.K. Perera, V.P.C. Dassanayake.** Converting existing Internal Combustion Generator [ICG] systems into HESs in standalone applications: Elsevier journal - Energy Conversion and Management 74, 2013

[21] **B. V. Lukutin.** - Renewable energy sources: Textbook for Universities: Printing house of Tomsk Polytechnic University, Tomsk, 2008

[22] **M.A. Surkov, A.M.Pupasov-Maximov** - Application of the Experimental software complex «Power System Simulation» and possibility estimation of large scale zoning of the territory of Russian Federation for optimal system structure with renewable energy sources": internet-magazine «Naukovedenie» №3, 2012

[23] **A.V.Kobelev -** Increase in efficiency of power supply systems with the use of renewable energy sources: synopsis of dissertation for the Ph.D., Lipeck, 2004

[24] **V.I. Velkin, M.I.Loginov, E.V.Chernobai** - Development of graphical model for choosing the optimal composition of equipment in cluster RES: proceedings of X International annual conference "Renewable and small energetics 2013", Moscow, 2013

[25] **V.V.Telegin** - Optimization of structure and parameters of autonomous energy complexes: scientific magazine «Fundumental researchs» №8, 2013

[26] **Wei Zhou, Chengzhi Lou, Zhongshi Li, Lin Lu, Hongxing Yang** - Current status of research on optimum sizing of stand-alone hybrid solar–wind power generation systems: Elsevier journal - Applied Energy 87, 2010

[27] **ASIAN DEVELOPMENT BANK.** Proposed Multitranche Financing Facility: Islamic Republic of Afghanistan: Energy Supply Improvement Investment Program; Report and Recommendation of the President to the Board of Directors: Asian Development Bank; November 2015 [cited 2017 Jan 21]. Available from: URL: https://www.adb.org/projects/47282-001/main#project-pds.

[28] **Fichtner.** Islamic Republic of Afghanistan: Power Sector Master Plan; TA-7637 [AFG]: Asian [29] ICE. Afghanistan Energy Sector Update. Main Conference Hall, Ministry of Economy: Interministerial Commission for Energy; 2016 Jan 26 [cited 2016 Dec 6]. Available from: URL: https://sites.google.com/site/iceafghanistan/.

[30] **MEW**. Renewable Energy Policy: Ministry of Energy and Water; 2015.
[31] **MEW.** Afghanistan Rural Renewable Energy Policy: Final Draft: Ministry of Energy and Water; April 2013.
[32] **ANDS.** Social and Economic Development Pillar: Energy, Transportation, Water Resource Management, Information and Communications Technology, Urban Development, and Mining Sector Strategies. In: Afghanistan National Development Strategy [2008-2013]: A Strategy for Security, Governance, Economic Growth & Poverty Reduction; 2008. p. 1–95.
[33] **Klett TR, Ulmishek GF, Wandrey CJ, Agena WF, Steinshouer D**. Assessment of undiscovered technically recoverable conventional petroleum resources of northern Afghanistan; 2006 Jan 1. Open-File Report 2006-1253.
[34] **Ershad AM, Brecha RJ, Hallinan K.** Analysis of solar photovoltaic and wind power potential inAfghanistan. Renewable Energy 2016; 85:445–53.
[35] **Bhandari R, Richter A, Möller A, Oswianoski R-P.** Electrification Using Decentralized Micro-Hydro Power Plants in Northern Afghanistan. J. sustain. dev. energy water environ. syst. 2015; 3[1]:49–65.
[36] **ADB.** Technical Assistance Report: Islamic Republic of Afghanistan: Renewable Energy Development; Project Number: 47266-001: Asian Development Bank; 2014.
[37] **Yıldız D.** Afghanistan's Transboundary Rivers and Regional Security. World Scientific News 2015; 16:40–52. Available from: URL: http://psjd.icm.edu.pl/psjd/element/bwmeta1.element.psjd-6b7fc256-4870-4e5b-b542-eab20e88cc00/c/WSN_16__2015__40-52.pdf.
[38] **Burns RK.** Afghanistan: Solar assets, electricity production, and rural energy factors. Renewable and Sustainable Energy Reviews 2011; 15[4]:2144–8.
[39] **Anwarzai MA, Nagasaka K.** Utility-scale implementable potential of wind and solar energies for Afghanistan using GIS multi-criteria decision analysis. Renewable and Sustainable Energy Reviews 2016; 71: 150-160.
[40] **Chaurey A, Narasimhan G, Chatterjee A, Fazli F, Musleh AJ, Haseib M et al.** Renewable Energy Roadmap 2032: TA-8808 AFG: Renewable Energy Development in Afghanistan. New Delhi, India: Asian Development Bank; IT Power Consulting Private Limited; March 2017.
[41] **Elliott D.** Wind resource assessment and mapping for Afghanistan and Pakistan. Golden, Color, USA: National Renewable Energy Laboratory [NREL]; 2011.
[42] **Tetra Tech.** Development of Wind Energy Meteorology and Engineering for Siting and Design of Wind Energy Projects in Afghanistan; September 2009.
[43] **Saba DS, Najaf ME, Musazai AM, Taraki SA.** Geothermal Energy in Afghanistan: Prospects and Potential; Prepared for Center on International Cooperation, New York University, New York, USA. & Afghanistan Center for Policy and Development Studies, Kabul, Afghanistan; February 2004.
[44] **Milbrandt A, Overend R.** Assessment of Biomass Resources in Afghanistan: National Renewable Energy Laboratory [NREL]; January 2011.
[45] **Zhenya Liu,** Global Energy Interconnection, ISBN: 978-0-12-804405-6, 2015 China Electric Power Press Ltd. Published by Elsevier Inc.
[46] https://seasonsyear.com/Afghanistan

[47] https://power.larc.nasa.gov/data-access-viewer/

[48] **A.V.Kobelev -** Increase in efficiency of power supply systems with the use of renewable energy sources: synopsis of dissertation for the Ph.D., Lipeck, 2004

[49] **Sajid Ali, Choon-Man Jang,** Optimum design of hybrid renewable energy system for sustainable energy supply to a remote island, Sustainability 2020, 12, 1280; doi:10.3390/su12031280.

[50] **US Environmental Protection Agency**, web-site: http://www.epa.gov/climatechange/ghgemissions/gases.html

[51] **A.G. Tsikalakis, N.D. Hatziargyriou -** Environmental benefits of distributed generation with and without emissions trading: Elsevier journal - Energy Policy 35, 2007

[52] **Jasbir S. Arora -** Introduction to Optimum Design: Second edition, 2004

[54]. **ADB** Private Sector Deal to Promote Solar Power in Afghanistan, 2004.

[53] **Ian MacWilliam,** Aga Khan Development Network, UNAMA Afghan Update magazine on the environment

[55] **United Nations Development Program (UNDP).** September 13, 2017. Retrieved 2019-04-20.

[56] **"Central Asia's Largest Off-grid Solar Power System:** Bringing electricity & hope to Afghanistan". North American Clean Energy. November 20, 2014. Retrieved 2019-04-20.

[57] **"'Green' Energy Demonstrates Progress in Afghan Province".** Archived from the original on 2013-02-17. Retrieved 2012-08-01.

[58] **"Energy that never run out". September** 13, 2012. Retrieved 2019-04-20.

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