MSc Program
Renewable Energy Systems

Potential of using photovoltaic systems in Kurdistan region-Iraq

A Masterôs Thesis submitted for the degree of
ñMaster of Scienceò

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October 2017, Vienna

Affidavit

I, **HOSHYAR AZIZ BAKER**, hereby declare

1. That I am the sole author of the present Master Thesis, " Potential of using Photovoltaic systems in Kurdistan region of Iraq ",
   107 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. That I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Abstract

The sun is consider as the main sources of energy. Using sun energy does not require complicated and costly technology. It can be used as a useful and energy source in most parts of the world. Also for countries which has not have enough non-renewable energy sources, using this energy can consider as the most suitable solution for development and economic growth.

Despite of Kurdistan region has abundant non-renewable energy sources such as crude oil and natural gas and because of that mostly electricity generate with natural gas, and the Kurdistan economy is dominated by the oil and natural gas industry, fortunately, as Kurdistan is located in sunny belt and due to the intensity of the sun's radiation in most parts of the Kurdistan region, using Photovoltaic (PV) technology to generate electricity is economically feasible and It could have significant savings in gas and oil consumption. Reducing the environmental pollution and most importantly the storage of fossil fuels for future generations, are consider as the major reasons of using renewable energy sources particularly photovoltaic technology in the region.

Using of PV technology is favorable but need to evaluate all technical and economic aspects in order to gain the most accurate results. This paper studies the economic and technical potentials of using PV technology in Kurdistan region especially large scale or utility-scale PV application. Ecological aspect are neglected as there is no proceeding any clear policy by the Kurdistan region government.

PV marketing situation in Kurdistan is studied by finding the key barriers in way of PV marketing growth and SWOT (Strength-Weakness-Opportunity- Threats) analysis has been done by address all strength, weakness, opportunity, and threats points. Some factors highlighted in order to take in consideration to improve the PV market in the region and to have an idea about public awareness, survey is done by distributing the questionnaire and the results are promising.

Despite of using PV in Kurdistan is consider as very new technology and there is no any FIT(Feed-In-Tariff), ecological policy, government support, technical knowledge, but Kurdistan can consider as suitable market of PV in future and using this technology with current conditions are economical feasible. Thus, need to think more about using this technology in the region.

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1- Introduction

Indeed the increasing use of energy and providing it for life survival is one of most important signs of new life. There are three category of energy that we have at our disposal. The first group is fossil fuels also called non-renewable energy sources, such as coal, oil and natural gas. Second group called renewable energy sources, such as solar, wind, tidal, wave energy, hydropower, geothermal, biomass which are renewed on their own without any human intervention also called clean energy sources as they do not damage the environment. The third group known as nuclear fuel such as uranium and plutonium which bring to us a great and amazing energy to us.

Heavy reliance of Industrial societies on energy resources, especially fossil fuels and due to high consumption, it cause getting empty of the huge non-renewable resources that have been formed over the centuries in layers of earth. Thus, this is the duty of new generation to turned to the renewable energy sources and spread their knowledge to exploit those renewable energy (RE) sources.

Despite of all advantages of RE sources, and due to cheapness and more availability of fossil fuels, at the moment the RE sources has a few share in providing world energy needs. However, all renewable energy sources existed since ancient times, but by development of science and technology, human has been able to harness those energy sources. Optimizing consumption of fossil fuels and switch to use renewable energy sources are two proposed options in order to improve the environment and out of the energy crisis.

With the increasing industrialization in the most developing countries and population growth in the world, energy demand, especially electrical energy is increasing day by day. Now a days, electricity has a big role in society life which is without electricity life imagine is difficult for humans. Achieving electricity is the most important human successes in the history of his life.

The sun is an inexhaustible energy source and the energy which receives by earth from sun is very high. Part of this energy is use for heating the earth and subjects on it and the part will be used for photosynthesis in plants. Another way of using solar energy is producing electricity by using photovoltaic cells that converts light directly into electricity.

The fuel is free for PV cells, operating cost is low due to low maintenance, clean and silence as there is no fuel and no moving parts in the process, ability to construct at any size, low construction cost, and reliable operation for long periods of time are the most advantages of photovoltaic system. Those advantages give us the power to choice photovoltaic systems as suitable choice in many cases.
In this thesis, possible potentials of using photovoltaic system for electricity generation in Kurdistan region of Iraq has been studied briefly, also current PV market in the region with brief look at overall PV systems working mechanism and global market situation.

1-1 Motivation

Kurdistan region is an optimal region for PV installation as it located 36 degree latitude and 44 degree longitude with Annual solar irradiation 1,754 Kwh/m^2/year which is very good potential. Kurdistan region of Iraq is located rich fossil fuel rich area (Oil & natural gas) but due to the cost of electricity generated by fossil fuels, thus photovoltaic systems are mostly can be used in remote areas isolated and far from the national grid electricity, such as rural villages and border areas.
Since 2014, Kurdistan region of Iraq suffered from economic crisis. Political differences with the central government, the fight against terrorism and crude oil prices are the main reasons of this economic crisis. The energy sector, like other sectors has been affected by this economic crisis specially electricity which is not stable and due to increasing demand in the region and not sufficient electric power generation, now electricity generation is considered as big issue in the region. Thus, Kurdistan regional government (KRG) by applying some strategies seek to deal with this economic crisis especially in energy sectors. Recently Ministry of electricity established department in order to research on possibilities of using renewable energies to produce electricity as alternative energy especially hydro power, solar and wind. As well as increasing day by day familiarity with and knowledge of people about renewable energies especially Photovoltaic systems can be considered as good signal in order to have more research in this field.

1-2 Core objective

The main reason behind investigating Photovoltaic systems like other kind of renewable energies is that those resources are clean and reducing the impact of greenhouse gas (GHG) and global warming. Although for Kurdistan region and developing countries which have been faced huge problems and conflicts, GHG impact and global warming is not considered an important issue but still there is some reasons like oil price fluctuations cause to increase incentives to invest and develop renewable energy sources in those regions.

The main objectives for this study is investigation on all possible potentials of Photovoltaic technology to producing electricity in Kurdistan region per each sectors (industrial, agriculture, residential, utility- scale, etcé). find out the way to using those potentials as much as possible also to analyze and assess the current situation of PV market in the region and propose the possible scheme and strategies in order to emphasize over all photovoltaic market in the region.

The aim of this paper is to answer below important questions about photovoltaic potentials in Kurdistan region of Iraq:

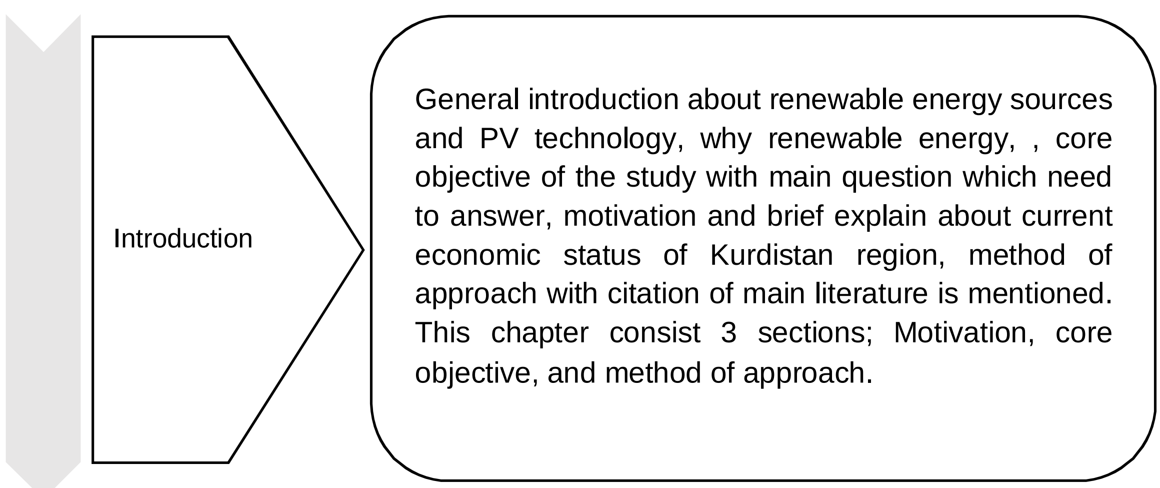
- What is the technical strength and barriers of using PV systems in the region?
- In economical aspect, what is SWOT analysis of PV market in Kurdistan region?
- Does using PV technology as alternative energy in Kurdistan has impact on region economic situation?
- Which sector (Industrial, Agriculture, residential, etcé) has more potential for using PV technology?
- Is it financially feasible using Photovoltaic systems for electricity production in the region?
- What is possible suggested strategies to emphasize PV market in the region?

1-3 Methodology of approach and work structure

In order to have the most accurate answer for question have been raised, many references has been used such as Internet research, books, , journals, publications and relevant literature which are related to the renewable energy and photovoltaic, also Kurdistan regional government websites. Below are the main references:

- Data from Kurdistan Regional Government / Ministry of electricity (MOE)
- Document and data from KRG / Ministry of planning (MOP)
- Data from KRG / Ministry of financial affairs (MOF)
- Data from KRG / Ministry of natural resources (MONR)
- Data from KRG / Kurdistan investment Board (KIB)
- Iraqi Kurdistan Economic Report
- Data Atmospheric Science Data Centre, ASDC
- Solar Electricty Handbook 2016; Solar Irradiance
- Data from international energy agency
- Reports from Solar Power Europe association
- Market analysis information from Green tech media (GTM Research)
- Report and documents from Global Solar industry website
- Report and Documents from national renewable energy laboratory (NREL) / PV research
- Reports from renewable energy world website
- Documents from Photovoltaic education organization website

The Structure of work in this study is as below:



PV Technology	General information about PV systems, concepts, general technical information about solar cells and working mechanism, advantage and disadvantages of using PV systems and global perspective of using PV systems has been explained. This chapter consist 4 sections; Concepts, technical overview on Solar cells, PV systems, and photovoltaic technology pros and cons.
Kurdistan Region	Current economic situation of Kurdistan, brief history of Kurd and Kurdistan, geography and population of the region, existing energy sources in Kurdistan region and electricity production in the region and future plans. This chapter consist 5 sections; History of Kurdistan, geography of Kurdistan, population of Kurdistan, economic of Kurdistan, and energy sources in Kurdistan.
Technical and Economical Appraisal of Photovoltaic systems in Kurdistan	Solar radiation in Kurdistan , Technical problems, barriers , strength , etcé of using PV in Kurdistan will explained in this part, Focusing on the economic aspect of using PV in Kurdistan region, Solar module & systems cost in Kurdistan, KRG (Kurdistan regional government) incentives and facilities regarding photovoltaic systems in region, the economic. This chapter consist 5 sections; solar radiation in Kurdistan, SWOT analysis, PV cost in Kurdistan, and government incentives.
Utility- scale solar PV power plants in Kurdistan	Technical assessment of utility ïscale solar power plants in Kurdistan will explained (capacity range from 500 KW to 50 MW) the results (efficiency, electricity generation, etcé) will be shown by charts and tables., the economic assessment of utility ïscale solar power plants in Kurdistan will explained (capacity range from 500 KW to 50 MW) the results (NPV, LRGC, Annuity, costs, etcé) will be shown by charts and tables. This chapter consist 3 sections; Utility ïscale solar power plants; technical assessment of utility ïscale solar power plants in Kurdistan and Economical assessment

Photovoltaic Marketing Situation in Kurdistan	Overview of global PV market, Current photovoltaic marketing, competition situation will explained in this chapter and base of deficiencies, barriers, some strategies will propose to develop photovoltaic marketing in the region. This chapter consist 3 sections; Overview of global PV market, Current PV market in Kurdistan, and Strategies to develop PV Marketing in the region.
Case studies	In this study 2 cases has been studied. Technical and economical results are highlighted. Off-grid non-domestic (telecom application), and Grid-connected distributed PV (normal house in Erbil city).
Conclusion and recommendations	Consist conclusions and all possible recommendations.
References	Consist all references.
Appendix	Consist all Appendix.

2- Photovoltaic technology

Photovoltaic technologies which is direct converting solar energy (photons) into electricity energy via PV cells. In order to understand more this converting process, need to understand first some concepts, overview on solar cells as the key element of the process and its structure, generations, development and working mechanism. Types of PV systems, highlight the advantage and disadvantage of using photovoltaic systems and global perspective of this technology.

2-1 Concepts

Photo electric

In 1887, the photoelectric effect was discovered by Hertz. While he was practicing his famous experiments on electromagnetic waves. The photoelectric effect is a phenomenon that emit electrically charged particles from the surface of the material by absorbing electromagnetic waves. Often this effect is defined as the electron emission from the metal surface when the light is on it. When a metal surface is exposed to a frequency higher than a certain amount of electromagnetic radiation, light is absorbed and the electrons are separated [Humphrey D.L]

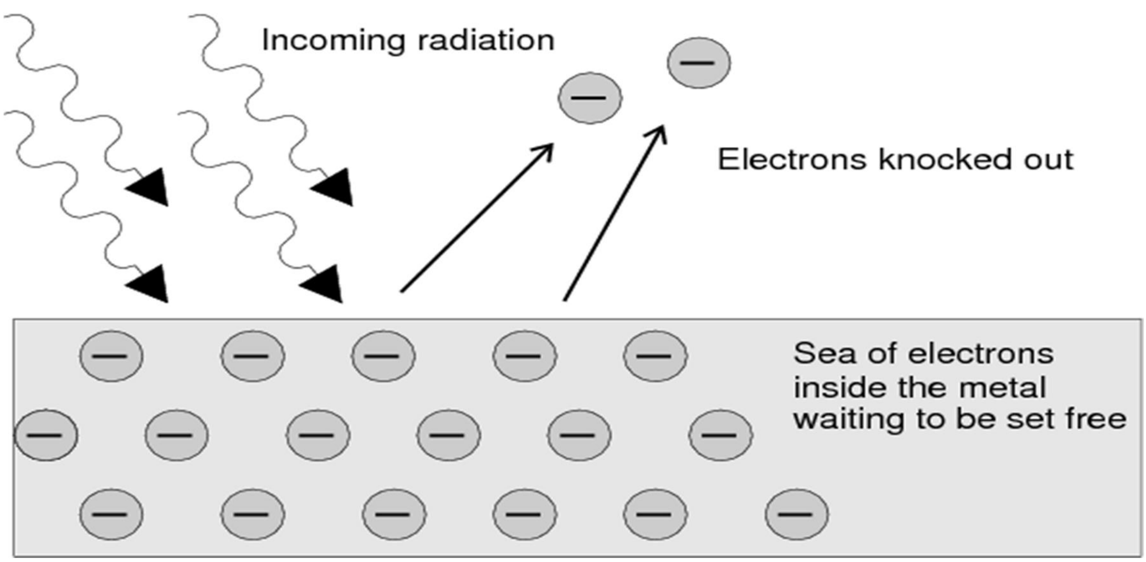


Figure 2.1. Photoelectric effect [Source: archive.cnx.org]

Photons of light beams have an energy characteristic that is determined by the light frequency. In the process of electrons exiting the metal, if the electron energy received from the photon is greater than the function of the photon, then the photon is removed from the metal. Increasing the beam's intensity increases the number of photons in a beam, resulting in more electrons, without the energy of any electrons being increased. Therefore, the energy emitted by the electrons does not depend heavily on the incoming light, but only on the individual energy of the photons [Sam Paolo M. (2017)]
In 1902, Philip Edward van NOLARD, realized that the energy of the separated electrons is increased by the increasing in the frequency or color of the radiant light. This contradicted the theory of James Clerk Maxwell, who explained that energy was proportional to radiation intensity. In 1905 Einstein solved this contradiction by describing the light as separate quantum fragments, called the photon, instead of continuous waves. Albert Einstein's mathematical description of how electromotive force induces the absorption of photons, suggested a simple quantum light, the same photon, and showed how they caused some phenomena, such as photoelectric [US department of energy (2011)].
Main application of photoelectric effect is in solar cells which are used in photovoltaic systems to produce electricity from sun lights by direct converting process. Other applications of photoelectric are; Photo sensors, Golden sheet electroscope, Photoelectron spectroscopy, Spacecraft, Night vision devices [Howell E. (2017)].

Photovoltaic phenomenon

Converting the energy of radiation into electrical energy without using any mechanical mechanisms is called the photovoltaic phenomenon. In fact, this phenomenon is based on the radiation particle's particle hypothesis. Any system that uses this property is referred to as a photovoltaic system. The photovoltaic system converts the energy sun lights directly into DC electricity energy by solar cells. Materials which uses in solar cells are semiconductors, those materials are made of silicon. When the sun shines to a photovoltaic cell, potential difference happened between two negative and positive electrodes, which causes the flow electrons between them [Hersch P. et al (1982)].

The photovoltaic effect discovered by Edmond Becquerel in 1839. The photovoltaic effect happen in PV cells. Two different types of semiconductors , p-type with majority hole and an n-type with majority electron create a p-n junction. Solar cells are composed of a p-n junction and light is composed of photons. When light is incident on these cells, energy of photon is transferred to the semiconducting material in the p-n junction, in fact the energy is transferred to the electrons in the material. Because of this energy transferring, electrons jump from lower energy level to higher energy level (this process will explain in next sections). This electron movement creates an electric current in the solar cell [Godfrey B. (2004)].

Semiconductors

Typically, objects in terms of passing or not passing electricity are divided into two category, conductive and insulator. But there is another group of objects that is neither fully conductive nor completely insulator. This particular group of bodies is referred to as semiconductor.

In the solid body the energy levels of the electrons makes strips, each strip contains a large number of discrete levels that are very close together. In the semiconductors, the highest filler bar is called the capacity strip and the lowest blank is the conductive strip, and the distance between these two strips is the forbidden area or the energy gap and there are no energy levels in this area. The amount of energy gap plays a decisive role in the properties of semiconductors have four electrons in last orbit. Germanium and silicon are two elements that have the property of semiconductors and as they have good physical condition, are used to make diodes, transistors, IC, etc. Germanium and silicon atoms are a three dimensional crystal, and by placing the crystals side by side, their crystalline network is made up. Due to the heat energy of the environment around the semiconductor, the covalent bond is broken and the electron is released. Versus of this electron motion, There is another motion in holes with positive charge. These holes are caused by the loss of electrons in the bond. Therefore, the number of electrons and holes are equal, but the motion of the electrons and the holes are in the opposite direction of each other [McKenzie S. et al (1990)].

When an element such as arsenic or antimony is injected into silicon or germanium, the four electrons of arsenic last orbit, is forms covalent bond with four silicon or germanium atoms and its fifth electron remains free. Thus, each atom of arsenic produces an additional electron, without creating a hole. This type of semiconductor is called N-type. In the N-type semiconductor, the number of electrons is larger than the number of holes, the electrons are majority and the holes are the minority. When an element such as aluminum or gallium is injected into semiconductor elements, the three electrons of aluminum or gallium last orbit, is forms covalent bond with three silicon or germanium atoms and the fourth bond has an electron deficiency and make a hole.

Therefore, each atom of aluminum or gallium produces a hole, without creating a free electron. This type of semiconductor is called P-type. In the P-type semiconductor, the number of holes is larger than the number of electrons, the holes are majority and the electrons are the minority. These semiconductors form the basis of the solar cells structure [Christopher (2001)]

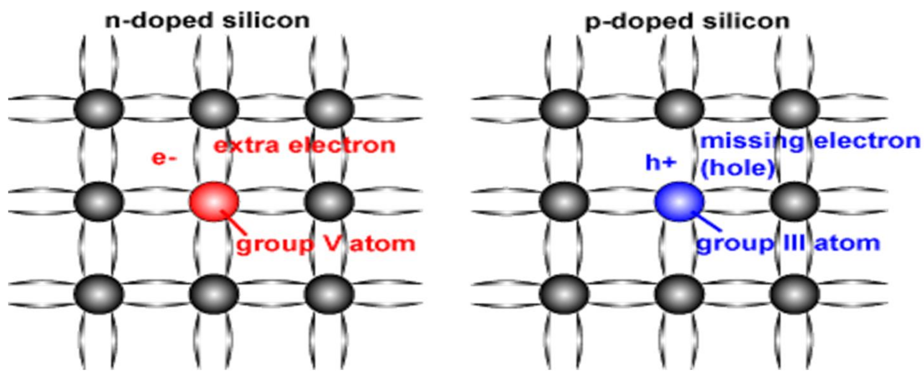


Figure 2.2. N-type and P-type Semiconductors ï Silicon [Source: asdn.net]

Solar radiation

The sun is made up of a hot plasma and has a magnetic field in the middle of it. The average sun's distance from the earth is nearly 149.6 million kilometers. This star consists of hydrogen and helium gases, those gases produce large explosions which causes production of strong beams of heat and light. These beams come from the sun to earth. Along the way, a third of them are distributed in space and the rest reach to the earth as the heat energy and light. In this long way, a lot of light and heat energy of the sun are lost, but as much as it reaches to the earth, it is enough to create the suitable conditions for our lives, animals and plants [Haji Saghati A. (2011)].

Sun light is consist of photons which has energy and by using PV technology can convert photons energy to electric energy and produce electricity. The thermal energy of the sun is transmitted through electromagnetic waves (such as visible light or ultraviolet waves). These electromagnetic waves have very high velocity which is equal to the speed of light. The amount of radiation outside the earth's atmosphere is 1353 W / m2. This parameter is known as the solar constant. Several factors influence the amount of energy emitted from the sun to earth's surface such as; steam and other gases in the air, small particles as well as droplets in the air, clouds, and earth rotation. Global horizontal irradiance (GHI) which is consist direct normal radiation (DNI) and diffuse horizontal irradiance (DHI), is the whole amount of radiation from sun which received by earth's surface [Boxwell (2011)].

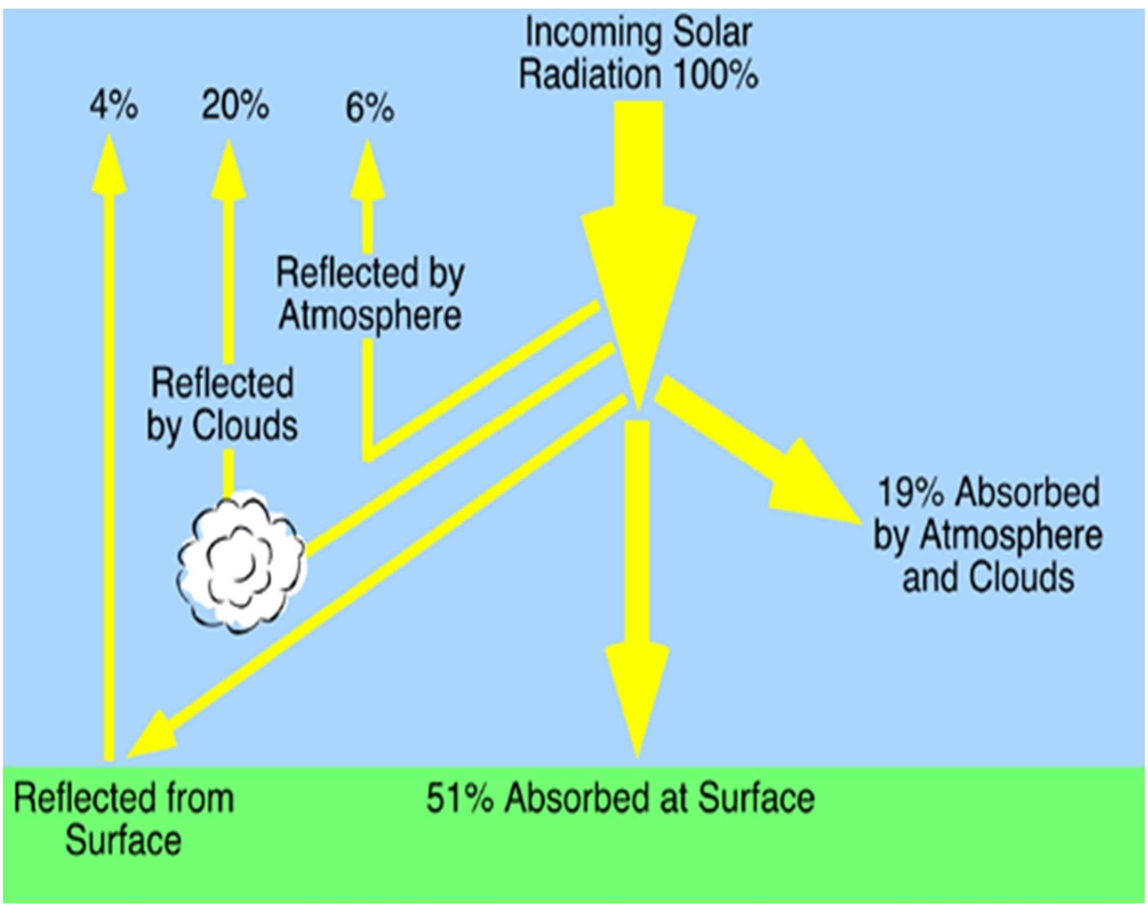


Figure 2.3. Incoming solar radiation by atmospheric and surface processes [Source: physicalgeography.net]

The air mass (AM) is the radiation angle of the sun to the earth and somehow expresses the amount of energy emitted into the earth. The amount of AM0 represents the amount of radiation reached outside of the earth's atmosphere which is used by satellites outside the earth's atmosphere. The amount of AM1 expresses the amount of radiation that shines to the earth vertically, and AM1.5 is the standard radiation rate, which is 1.5 times of AM1 [Qahrrodi M.M. (2015)].

2-2 Technical overview on solar cells

Solar energy is converted directly or indirectly to other forms of energy, such as heat or electricity. By using solar cells can convert solar energy into electricity. The solar cell base structure consists of semiconductor materials that generate electrical energy by absorbing light and moving the electron between energy levels.

Solar cell structure

Solar cells are usually made of semiconductor materials, particularly silicon. Semiconductor type P and type N are the main part of solar cell. As silicon is a very smooth material thus, it has high ability to reflect light, the reflected photons from solar cells are not useable for solar cells, and for this reason antireflective coating uses in the solar cells and it reduce the reflection of photons Also cover glass uses for cell protection. In general solar cell consists of 6 layers that each layer forms a specific material as below:

- Cover glass
- Antireflective coating
- Contact grid
- N-type Si
- P-type Si
- Back contact

Solar cells made of organic materials have less efficiency compared to their silicon counterparts, but they are suitable for non-industrial use due to have less capital cost and flexibility [Fechner (2016)]

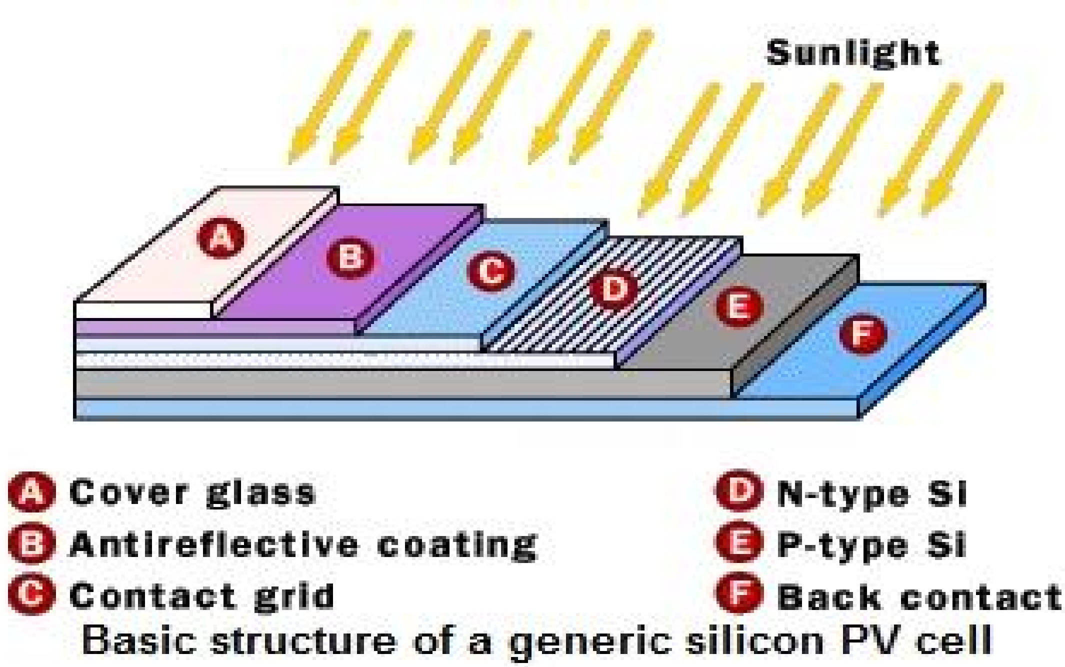


Figure 2.4. Basic starcture of Silicon solar cell [Source; pinsdaddy.com]

Solar cell generations

Traditionally there are three type or generations of solar cells which are: Crystalline Silicon, it is the first generation PV cell made from silicon. Mono silicon or Single crystalline has higher efficiency and thus higher cost compare to the polycrystalline silicon or poly silicon. The 2nd generation of PV cells are called thin film Solar Cell (TFSC). Indeed, thin film solar cells as 2nd generation have lower efficiency than 1st generation (crystalline silicon). This technology has been developed for Building Integrated Photovoltaic (BIPV). In this technology, semitransparent solar cells are used also can be used as window glass. Thus, the BIPV technology is possible to produce electric power and also for window painting. Organic Photovoltaic Cell (OPVC) is consider as 3rd PV cell generation, in this technology uses organic, electronic conductive polymers or small molecules for light absorption and electrical charge transport. Low cost and large scale production capability with flexibility are the benefits of this type of solar cells and low efficiency, low stability and low strength compared to traditional non-organic PV cells consider as disadvantage of this technology

OPVC technology is still in R&D stages and not ready for mass commercialization. In 2009, about 85% of the PV solar cell market was dominated by crystalline silicon cells while only 15% was represented by thin film solar cells [Fechner (2016)].

Table 2.1. Advantage and disadvantages of mono and poly crystal silicon cells. [Source: Energy Informative (2015)]

	Advantages	**Disadvantages**
Mono crystalline	• Monocrystalline solar panels have the highest efficiency rates since they are made out of the highest-grade silicon • Monocrystalline silicon solar panels are space-efficient. • Monocrystalline solar panels live the longest.	• Monocrystalline solar panels are the most expensive. • If the solar panel is partially covered with shade, dirt or snow, the entire circuit can break down. • Monocrystalline solar panels tend to be more efficient in warm weather.
Poly crystalline	• The process used to make polycrystalline silicon is simpler and cost less. • Polycrystalline solar panels tend to have slightly lower heat tolerance than monocrystalline solar panels.	• The efficiency of polycrystalline-based solar panels is typically 13-16%. • Lower space-efficiency.

Solar cell working mechanism

Solar cell is the one of the most important parts and only generator in a solar PV system. It is consider an electrical device (p-n junction) that converts the sunlight directly into electricity (DC) using the photovoltaic effect. Two important processes Involves for current generation in a solar cell which known as the ñlight-generated current,ò first is absorption of incident photons to create electron-hole pairs. The sun light is made of photons or solar particles. This photon consist energy values. When a photon hits a photovoltaic cell or solar cell, it may be reflected, transmitted, or absorbed by the PV cell. Only absorbed photons provide energy for generating electricity. When enough sunlight or energy is absorbed by the semiconductor body, the electron is displaced from the atomic bodies.

When the electrons leave position N and holes are formed. The number of electrons is high, each carrying one negative charge and going to the front of the cell's surface, resulting in a lack of load balancing between the front and rear end of a voltage potential. It looks like a positive and negative pole of a battery. When the two levels are connected through an internal path, the electricity flows. [Messenger et al (2003)].

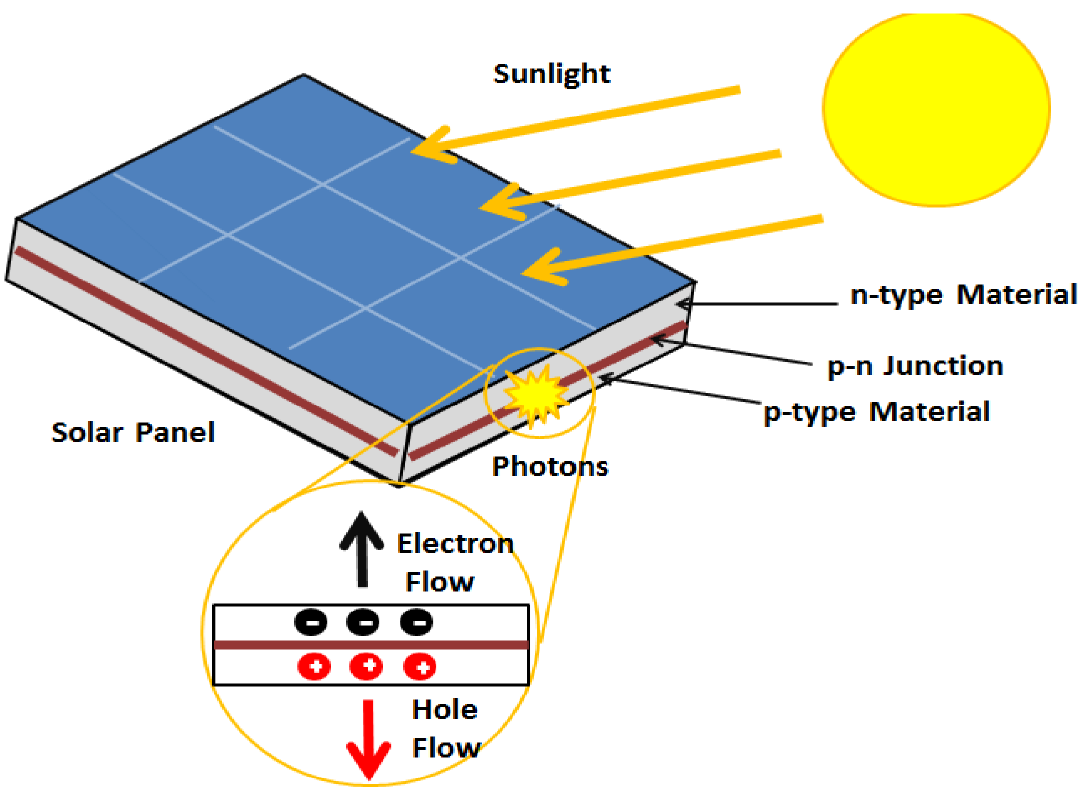


Figure 2.5. Photovoltaic effect in PV cell [Source: www.energyeducation.ca]

Solar cell development

In 1839, Alexandre Edmond Becquerel observes the photovoltaic effect. The history of solar cells beginning with this observation. This history divided into 6 phases as bellow:

- **Phase 1** (Discovery Years ; 1839ï 1904): In this perioed of time PV effect has been observed for first time by Becquerel, solar cells has been developed by using seleniuom on a thin layer of the gold in order to increase effeciency of solar cells and semconductor- junction solar cells has been made by Wilhelm Hallwaches.
- **Phase 2** (Scientific Foundation; 1905 ï 1950) : A paper explaining the PV effect on a quantum basis published by Einstein in 1905, in this period, some theories has been developed such as; theory of high purity semiconductor by A. H. Wilson in 1931, Little adapt the Czochralski method of crystal growth in order to make single-crystalline germanium and silicon by Gordon Teal and John in 1948.
- **Phase 3** (Demonstration of the First Practical Device 1950 ï 1959) : solar cells has been produced for space activities at Bell Labs in 1950. In 1954, the first modern silicon solar cell with 6% effeciency has been invented by Bell Labs. commercial solar cell with 10% efficient has been created by Hoffman Electronics, and in order to decreasing solar cellos resistance, using of a grid contact has been introduced.
- **Phase 4** (New Photovoltaic Devices; 1960 ï 1980): in this perioed of time, solar cellos effeciency has been increased to 14% by Hoffman Electronics. Telstar communications satellite, Soyuz 1 (first manned spacecraft) and Skylab powered by solar cell. In 1976, first Amorphous silicon PV cells with 1.1% effeciency created by David carlson and christopher. Global PV cells production exceeded 500 kW.
- **Phase 5** (Slowing PV development ; 1980 ï 2000): in this period due to some reasons such as plitical climate, protection oil supplies, this cause the slowing PV project development. Operating first concentrating PV system using Fresnel Lenses funded by USA and Saudi Arabia with 350 KW in 1981, Centre for Photovoltaic Engineering at the University of New South Wales created silicon cells with 20% effeciency in 1985. JX Crystals Inc demonstrated the first ThermoPV heat & electricity Co-generation MidnightSunÊ Stove in 1998.

- **Phase 6** (International participation in PV cell deployment; 2000 ï Present): Indeed this period started with create feed-In-Tariff (FIT) by Germanyọs renewable energy sources act in 2000. The silicon solar PV cell has been established as the dominate cell. 28% efficient

CPV module has been demonstrated by K. Araki et al in 2004. Construction of Nellis Solar Power Plant installed in 2007. In 2013, global solar PV installations passes 100 GW. Concentrator PV (CPV) development is consider as an opportunity due to the higher module efficiencies. Efficiencies of the Concentrator Photovoltaic module are continuing increase with the most recent module efficiency at 35.9%. CPV obviously a future opportunity for development potentially which is leading to cheapest solar electric power [Lewis .M. F. (2014)].

2-3 Photovoltaic systems

Sample Solar PV System is basically consist of some components which are, solar panels (photovoltaic or PV modules) to convert sunlight to electricity. To increase the electrical power that can be generated, a number of modules are connected together. PV module consists of a number of interconnected solar cells, one or many such panels make solar array. The DC isolator to provide a safe means of disconnecting the solar array from the inverter. Use inverter device to converts the direct current electricity which is produced by the PV panels to the alternating current (AC) form that is required for the National Grid and for the operation of most electrical appliances need. Another functions of inverter are provides a fail-safe link between the solar generator and the mains electricity network and If any problem happen in the PV system or a fault on the electricity network, the inverter would make the system safe. The electricity which produced by photovoltaic system is counts or measured by the generation meter. This counting is essential and importuning to measurement the revenue of feed ï in ï Tariff. The solar photovoltaic system is disconnecting from the electricity source by the main isolator [1].

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[1]: www.freegreenelectricity.co.uk

BOS or PV balance-of-system refers to the components that move direct current energy generated by PV panels through the conversion system which in turn generate AC electricity. BOS applies to all types of solar applications such as commercial, residential, agricultural, public facilities, and solar parks [Civic Solar (2011)]

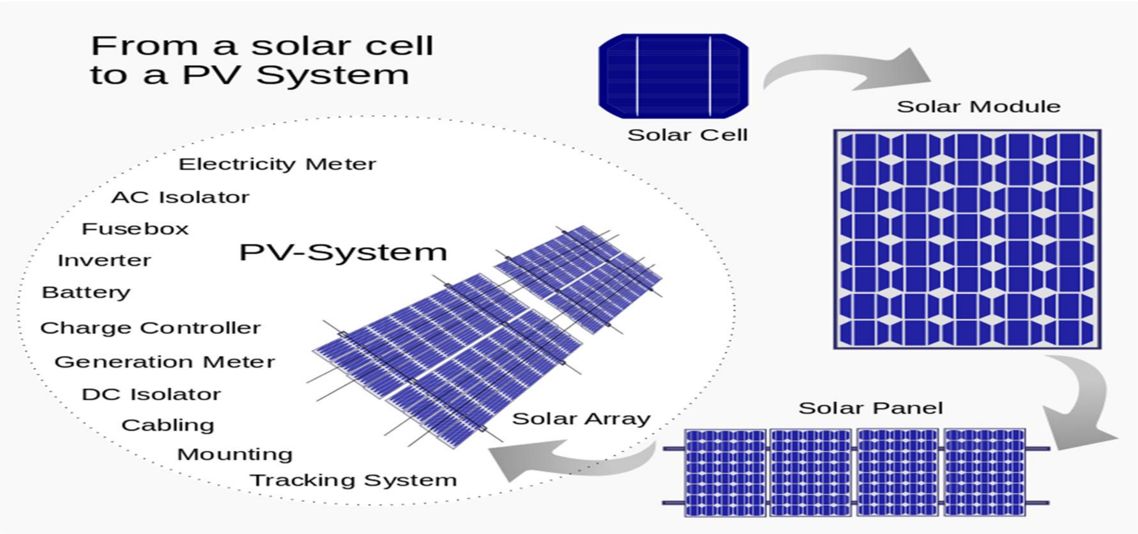


Figure 2.6. Diagram of the possible components of a photovoltaic system [Source: Wikipedia.com]

Solar photovoltaic power systems is using on space satellites, additional to that, Currently, many various types of photovoltaic systems used including: Remote stand - alone without battery storage, Remote stand - alone with battery storage, Small modules for calculators and toys, Residential grid connected with DC to AC inverter, Commercial grid connected with inverters, and PV fields for utility power generation [Lewis F. et al (2010)].

Concerning energy efficiency and reliability of PV system, the power conditioning units (inverter) play important role. The produced energy of PV system depend on some factors which are Incident solar irradiation, module temperature and the operating point of the PV modules. Thus, the PV system need power conditioning components in order to optimize the operating condition. Electricity generated by PV system is DC form and need to convert in to alternating current form of the desired voltage and frequency (230 V, 50 Hz). Some kind of inverter uses for grid-tied PV system which are central inverter for PV power plant >10 KW, in this case many parallel strings connected to a single central inverter. String inverter, in this technology the PV plant divided to several parts, each consist several parallel strings assigned to a designed inverter which called string inverter. Another inverter technology which is use for small PV systems is module integrated inverter. In this case use one inverter for each module for scales 50 to 400 W [Fechner (2016)].

Basically PV systems installed in way to yield maximum of energy. Thus, not only local weather situation taken in consideration and need to consider some other important factors during the PV system planning. Planning process of PV system is consist some steps which are, determine load power consumption in Watt-hours per day. Load is the appliances and devices (TV, light, water pumps, etc.) that consume electrical power. In case system is not grid connected then need to determine battery banks size which is decide how much storage provide by battery banks in days autonomy. In battery based PV systems, batteries using for strong electricity. In order to find PV array capacity, first need to find solar irradiance in local area which is measuring the intensity of sunshine at that area (W/m^2), orientation and inclination to achieve optimum energy yield. PV system planner should take care of shadowing effect on the system. Shadow has substantial effect on reducing energy yield of the PV system then even small shadow has to be avoided absolutely. Finally proper operation and maintenance according to the standards as needed [Fechner (2016)]

2-4 Perspective of using PV

According to the World Energy Council, now the share of renewable energy in total global electricity production is 23% and over 30% of the total global installed power generation capacity.

From 2011 to 2013, global photovoltaic production grow reached an average 78% per year. Recently, growth of the expansion of manufacturing capability and PV manufacturing production slowed. From 2011 to 2013, their respective annual growth rates decreased to 4% per year and 8% per year. In 2013, global PV module manufacturing capability was 60.5 GW per year and global PV module production was 39.9 GW [International energy outlook (2016)].

Table 2.2. World solar PV manufacturing production and capability, 2006 -13 (GW) [Source: International Energy Agency (2017)]

	2006	2007	2008	2009	2010	2011	2012	2013
Manufacturing capability	2.9	7.7	12.7	20.3	34.8	52	58	60.49
Module production	2.07	3.98	7.05	11.26	21.4	36.6	36.49	39.87

Some PV manufacturing companies have been downsizing due to the slow growth of PV module production. Germany as example reported to the IEA that at the end of 2008, a total 62 companies with more than 32,000 employees operating in the country, but at the end of 2013, down to a total 40 PV companies were operating in that country, with approximately 11,000 employees (IEA 2016). In recent years, China continues to be the largest producer of PV modules. ñ*In 2012, China installed 0.2 GW of solar PV capacity, and at the end of the year bringing its total installed PV capacity to 3.3 GW"* [International energy Outlook (2016): 86].

In 2012, global installed solar PV capacity reached to 90 GW. Total installed solar PV capacity in the countries (Germany, Italy, Japan, Spain, France, and china) represented 76% of the world total in 2012 and 61% of the global target total for 2020. Total more than 350 GW is the combined national targets for 2020. Concerning PV manufacturing capability, by considering 60 GW per year as current, there is enough capability to supply an additional 400 GW of new capacity between 2013 and 2020. [Joshua S. H. (2016)].

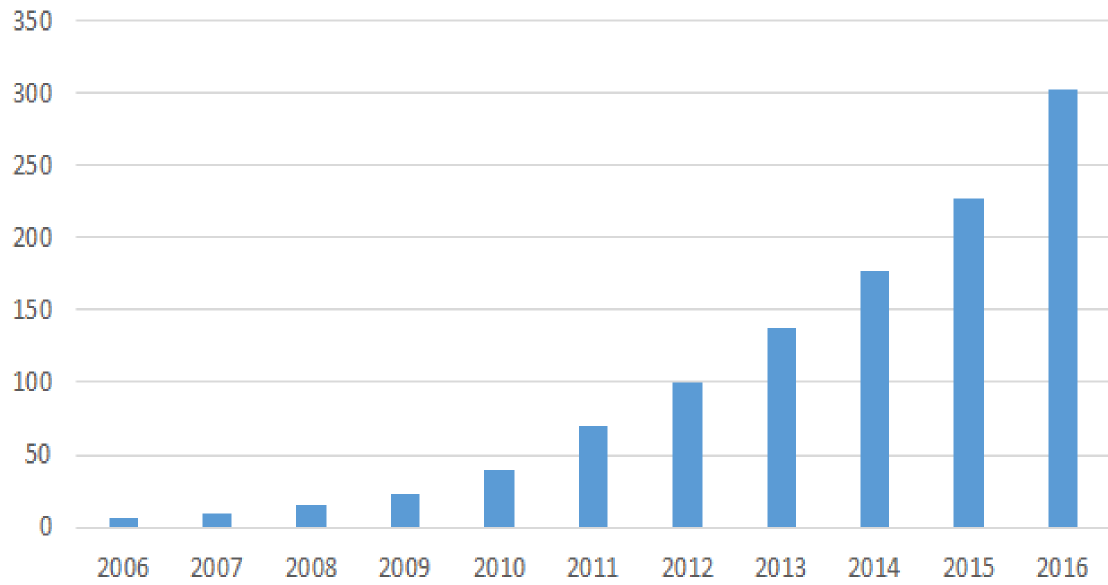


Figure 2.7. Solar PV global installed capacity 2006-2016. [Source: Energymarketprice.com]

Global solar installation levels are expected to for reaching 76 GW for 2016 and up 48% over 2015. The US is expected to have installed a relatively impressive 13 GW in 2016. Japan is expected to follow as third largest solar market in 2016 with 10.5 GW and India is expected to follow as the fourth largest solar markets in 2016 with 4.2 GW [Joshua S. H. (2016)].

2-5 Pros and cons of using PV

PV systems do not contribute to global warming, unlike coal, oil, and natural gas fired power plants. The sun is an unending energy source and PV system is not bound by material or land shortages. PV cells are reliable and already cost effective in certain applications. Photovoltaic systems use the sun energy to produce electricity thus, it is free and abundant and it is available anywhere there is sunlight. Solar PV is environmentally friendly as electricity generation with PV panels is no harmful greenhouse gas emissions. Compared to costs of other renewable energy systems, O&M costs of PV panels are low, almost negligible as it has no mechanically moving parts. PV systems are a perfect solution for residential applications as they are totally silent without any noise at all. Subsidy funding from government side is the important factor to make solar photovoltaic system be an attractive investment. Installation of PV panels especially for residential application on rooftop or on the ground is easy [Feyza A. (2012)]

Despite of all advantages of PV systems, there is some disadvantages of those system which need to take in consideration. Solar energy has an issue, at night canôt use the system as not shining at night also during day time if rainy or cloudy weather. To convert direct electricity from PV panels to alternating electricity in power networks, require solar inverters as additional equipment. Photovoltaic panels require not only Inverters but also storage batteries for a continuous supply of electric power, which mean need extra costs. PV systems require relatively large areas for deployment, in case of ground mounted installation. Compared to the efficiency of other renewable energy systems, PV panelôs efficiency are relatively low between 14%-25% [Luque A. et al (2011)].

3- Kurdistan Region

Kurdistan regional of Iraq is the only autonomous region in north of Iraq.. The region is officially governed by the Kurdistan Regional Government (KRG). Kurdistan region as a federal region of IRAQ is in way to develop rapidly in all sector particularly in industry and public services sector which need electricity as main essential item. Most of power plants in Kurdistan are using natural gas as fuel and has a good fossil fuel resources. The Kurds are one of the native peoples of the Middle East. They speak Kurdish, an Indo-European language. Four countries (IRAQ, IRAN, Turkey and Syria) are the land of the Kurds. But only in two of these countries which are Iraq and Syria, Kurds have established a forms of autonomy. In Iraq, Kurds primarily inhabit in four provinces (Erbil, Sulaymani, Dohuk, and recently Halabja) that make up the Kurdistan Regional Government.

Figure 3.1. Majority Kurds population region, include the autonomous Iraqi Kurdistan [Source: france24.com]

After World War I, when Ottoman Empire collapsed, the new country of Iraq was formed in 1921 from the Ottoman states of Baghdad and Basra. In 1926, the northern state of Mosul with was added to the new formed country under British mandate. The Kurdistan regional government was officially recognized as a semi-independent region in the 2005 Iraqi constitution.

3-1 – Geography of Kurdistan

ñ*Kurdistan region is Located between latitudes 34° 42’ N and 37° 22' N and between longitudes 42° 25’ and 46° 15’ east, has borders with Iran to the east, Syria to the west, , and Turkey to the north*ò[Husami M. S.(2007): 36]. With 41,000 Square Kilometer area, Kifri (140m) is the lowest point in the region, and the highest point is the Peak of Halgurd (3660m) in Choman. Kurdistan region is traversed by the Tigris River, this river has three branches, the Upper Zap, the Lower Zap and Sirwan. The climate of the Kurdistan is semiarid continental, in winter cold and wet and very hot and dry in summer. Autumn is dry and mild, spring is the most beautiful season in the region and the Kurdish New Year (Nawroz) is celebrated by the people in this season (March, 21). In July and August, the hottest months, cooling slightly in November [2].The average height of the Kurdistan Region Mountains is about 2,400 meters, the highest peak, Halgurd, is in Erbil government, near Choman city and close to region border with Iran with 3,660 meters height [UNEP (2003)].

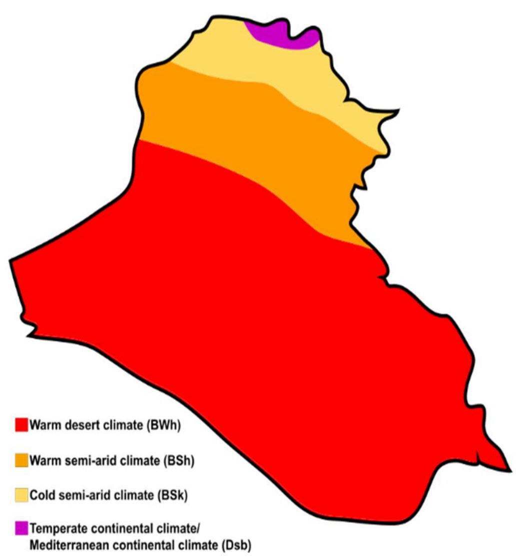


Figure 3.2. Iraq (include Kurdistan Region) map of Köppen climate classification [Source: www.wikiwand.com]

[2]: www.cabinet.gov.krd

3-2 - Population of Kurdistan

The total population of the Kurds is nearly 30 million which are live in four country (Iran, Iraq, Syria, and Turkey). 5.5 million Are live in Iraq in federal region under name Kurdistan region of Iraq. This is 18% of the total Kurds population. The population of Iraq is 32.6 Million and Kurdistan region population is 17.5% of the total Iraq population. [CIA World Fact book (2014)]. 36% of region population are young population which mean aged 0-14 years, 50% are aged less than 20 years and 40% of the region population are aged over 63 year [Husami M. S. (2007)].

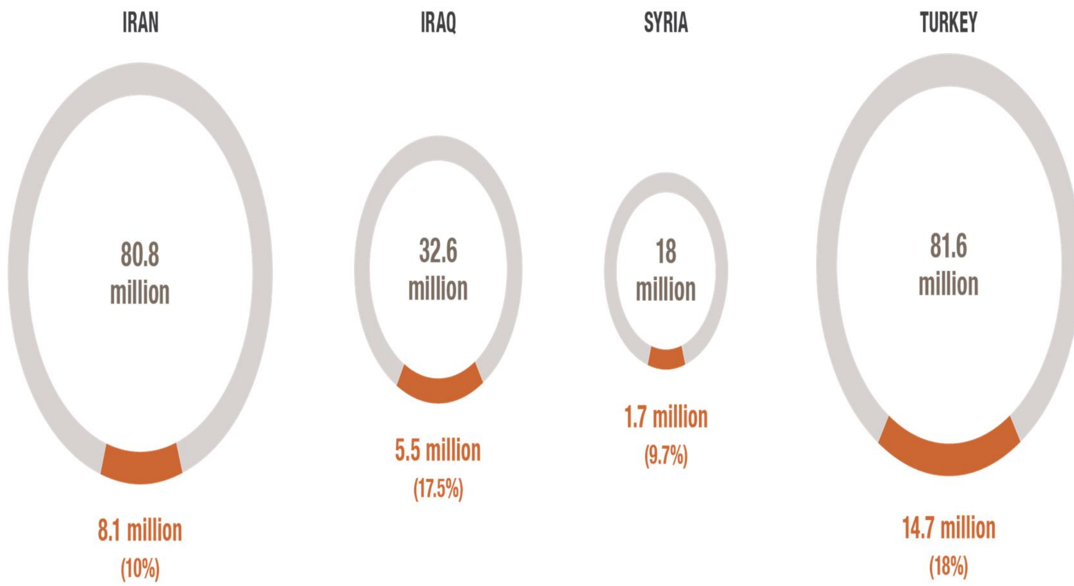


Figure 3.3. Kurds population include Kurdistan region of Iraq [Source: CIA World Fact book (2014)]

3-3- Economic of Kurdistan region

The Kurdistan region's economy is depended on the oil and natural gas industry, agriculture, tourism, and livestock farming as non-oil economic activity. The Crude oil production has been started in 2013 with 250,000 (bpd), it reached to 700,000 (bpd) in 2017 and estimated 2 million (bpd) for 2019 [KRG. MONR (2017)]. In comparison with other parts of Iraq (central and south region of Iraq), Kurdistan region is more developed because of relative peace in the Kurdistan region.

Table 3.1. GDP per Capita of Kurdistan region [Source: Investment Factsheet Kurdistan Region (2012)]

Kurdistan region of Iraq	
Gross Domestic Product	USD 23.6 billion (2011 est.)
Gross Domestic Product per capita	USD 4,452 (2011 est.)
Gross Domestic Product composition by sector:	Services (30.1%),
	Public services (20.6%),
	Agriculture (17.5%),
	Trade & Transport (13.5%),
	Mining & Manufacturing (9.4%),
	Construction (7.6%),
	Banks & Insurance (1.3%)

3-4- Energy Sources in Kurdistan

Kurdistan region has abundant hydrocarbon supplies, Because of that mostly electricity generate with natural gas. In terms of Electricity availability in Kurdistan, ñ*The level of access to main electricity grid for both urban and rural areas is close, approximately 72 percent of urban and 64 percent of rural households report that their main source of electricity comes from the public network, while 28 percent of urban and 34 percent of rural households report using shared generators as their main electricity source*ò [(KRG

2020)- Ministry of Planning Report (2013):24]. Today, installed capacity electric power plants is close to 5.5 GW. In Kurdistan, the main fuel which use in power plants for producing electricity is natural gas. 5 power plants with total installed Capacity 4,600 MW use natural gas as fuel to produce electricity [KRG ï Ministry of Electricity (2017)]

Table 3.2. Electricity power plants in Kurdistan region [Source: KRG ï Ministry of Electricity (2017)]

State	Power Plant Name	Capacity MW	Fuel	Remarks
Erbil	Khormala	600	Natural Gas	
	AGPS	1500	Natural Gas + Diesel	Combine Cycle
	E29 MW	29	Diesel	
Sulaymany	Chamchamal GPS	1000	Natural Gas + Diesel	Combine Cycle
	Tasluja	40	Diesel	
	S29 MW	29	Diesel	
	Bazyan	500	Natural Gas	Test
	Dokan	400	Hydro Power	
	Darbandikhan	240	Hydro power	
Dohuk	D29 MW	29	Diesel	
	DGPS	1000	Natural Gas + Diesel	Combine Cycle
	Baadre	143	Diesel	

The electricity generation in Kurdistan is rapidly increased from 2009, which is from 452 MW in 2008, it reached to 2,084 MW in 2012. This amount has been increased to 2,653 MW in 2015. But in 2016, due to some technical problems it decreased to 2,481 MW [KRG ï Ministry of Electricity (2017)]

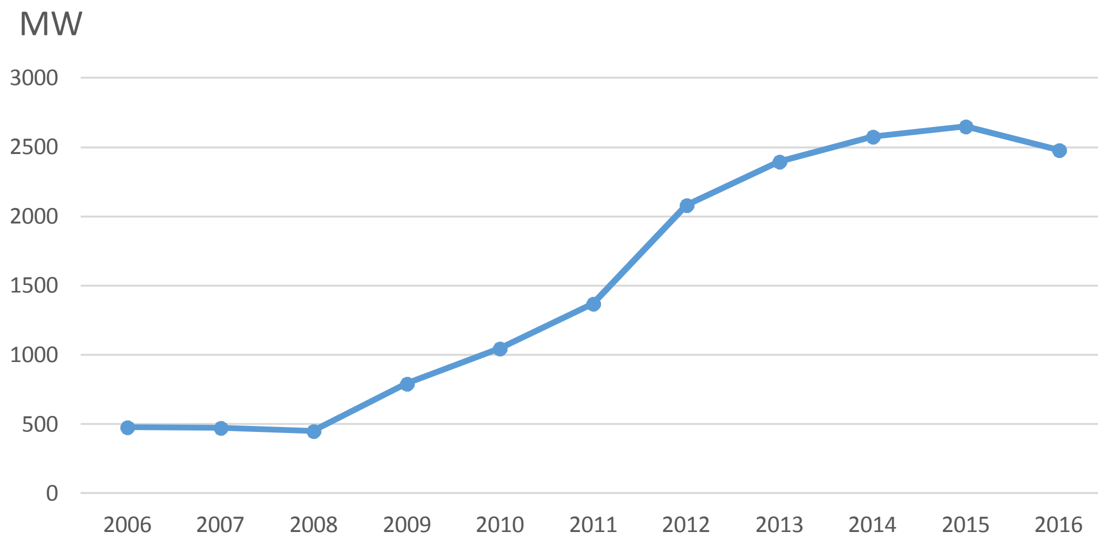


Figure 3.4. Electricity generation in Kurdistan [Source: KRG ï Ministry of Electricity (2017)]

The electricity imported to Kurdistan from neighbor countries has been started from 2006, in this year about 157 MW has been imported from turkey and 134 MW imported from central government of Iraq. In 2009, 5 MW imported from Iran to Kurdistan and the imported amount decreased from turkey and Iraq to Kurdistan. The trend is decreased year by year and in 2016, it decreased to 3MW which imported only from Iran.

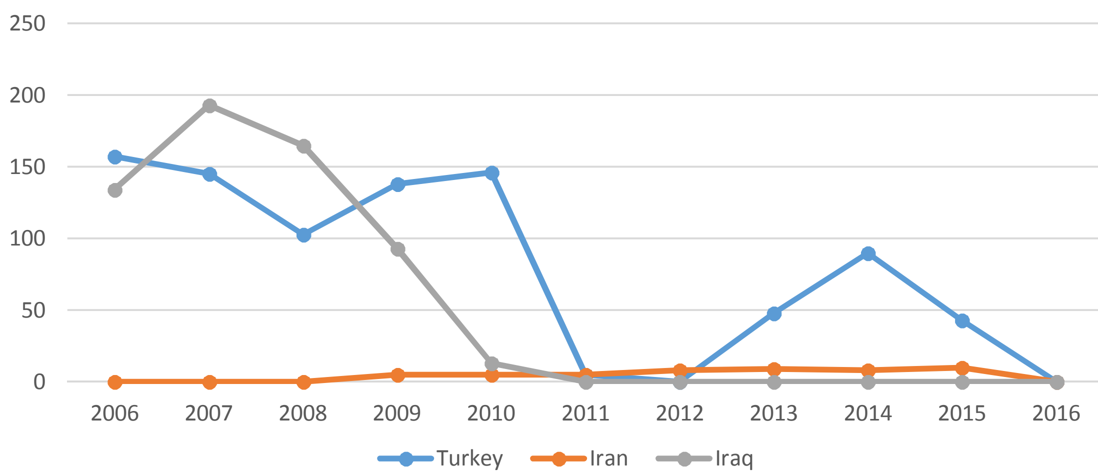


Figure 3.5. Imported electricity from neighbor countries to Kurdistan [Source: KRG ï Ministry of Electricity (2017)]

After 2003, due to quick development of Kurdistan region, there is rapid raising in electricity demand. In 2006, the electricity demand was 1,457 MW, this amount reached to 4,525 MW in 2014, and 5,253 MW in 2015 due to political crisis and war happened in the area, and huge immigration of the people to the Kurdistan region. In 2016, as many of refuges have returned to them place this demand decreased to 4,337 MW.

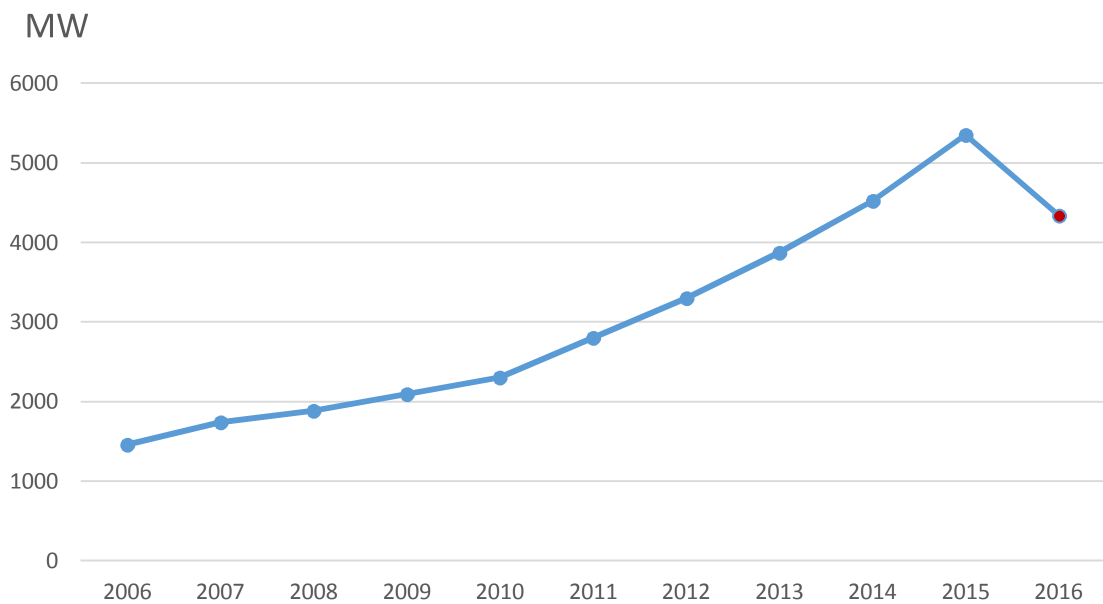


Figure 3.6. Electricity demand in Kurdistan [Source: KRG ï Ministry of Electricity (2017)]

The national grid electricity is not stable in Kurdistan, the availability of grid is fluctuated in seasons. The less availably is in the winter (January) less than 10 hours per day to high availability in summer more than 18 hours per day. The price of electricity energy is started from 0.02 $ for energy consumption 0-600 KWh and 0.72 $ for over 5,000 Kwh electricity energy consumption. Indeed as the availability of electrical power in Kurdistan is not stable which mean national grid power is not sufficient to cover all consumers demand, thus it had to seeking for another alternatives to cover the 24 hours consumer power demands. As energy measurement Kurdistan proceed the standards which is KWh, but for domestic generators is not proceeding the standards and it is base of any consumers request the amperes from the generator owner. This is special case which is applied in Kurdistan and other places in Iraq.

The price of ampere is controlled by government and it is deferent in seasonal basis. The price is fluctuated in seasonal basis from 6 $ per ampere to 12 $ per Ampere.

Table 3.3. Electricity energy price in Kurdistan [Source: KRG ï Ministry of Electricity; electricity sales office (2017)]

Kwh	IQD	USD
0-600	25	0.020
600-900	35	0.028
900-1500	50	0.040
1500-3000	60	0.048
3000-5000	80	0.064
>5000	90	0.073

4-Technical and Economical appraisal of Photovoltaic systems in Kurdistan

In this chapter the technical and economic situation of PV systems are studied as well as Kurdistan government incentive in this field.

4-1 solar radiation in Kurdistan

Kurdistan region is an optimal region for PV installation as it located 36 degree latitude and 44 degree longitude, thus PV modules need to be oriented towards the south.

Table 4.1. Solar irradiation of Kurdistan region [Source: Atmospheric Science Data Center (2017)]

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Night Hours	13:42	12:58	11:56	10:59	10:08	9:42	9:53	10:35	11:30	13:04	13:24	13:53
Day Hours	10:18	11:02	12:04	13:01	13:52	14:18	14:07	13:25	12:30	10:56	10:36	10:07
Wh/m²/ day	2,400	3,110	4,360	5,380	6,600	7,610	7,320	6,660	5,530	3,870	2,720	2,160
PSH	2.4	3.11	4.36	5.38	6.6	7.61	7.32	6.66	5.53	3.87	2.72	2.16
Days / Month	31	28	31	30	31	30	31	31	30	31	30	31
KWh/ m²/Month	74.4	87.1	135.2	161.4	204.6	223.2	226.9	206.5	165.9	120	81.6	67

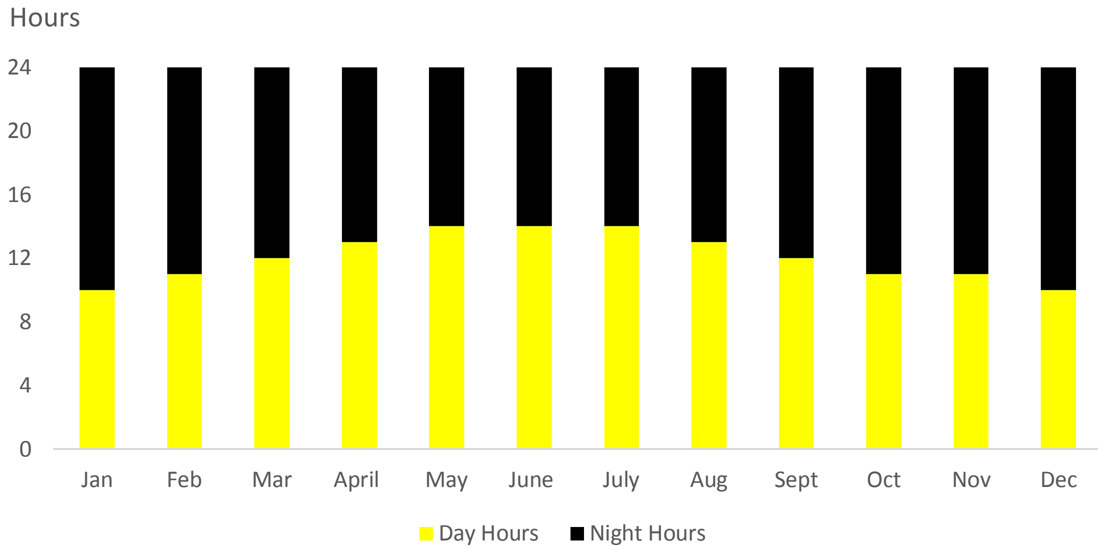


Figure 4.1. Day and Night hours in Kurdistan region / north of Iraq [Source: ASDC]

Annual solar irradiation for Kurdistan is: 1,754 Kwh/m^2/year which is very good potential. Max Solar irradiation is in July (226.9 Kwh/m^2/month) and Min Solar irradiation is in December (67 Kwh/m^2/month).

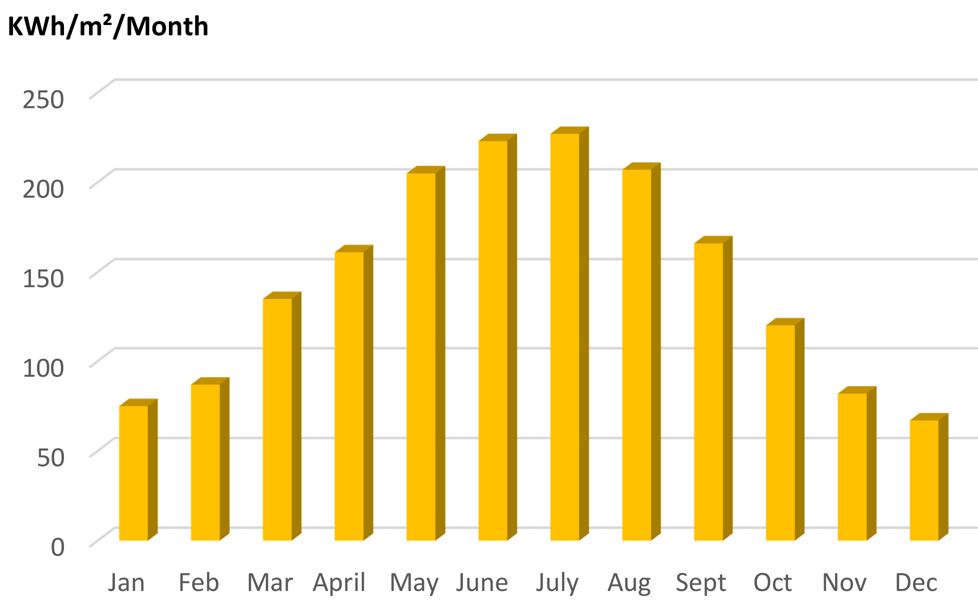


Figure 4.2. Solar insolation in Kurdistan region / north of Iraq [Source: ASDC]

Concerning solar radiation and solar angles in Kurdistan, solar radiation calculator software version 1.0.7 has been used for obtain the total solar radiation normal to the sun, total solar radiation on horizontal surface, and total solar radiation on vertical cylinder per months from January to December. Also solar altitude angle and solar azimuth angle [Solar radiation calculator version 1.0.7]

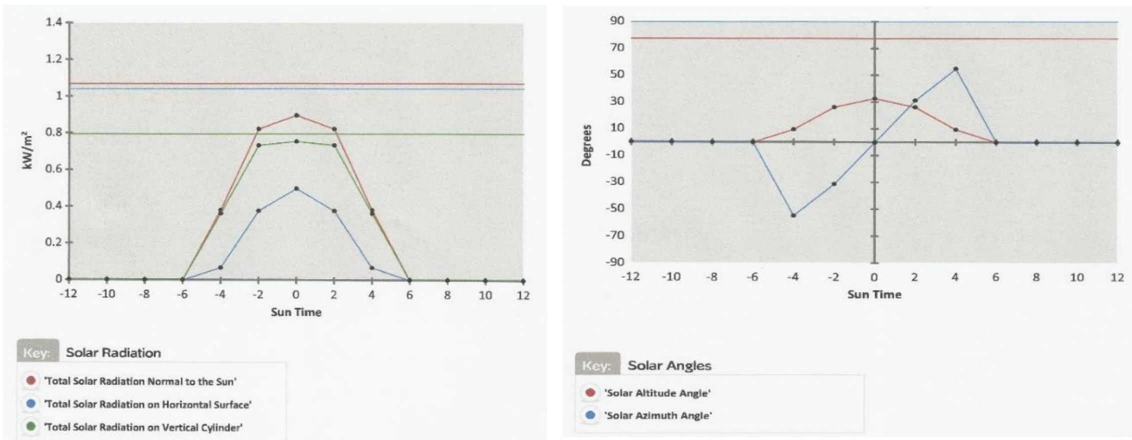


Figure 4.3. Solar radiation and solar angle in Kurdistan for January [Source: Solar radiation calculator version 1.0.7]

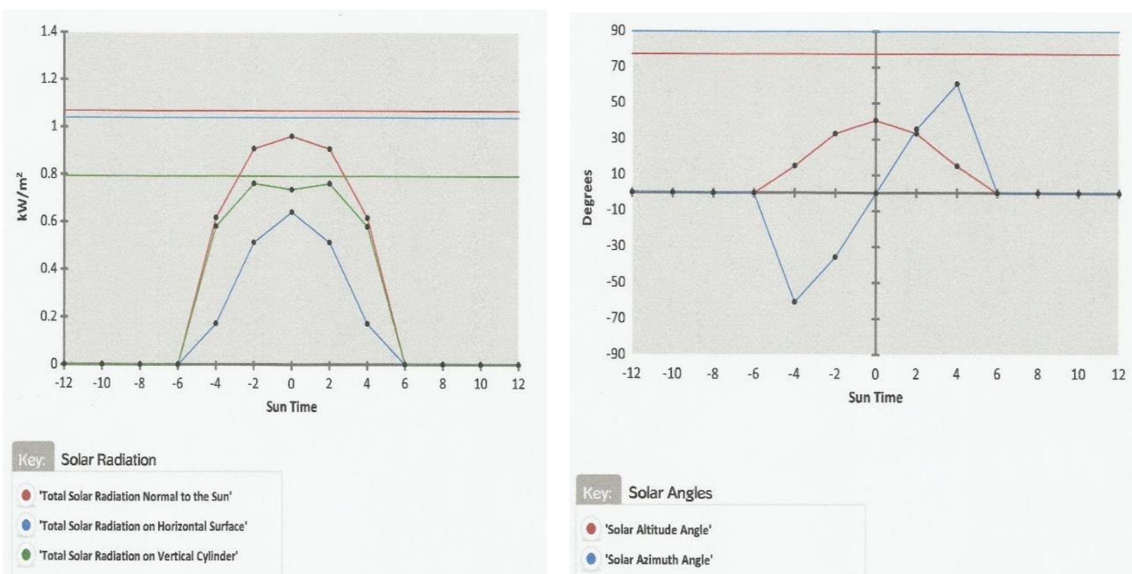


Figure 4.4. Solar radiation and solar angle in Kurdistan for February [Source: Solar radiation calculator version 1.0.7]

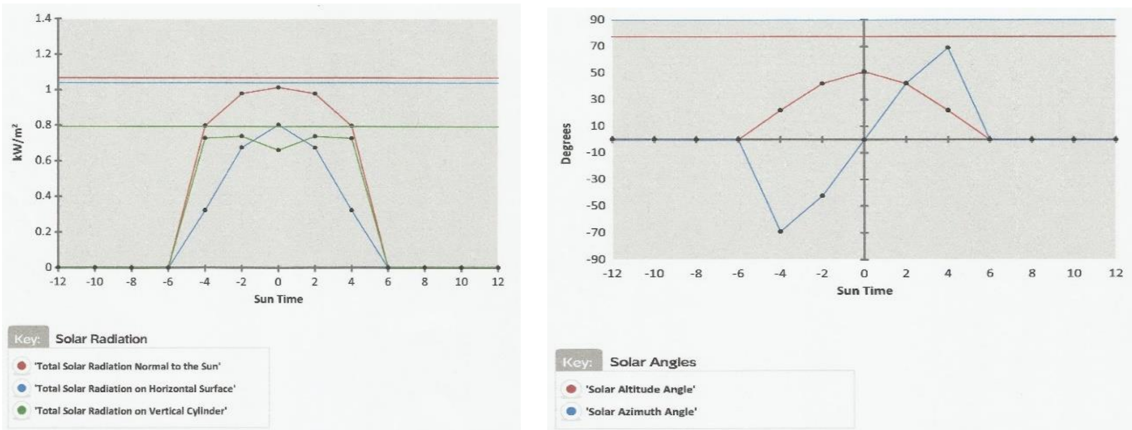


Figure 4.5. Solar radiation and solar angle in Kurdistan for March [Source: Solar radiation calculator version 1.0.7]

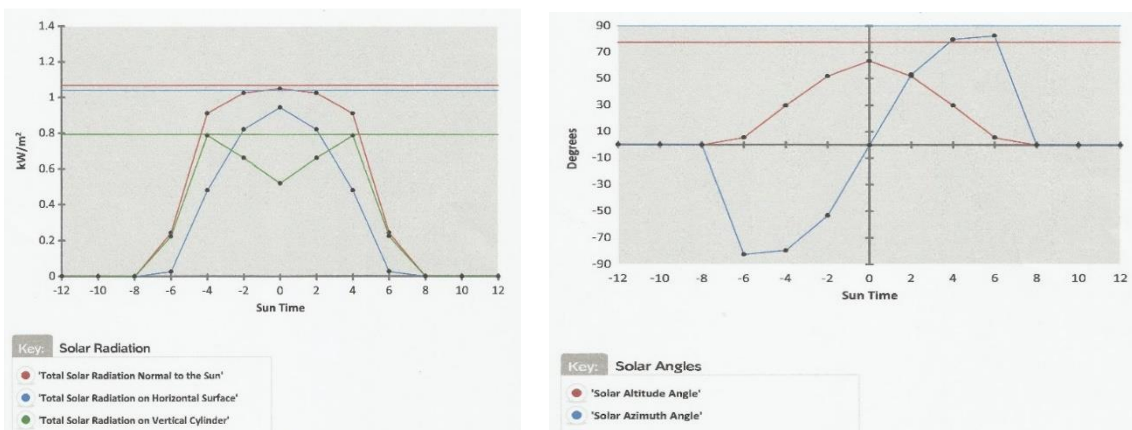


Figure 4.6. Solar radiation and solar angle in Kurdistan for April [Source: Solar radiation calculator version 1.0.7]

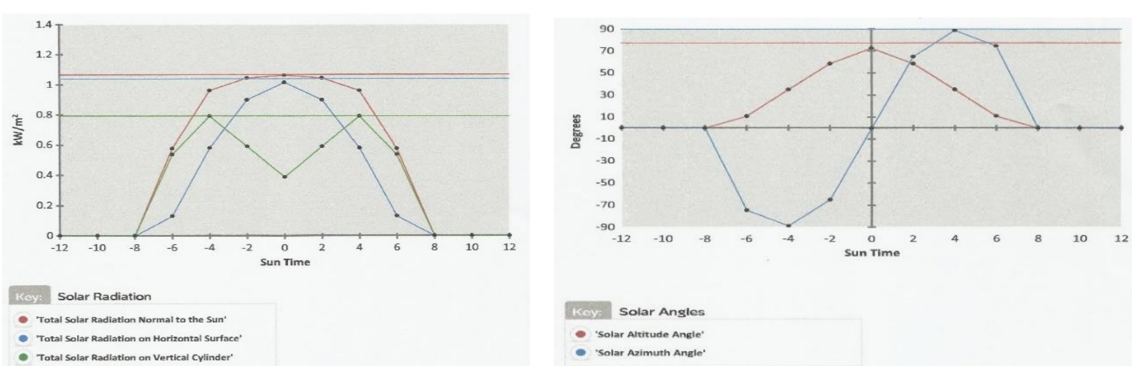


Figure 4.7. Solar radiation and solar angle in Kurdistan for May [Source: Solar radiation calculator version 1.0.7]

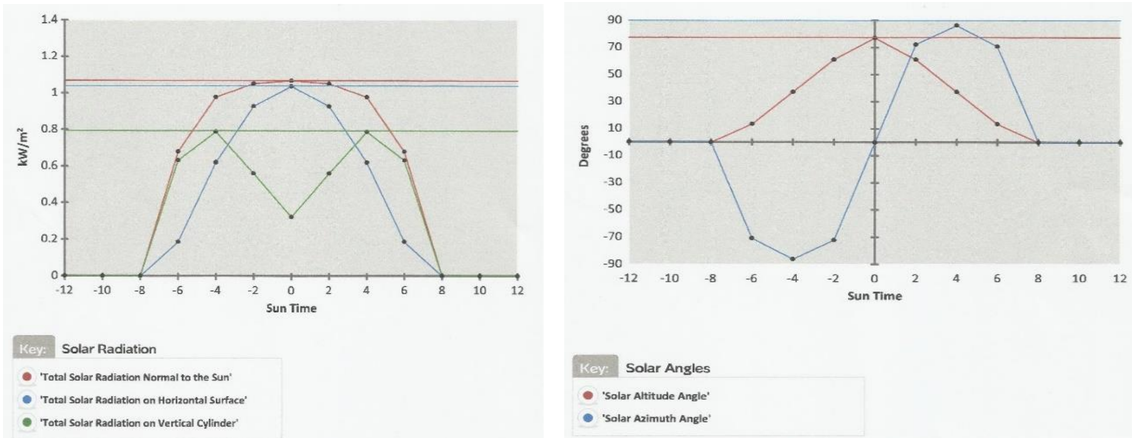


Figure 4.8. Solar radiation and solar angle in Kurdistan for June [Source: Solar radiation calculator version 1.0.7]

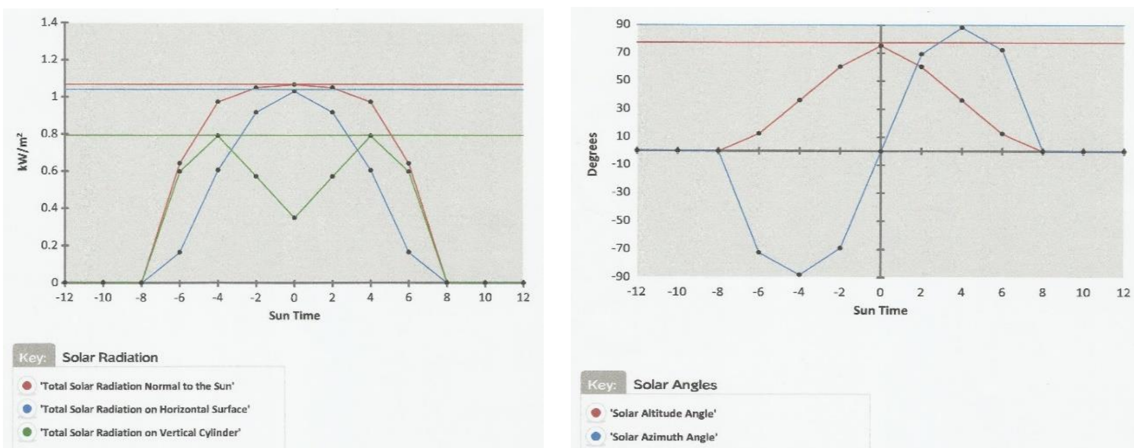


Figure 4.9. Solar radiation and solar angle in Kurdistan for July [Source: Solar radiation calculator version 1.0.7]

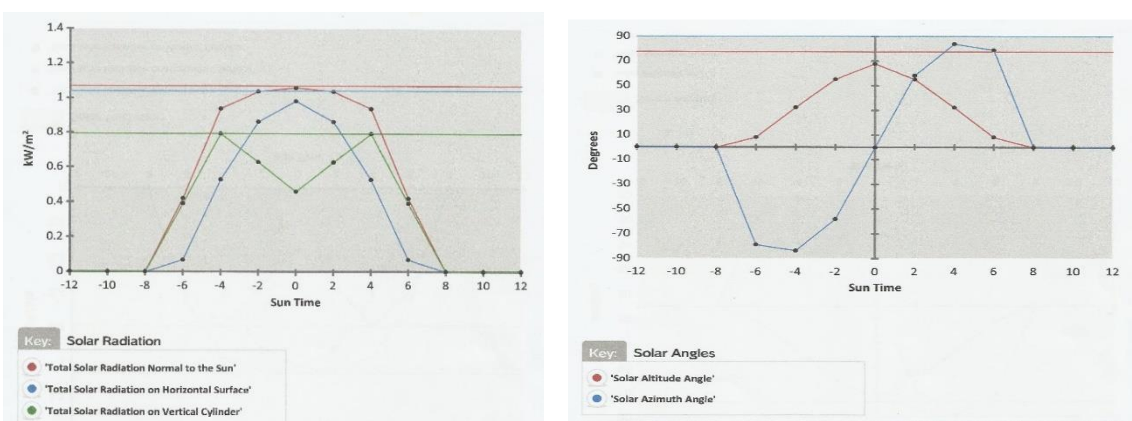


Figure 4.10. Solar radiation and solar angle in Kurdistan for August [Source: Solar radiation calculator version 1.0.7]

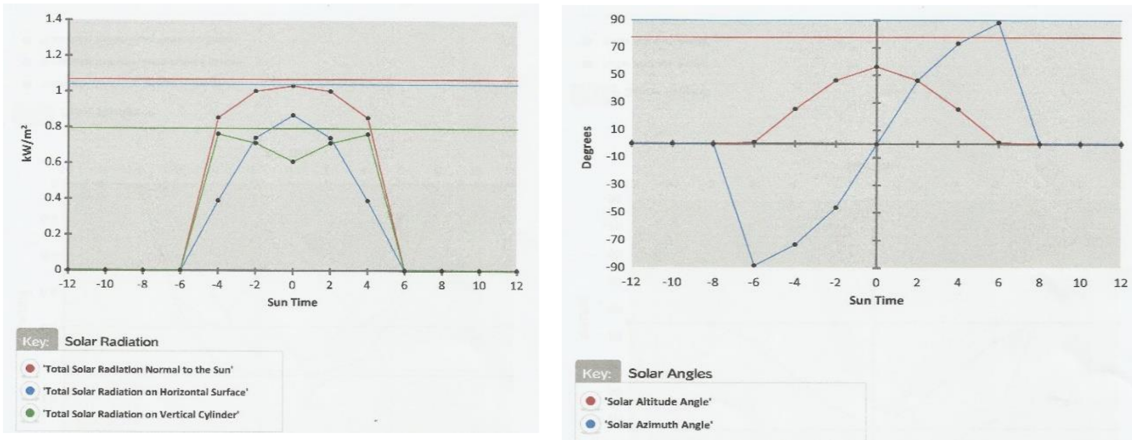


Figure 4.11. Solar radiation and solar angle in Kurdistan for September [Source: Solar radiation calculator version 1.0.7]

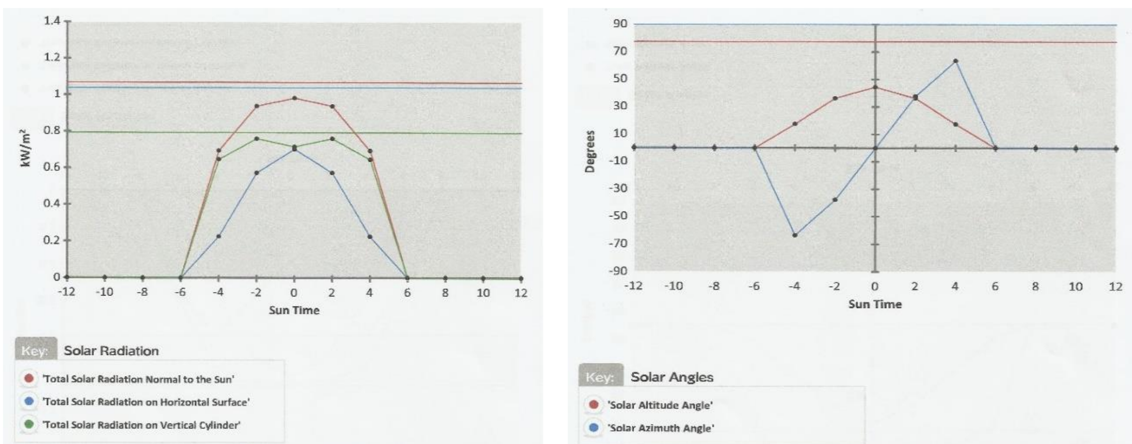


Figure 4.12. Solar radiation and solar angle in Kurdistan for October [Source: Solar radiation calculator version 1.0.7]

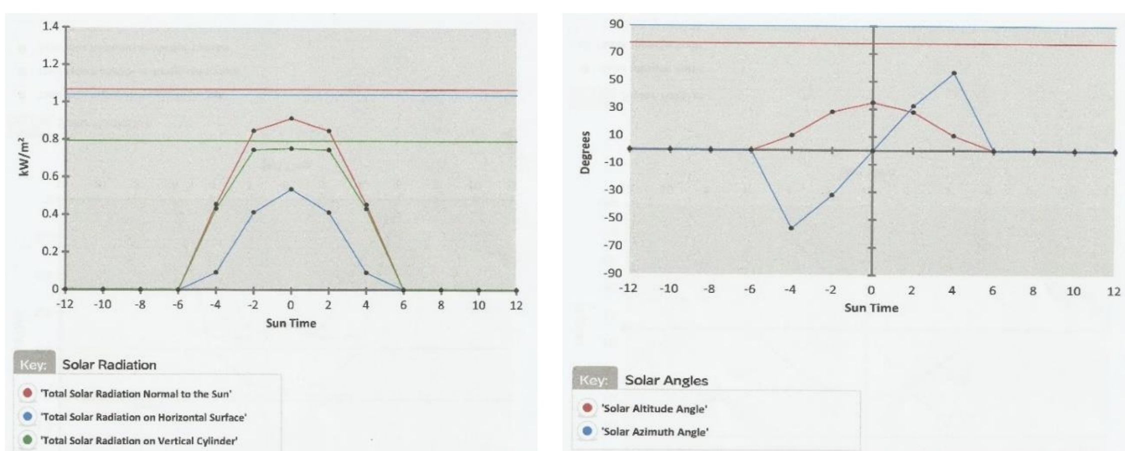


Figure 4.13. Solar radiation and solar angle in Kurdistan for November [Source: Solar radiation calculator version 1.0.7]

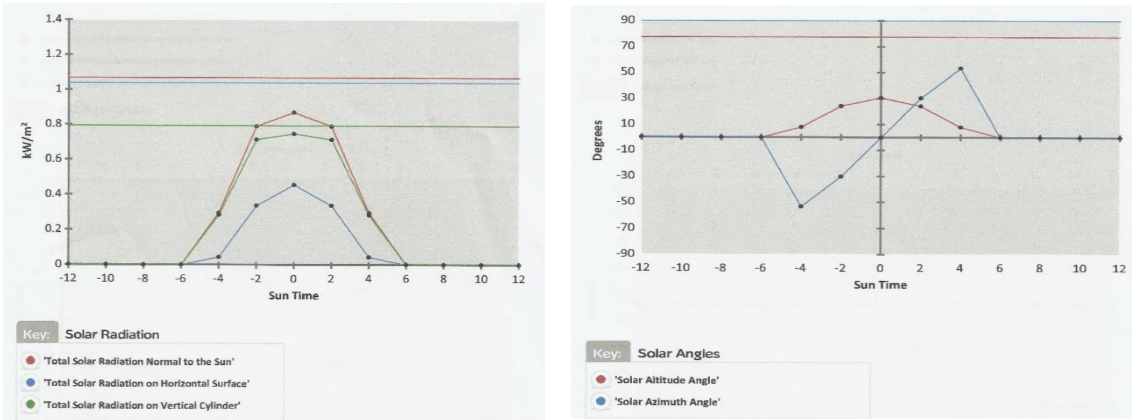


Figure 4.14. Solar radiation and solar angle in Kurdistan for December [Source: Solar radiation calculator version 1.0.7]

4-2 PV costs in Kurdistan

Several factors are effected on solar photovoltaic costs, same as capital cost, capacity factor and discount rate [3]

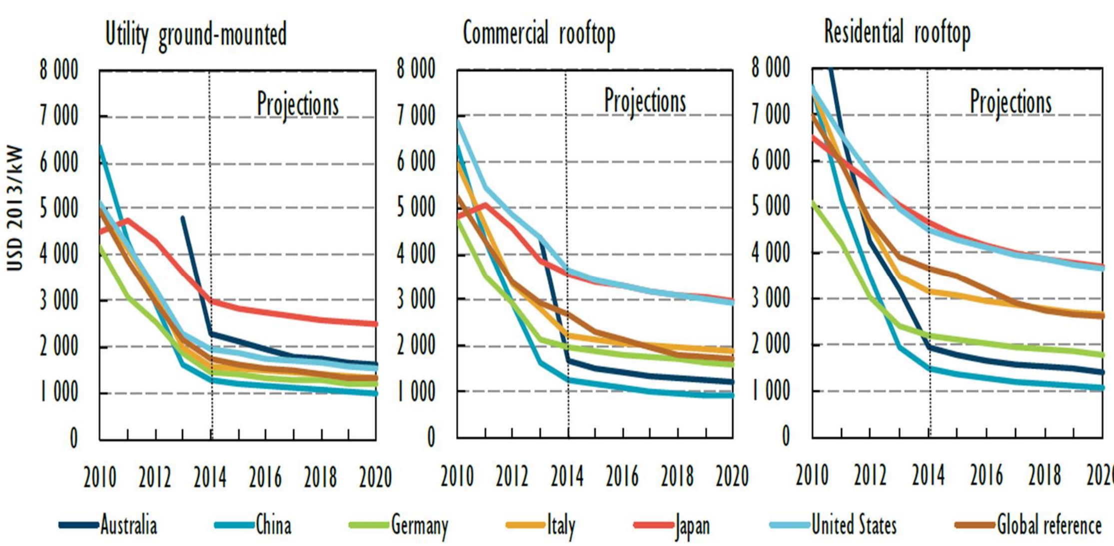


Figure 4.15. Overview of capital costs of PV applications [Source: IEA (2014)]

[3]: www.theenergycollective.com

In Kurdistan region, there is no clear capital costs for renewable energies as those energies are not developed yet. Kurdistan is free market for any new technology and the government give lot of facilities to investors in order to invest in the region especially in electric power generation. But still no any clear price for photovoltaic modules or packages in the region it means customers do not have clear scope to select the product with convenient price, and due to lack of knowledge and trust about the technology, the feasibility study of the PV technology is complicated. As price can see that the chines products have better price than European brands but also there is price deference in chines brands.

Table 4.2. Prices of solar PV systems in Kurdistan /Chines brand [Source: www.greensunniva .com]

Off Grid Solar System Capacity (Solar PV Packages include the PV modules, inverter and Batteries)	**Suppliers**		
	Yingi Solar (China)	**Ever exceed (China)**	**China Land (China)**
1,000 W	1,900 $	1,652 $	1,408 $
3,000 W	5,650 $	4,183 $	3,740 $
5,000 W	7,950 $	7,073 $	6,710 $
10,000 W	15,900 $	14,618 $	13,310 $
15,000 W	23,200 $	28,103 $	23,100 $
20,000 W	30,800 $	34,983 $	26,235 $

For example survey has been done to find the price for 3KWel package solar PV system with 8000 Watt-hours battery banks, uses for normal house include PV module, inverter and battery banks, the below prices found:

3 KW solar PV package with 8 Kwh battery backup with Inverter

- Solenergi (Denmark products) = 16,668 $
- Power men company / PMC (Spain Products) = 11,952 $
- Yingi Solar (China) = 5,650 $
- EverExceed (China) = 4,183 $
- China Land (China) = 3, 740 $

4-3 Government incentives

In 2006, the Kurdistan board of investment (KIB) was established. The Board of investment is responsible for creating investment opportunities in the region, providing a professional service to investors and working to rebuild Iraq through the Kurdistan region. According to the law No.4 of 2006 (investment law in Kurdistan region of Iraq) section 4 which is related to the allocation of the lands for investment project, the land for power plants such as solar PV parks will allocated by government means no any costs will consider for land [4].

Before recession happened in Iraq as well as Kurdistan, for any investment project (Solar PV power plants as example) which done in Kurdistan through Kurdistan investment board, addition to allocate the needed land, 60% of investment cost dedicated by government through KIB. The remaining 40% by investor. But now almost 100% of investment to be given by investor. Only land will allocate by government. Despite of all economic and political crisis in the region, Kurdistan regional government trying to initiate the studies about using renewable energy in the region particularly solar energy.

[4]: www.kurdistaninvestment.org/docs/InvestmentLaw.pdf

5- Utility- scale solar PV power plants in Kurdistan

5-1 Utility- scale solar PV power plants

Indeed as PV technology application, there are four applications for PV power systems; Grid-connected centralized PV or utility- scale PV power plants which is providing centralized power into the grid, off-grid domestic that is providing electric power to areas that are not connected to the grid, off-grid non-domestic ï use in some application such as telecommunication and grid-connected distributed PV which is Providing electricity to a speciýc customers that connected to the grid [World bank group (2015)].

In Kurdistan region about 90% of the electricity power generation is done by private sector, but still the transmission and distribution of electricity is under government responsibility. Therefore, can consider that the Kurdistan has a convenient environment for private investors to invest on electricity power generation sector and PV technology is consider as good opportunity. Thus, by considering above concepts, in this chapter the utility- scale PV power plants in Kurdistan has been studied.

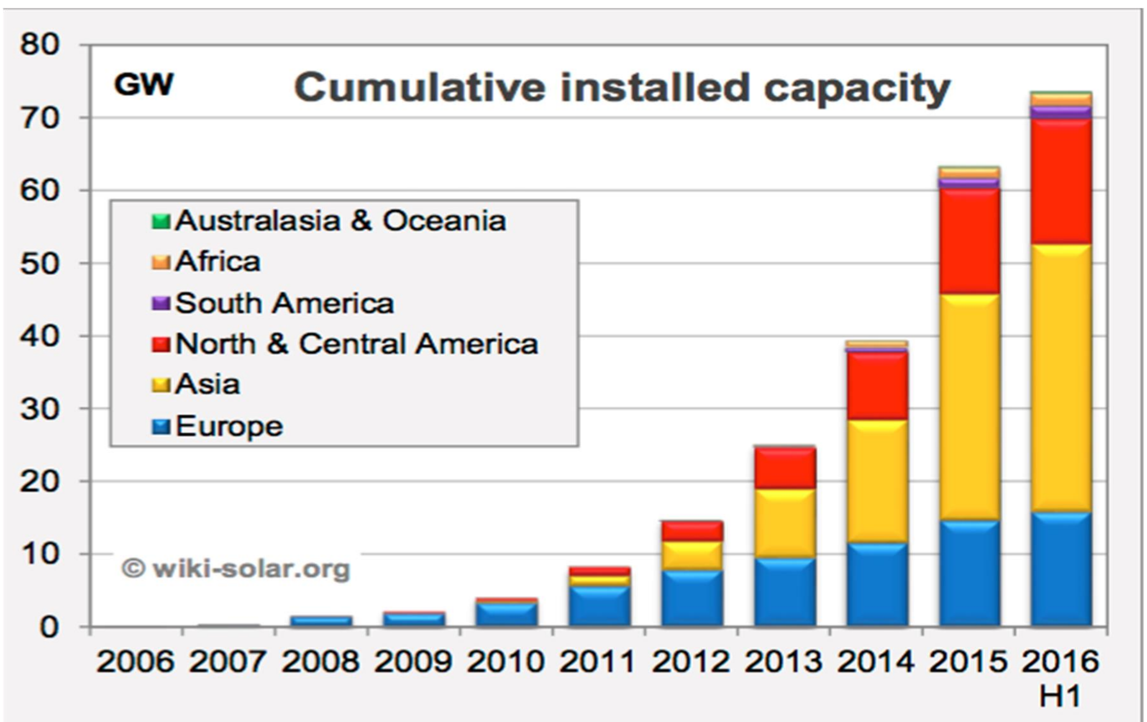


Figure 5.1. Cumulative utility scale solar installation by country 2016 [Source: www.solarreviews.com]

Utility ï scale solar PV power plant is consider a large-scale photovoltaic system which designed for producing electric power into the electricity grid, also known as solar park. In 1982, Arco Solar was build the 1st solar power plant (solar park) with capacity 1 Mega Watt at California. The most of existing solar parks are operated by private investors or independent power producers, and almost supported in part by regulatory incentives such as feed-in tariffs or tax credits [Arnett J.C et al. (1984).]. The USA, China, India, France, Canada, and Italy, have also become major markets. By introduction of feed-in tariffs in 2008, Spain with some 60 solar parks over 10 MW, became briefly the largest market [Wiki-solar (2013)]. In 2016, the solar photovoltaic cumulative installed capacity increased from some GW to more than 70 GW, and the big share is belonged to Asia.

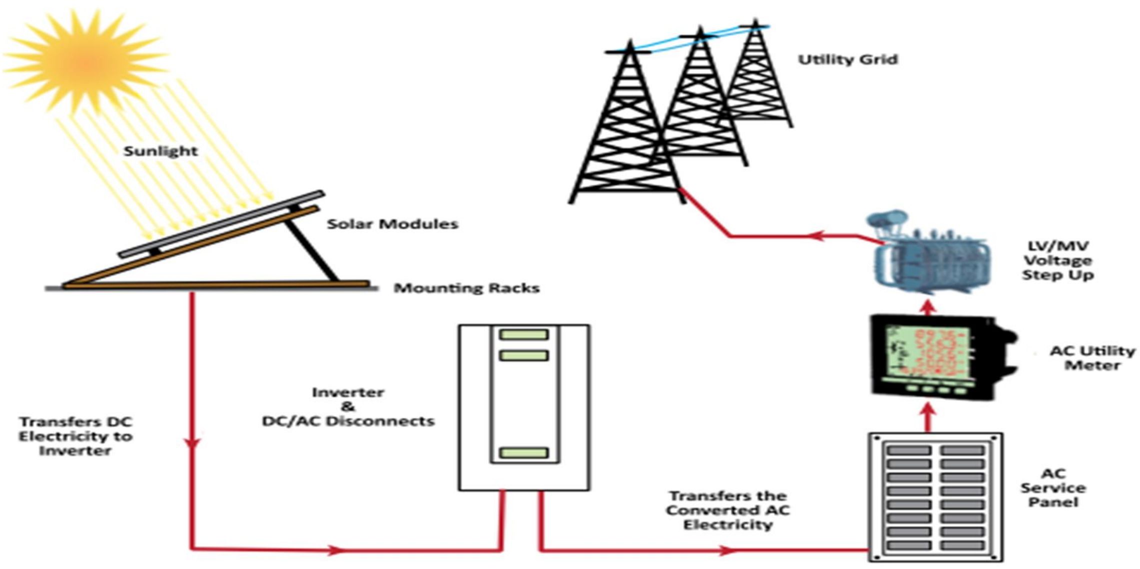


Figure 5.2. Overview of Solar PV Power Plant [Source: World Bank group (2015)]

5-2 Technical assessment of the utility- scale solar PV power plants in Kurdistan

For technical evaluation, the efficiency, performance ratio and capacity utilization factor are calculated. Solar cell efficiency which is the efficiency rating measures what percentage of sunlight hitting a panel gets turned into electricity that you can use.

The efficiencies of available commercially crystalline silicon solar cells is between 14 ï 20%, some standards use to compare the performance of crystalline cells. The standard IEC 61215 can be used for this purpose which uses standard temperature and conditions

(STC), namely cell temperature of 25 °C +/- 1K, an irradiance 1000W/m² and air mass of 1.5 [Fechner (2016)]

Some factors affect solar array efficiency including panel orientation, panel pitch, Temperature and shade. Indeed, shade is the important factor to reduce solar panel efficiency. With poor solar design, even a little shade on one panel can shut down energy production on all of other panels. The maximum efficiency of a PV panel can be calculated by bellow equation [Luque A. et al (2011)].

$$\eta_{max} = \frac{P_{max}}{E * A_{cell}} \quad \text{[Equation 4.1]}$$

According to the equation 4.1, for case 500 KW solar power plant, 12.5% efficiency the can be derived as efficiency.The same efficiency is calculated for the PV power plants from 1 MW to 50 MW. Nominal plant output (KWh) or the target yield (KWh) is the theoretical annual energy production, which is calculate as bellow:

Target yield = Solar radiation x Collector Area x PV Efficiency (%) [Equation 4.2]

Thus, the target yield of 500 KW PV power plant is 877,000 (KWh) by using solar radiation 1,754 (KWh/m²/a), module efficiency of 12.5 and collector area 4,000 (m²) for 500 KW installation. The performance ratio is the ratio between actual yield and the target yield which in case of high performance PV power plants it reach 80% this can be calculated by the following equation:

$$PR\ (\%) = \frac{\text{Actual Yield (KWh)}_{AC}}{\text{Target Yield (KWh)}_{DC}} \quad \text{[Equation 4.3]}$$

By assuming a PR of 80% in performance ration formula (Equation 4.3) the amount of actual energy output 701,600 (KWh) can be obtained for 500 KW photovoltaic power plants. The target yield and actual energy output of the PV power plants capacity range from 1MWel to 50 MW in Kurdistan is illustrated in below Figure.

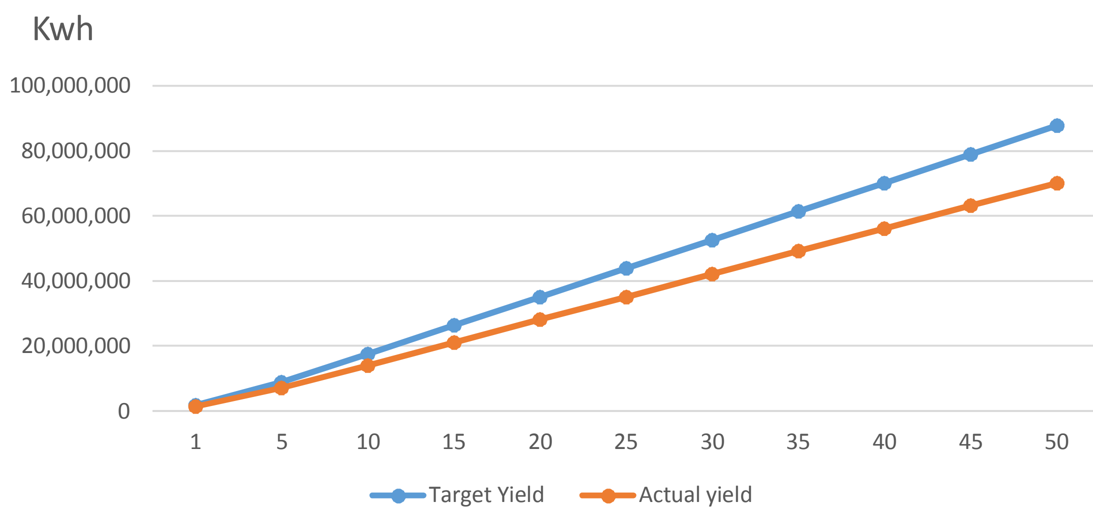


Figure 5.3. Target energy yield and actual energy yield for the PV power plants from 1MWel to 50 MW in Kurdistan [Source: Own graph]

The performance ratio or quality factor shows the proportion of the solar energy which is not converted into useable energy. The quality factor consider all pre-conversion losses, thermal losses, inverter losses and conduction losses.

The performance of a PV power plant which is uses in order to compare PV installation with other technologies is often denominated by a metric called the capacity utilization factor (C.U.F). [Ashish V. et al (2015)].

$$\text{C.U.F (\%)} = \frac{\text{Actual Plant Yield (KWh)}}{\text{Installed Capacity (KW)} \times 8760 \text{ hours}} \qquad \text{[Equation 4.4]}$$

Two key parameters which are solar radiation received and the number of clear sunny days experienced by the PV power plant location are the factors affect the energy generation of a plant and capacity utilization factor as well. Capacity utilization factor amount for 500KWel plant can be calculated by using equation 4.4, and for case 500 KW as example, 16% can be determined as capacity utilization factor. The same capacity factor amount is calculated for the PV power plants from 1 MW to 50 MW.

5-3 Costs and economic assessment of the utility- scale solar PV power plants in Kurdistan

In order to assessment the economic feasibility of the power plants, dynamic investment valuation in conducted by using the net present value calculation.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$ [Equation 4.5]

$$CRF = \frac{r \cdot (1+r)^T}{(1+r)^T - 1}$$ [Equation 4.6]

$$\alpha = NPV \cdot \frac{r \cdot (1+r)^T}{(1+r)^T - 1}$$ [Equation 4.7]

NPV	Net Present Value [ú]	CRF	Capital recovery Factor
T	Investment Horizon [Year]	Ŭ	Annuity
t	Year Count	r	Discount rate
Ct	Cash flow in year t [ú]	C0	initial cost [ú]

For PV power plant projects, how much electricity does the system generate and how well does the system perform are two fundamental questions for investors and operators. Electricity generation of PV power plants is dependent of some factors which are: amount of local solar irradiation, type of PV panels, orientation and inclination of the PV panels, shading, installed inverter, system ventilation and losses of cables. Due to a photovoltaic panels boom in the last years the cost of PV panels have decreased and is expected decrease more due to increasing experience in this field [Fechner (2016)].

The average cost of grid connected PV packages < 1000 KW is 2.55 ú/W installation, 2 ú/W for grid connected PV plants between 1MWel to 5 MW, and 1.8 ú/W for grid connected PV plants > 5MW.The packages include solar panels, batteries, charge controller, inverter and other accessories (for > 5MW plant exclude High voltage substation and transmission line if required) [Power Men company 2017]. Type of panels are poly-crystalline silicon as they are cheaper than mono-crystalline silicon panels 20 years is assumed as investment horizon as the supplier of PV packages guarantee a solar panels performance for this period of time. For operation and maintenance costs assumed 0.50% of investment cost. The price of electricity sale or revenue per KWh is assumed 0.03 ú / KWh.

Table 5.1. Overview of the economic data for the 500 KW to 50 MW PV plants in Kurdistan Region [Source: Own calculated data]

Investment horizon		20 Years	
Discount Rate (Estimated)		2%	
Solar Irradiation / year		1,754 KWh/m²/year	
Electricity Sale per KWh		0.03 ú / KWh	
Electricity Sale Escalation		2%	
PV Power Plant	**Investment Costs**	**Actual energy yield**	**O & M costs / year**
500 KW	1,275,000 ú	701,600 Kwh	6,375 ú
600 KW	1,530,000 ú	841,920 Kwh	7,650 ú
700 KW	1,785,000 ú	982,240 Kwh	8,925 ú
800 KW	2,040,000 ú	1,122,560 Kwh	10,200 ú
900 KW	2,295,000 ú	1,262,880 Kwh	11,475 ú
1 MW	2,040,000 ú	1,403,200 Kwh	10,200 ú
2 MW	4,080,000 ú	2,806,400 Kwh	20,400 ú
3 MW	6,120,000 ú	4,209,600 Kwh	30,600 ú
4 MW	8,160,000 ú	5,612,800 Kwh	40,800 ú
5 MW	8,925,000 ú	7,016,000 Kwh	44,625 ú
10 MW	17,820,000 ú	14,032,000 Kwh	89,250 ú
15 MW	26,775,000 ú	21,048,000 Kwh	133,875 ú
20 MW	35,700,000 ú	28,064,000 Kwh	178,500 ú
25 MW	44,200,000 ú	35,080,000 Kwh	223,125 ú
30 MW	53,550,000 ú	42,096,000 Kwh	267,750 ú
35 MW	62,475,000 ú	49,112,000 Kwh	312,375 ú
40 MW	71,400,000 ú	56,128,000 Kwh	357,000 ú
45 MW	80,325,000 ú	63,144,000 Kwh	401,200 ú
50 MW	89,250,000 ú	701,60,000 Kwh	446,250 ú

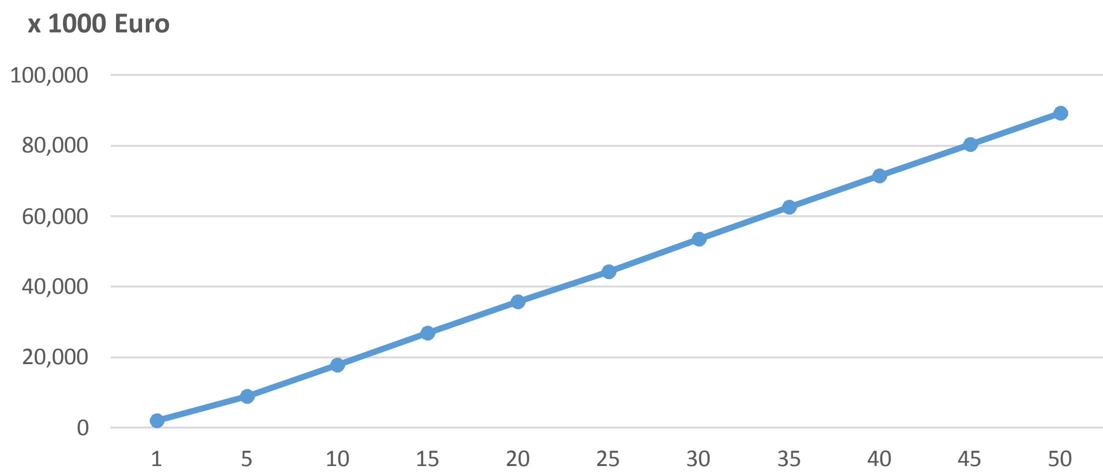


Figure 5.4. Investment Cost (Euro) for the PV power plants from 1 MW to 50 MW in Kurdistan [Source: Own graph]

Table 5.2. Overview of the economic appraisal for the 500 KW to 50 MW PV Power Plants [Source: Own calculated data]

PV Power Plant	NPV	Annuity
500 KW	-€ 329,240.39	-€ 20,135
600 KW	-€ 395,088.47	-€ 24,162
700 KW	-€ 433,936.54	-€ 26,538
800 KW	-€ 526,784.62	-€ 32,216
900 KW	-€ 592,632.70	-€ 36,243
1 MW	-€ 106,784.62	-€ 6,531
2 MW	-€ 213,569.24	-€ 13,061
3 MW	-€ 320,353.86	-€ 19,592
4 MW	-€ 427,138.48	-€ 26,122
5 MW	€ 845,317.29	€ 51,697
10 MW	€ 1,720,634.57	€ 105,228
15 MW	€ 2,535,951.86	€ 155,090
20 MW	€ 3,381,269.15	€ 206,787
25 MW	€ 4,651,586.43	€ 284,476
30 MW	€ 5,071,903.72	€ 310,181
35 MW	€ 5,917,221.01	€ 361,878
40 MW	€ 6,762,538.30	€ 413,575
45 MW	€ 7,614,804.94	€ 465,696
50 MW	€ 8,453,172.87	€ 516,968

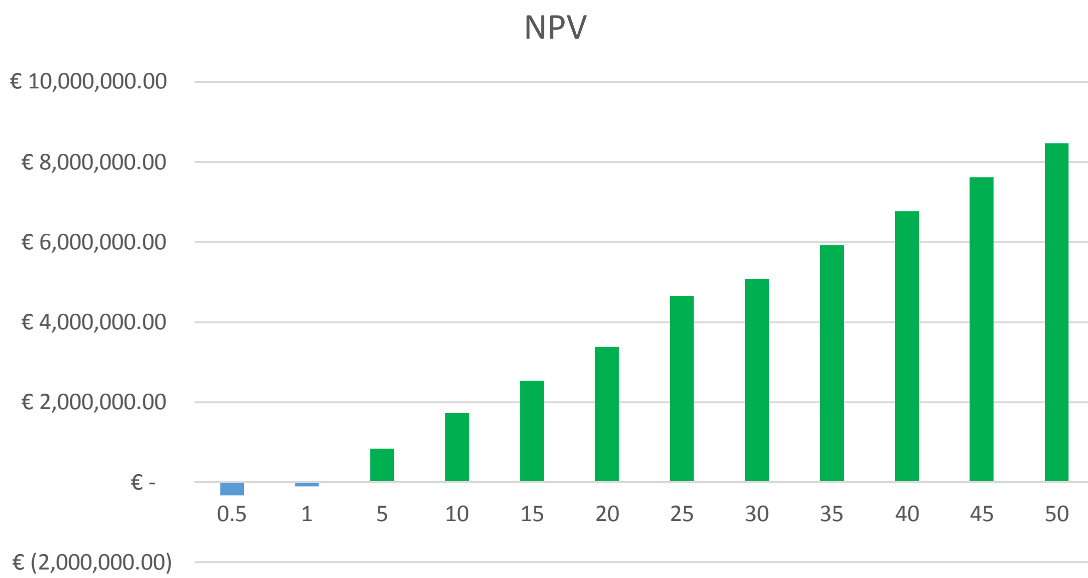


Figure 5.5. Net Present Value chart for utility scale PV power plants in Kurdistan 500 KW to 50 MW [Source: own calculated data]

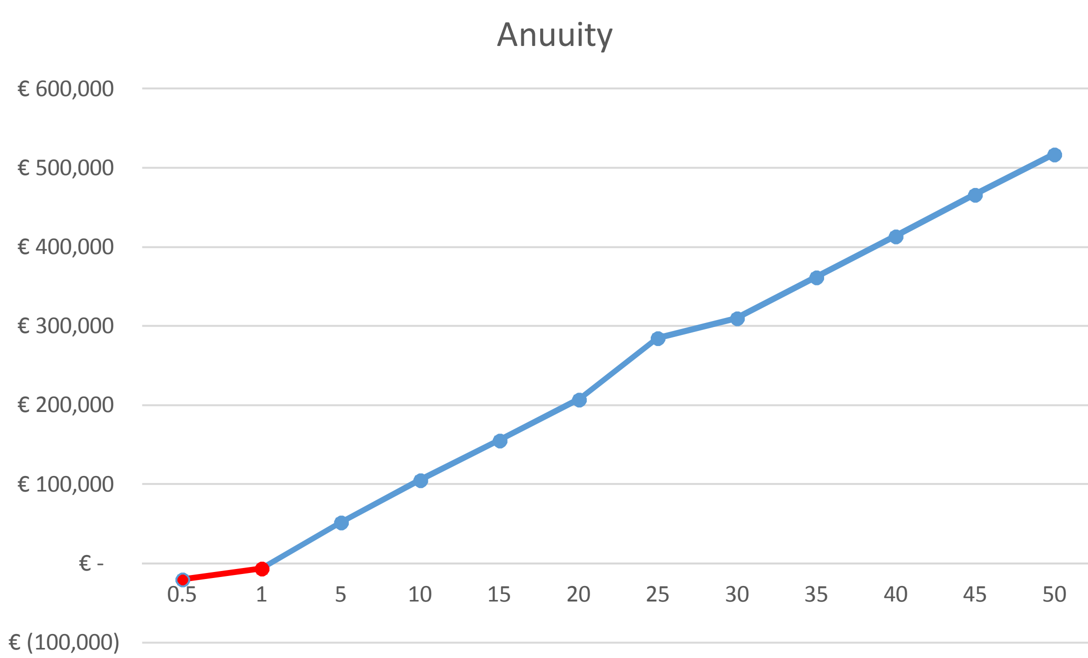


Figure 5.6. Net Present Value chart for utility scale PV power plants in Kurdistan 500 KW to 50 MW [Source: own graph]

6- Photovoltaic Marketing Situation in Kurdistan

In this section, global photovoltaic market trends and current PV market situation has been studied with SOWT analysis and all possible strategies in order to emphasize the PV market in Kurdistan. Also a questioner is submitted to the participants with the sample 150 to get information about Kurdistan people awareness on PV systems.

6-1 Overview of global PV market

As global PV market trends, China, United States, India and Japan are considered as the worldô four largest PV markets, they represent nearly three quarters of global PV demand in 2017. There is strong growth of solar installation in many emerging countries but solar demand still depending on a handful of countries. In 2017, PV demand growth is expected to slow, as a result, 16 percent drop from 2016 [IHS Market (2017)].

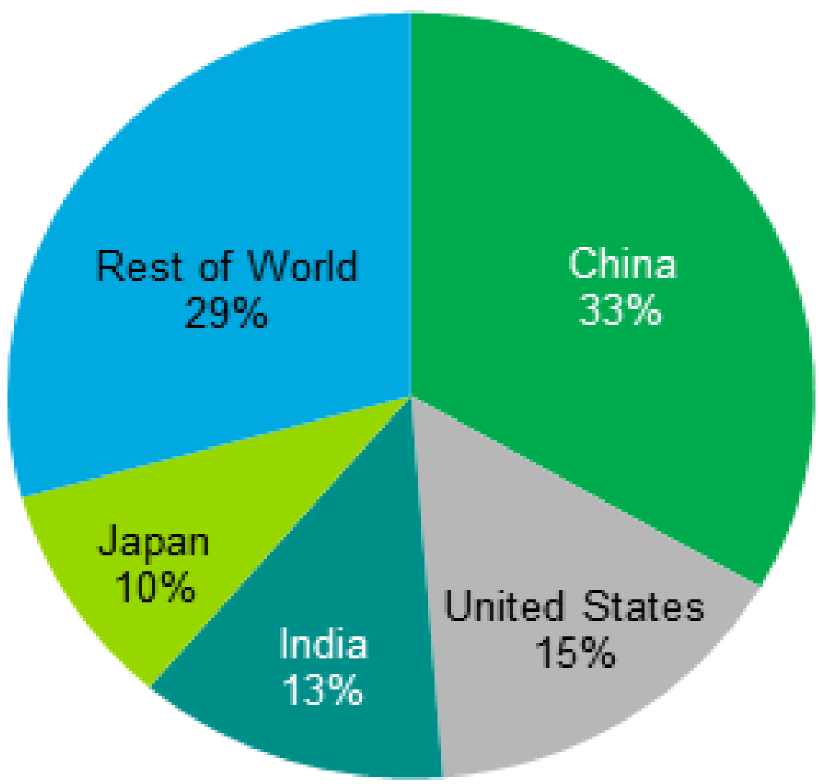


Figure 6.1. Global PV installation in 2017- %of MW [Source: IHS market (2017)]

PV module manufacturers have considerably reduced the number of capacity expansion due to the photovoltaic demand growth is expected to slow. Crystalline-silicon PV module manufacturing capacity grew 21% in 2015 and 17% in 2016, but is forecast to expand only 5% in 2017 [IHS Market (2017)]

Concerning USA, despite of 97% growth in 2016, demand will contract by over 10%. China, similar 30+ GW expectation in 2017 demonstrate the industryǒs dependence on chinaǒs opaque policy- driven demand. For Japan, policy transition toward auction results in 25-30 GW of approved projects being canceled, though 8 GW still likely in 2017. Concerning India, a nearly 30 GW tender pipeline and rapidly declining costs will spur doubling of 2016 demand this year [Attia B. (2017)]

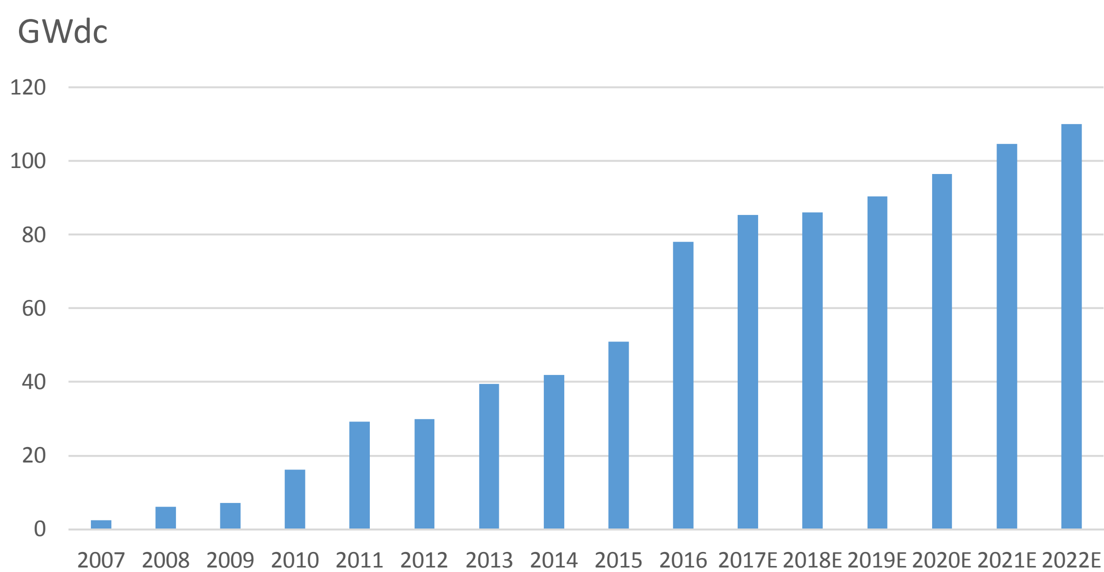


Figure 6.2. Major shift expected in the global solar market in 2017 [Source: GTM research global solar demand monitor (Q1 2017)]

6-2 Current PV Market in Kurdistan

SWOT analysis

As important item in this study, SWOT analysis has been done which consist analysis the strengths, weaknesses, opportunities, and threats of PV technology in Kurdistan market. It is obvious that Kurdistan region PV market is not comparable with Europe market even with neighbor countries but can optimistically consider as good opportunity in not far future.

As strength, Kurdistan is in sunny belt which is an optimal region for PV installation as it located 36 degree latitude and 44 degree longitude. Annual solar irradiation for Kurdistan is: 1,754 Kwh/m²/year which is very good potential. Max Solar irradiation is in July (226.9 Kwh/m²/month) and Min solar irradiation is in December (67 Kwh/m²/month). As already mentioned In comparison with other parts of Iraq (central and south region of Iraq), Kurdistan region is more developed because of relative peace in the Kurdistan region. Also by increasing energy demands in the region, RE technologies particularly PV systems can be sue as alternative energy.

As Weakness, many factors can be considered such as low educational and technical knowledge levels, high PV costs, unpopular technology, lack of FIT (Feed ï In-Tariff) in the region, no subsidies, lack of research and development studies, region consider as unskillful and immature market for PV technology such as other renewable energies, and the dust.

As Opportunity, Kurdistan is free market for any new technology particularly in energy sector and government give more facilities to the investors especially in electricity generation. The Board of Investment is responsible for creating investment opportunities in the region, providing a professional service to investors and working to rebuild Iraq through the Kurdistan region. According to the law No.4 of 2006 (investment law in Kurdistan region of Iraq) section 4 which is related to the allocation of the lands for investment project, the land for power plants (PV solar parks) will allocated by government means no any costs will consider for land.

As Threats, low price of traditional energy source which called in the region commercial power, Kurdistan region has abundant hydrocarbon supplies, Because of that mostly electricity generate with natural gas therefore there is not substantial room for renewable energy sources such as PV system due to that less interest from government towards solar PV systems. Low Kurdistan people awareness and capability to invest on this sector. Recent region economic and political crisis also can be considered as threats for this technology.

Strengths

- Kurdistan Located in sunny belt.
- Annual solar irradiation for Kurdistan is: 1,754 Kwh/m²/year.
- Availability of land accoridng to Investment law No.4 of 2006
- Average day time 12 h/day

Weakness

- Lack of Feed-In-Tarif .
- Lack of reaserch and development studies.
- Dust
- High capital costs of PV
- Low technical knowldge and educational level.
- Unskillful PV market (Immature PV market)

Opportunities

- Kurdistan is free market for any investment.
- Kurdistan investment board facilities for power geeneration investors include PV technology.
- PV application in many fields and sectors such as resedintial , agriculture, etc.

Threats

- Low price of elelctricty in the region.
- Region is depending on fusel fules for power generation.
- Less interest from government towards solar PV systems.
- Low kurdisatn people knowldge and awearness about PV technology

Kurdistan People awareness of PV technology

In order to gather information about kurdistan people knowldge on photovoltaic technology and itôs applications, a sample questionnaire has been prepared. 150 perople participated in this questinnare.

As participates age, they are segmented accoridng to four group with following results; 14% are 16-25 years, 50% are 26-36 years, 15% are 36-45 years, and 21% more than 45 years.

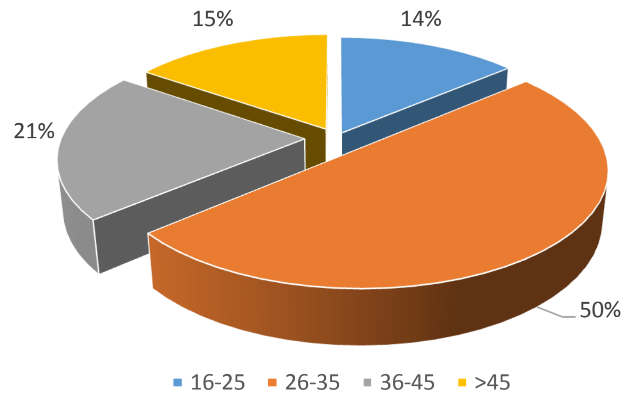


Figure 6.3. Participantôs age [Source: Own graph]

As educational level or background the participants are segmented to 7 groups as below and following results; about 58% of participants have BSc educational background.

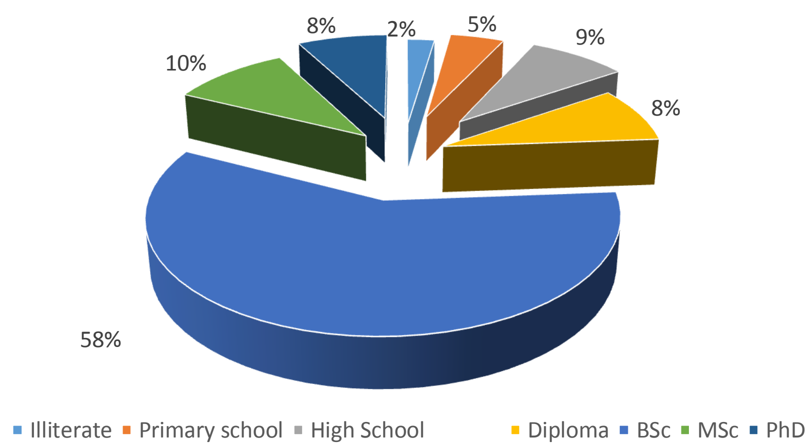


Figure 6.4. Participantôs education level [Source: Own graph]

As occupation, four groups are participated as below, more than 66% are work in private sector, 16% work in public or government sector, 11% are self- employment and 7% are unemployed.

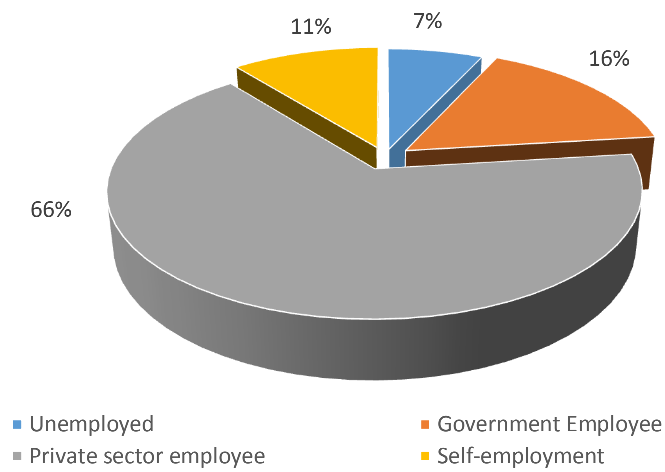


Figure 6.5. Participantôs occupation [Source: Own graph]

For monthly incomes participants are segmented in 6 group from less than 500,000 IQD (less than 400 $) to more than 4,000,000 (3,200 $) per month. The results are shown in below chart.

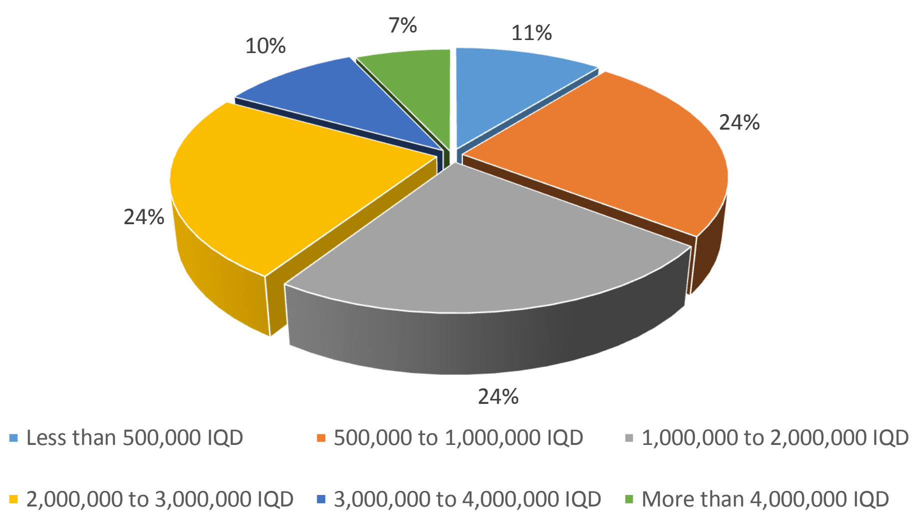


Figure 6.6. Participantôs monthly income [Source: Own graph]

Questions:

Q1. Did you know that sunlight can convert directly to the electricity energy?

This question was asked to participants to test whether they have knowledge about converting directly sunlight into electricity technology. The results shows that 79% of participants have information about this process.

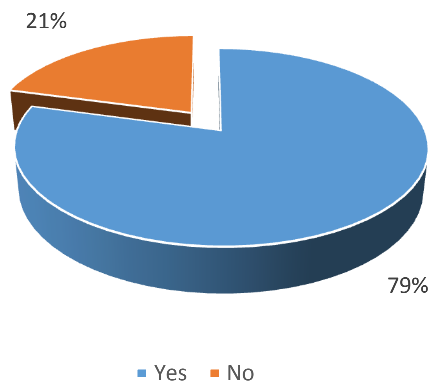


Figure 6.7. Result of participantôs answer for Q1 [Source: Own graph]

Q2. Have you heard about 'Photovoltaic '?

This question was asked to participants to test whether they have heard about ôPhotovoltaicô The results shows that 65% of participants have heard about ôPhotovoltaicô

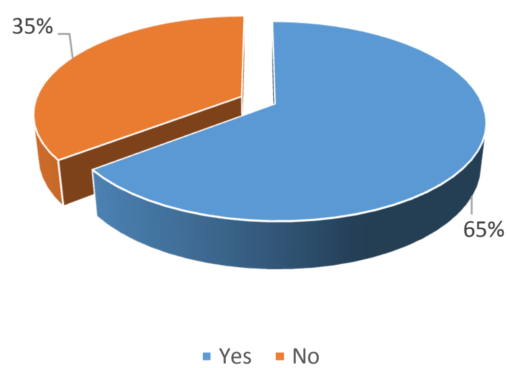


Figure 6.8. Result of participantôs answer for Q2 [Source: Own graph]

Q3. Did you know that you can install PV system in your own house in order to produce electricity?

This question was asked to participants to test whether they have knowledge about possibility to use or apply PV system in residential application or the houses to produce electricity. The results shows that 57% of participants have known that.

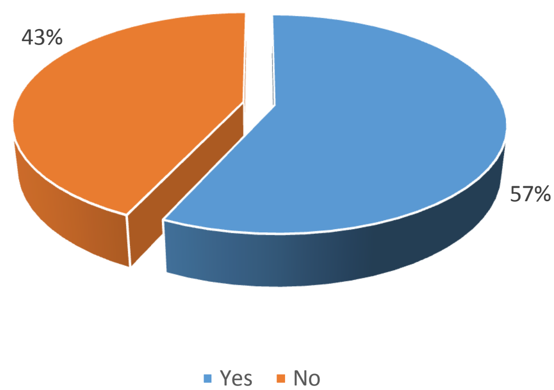


Figure 6.9. Result of participantõs answer for Q3 [Source: Own graph]

Q4. Have you thought about installing PV system in your own house?

This question was asked to participants to test whether they have or had plan to install PV system in them own house in order to produce electricity from the PV modules. The results shows that 46% of participants have or had plan to install PV system in them own house.

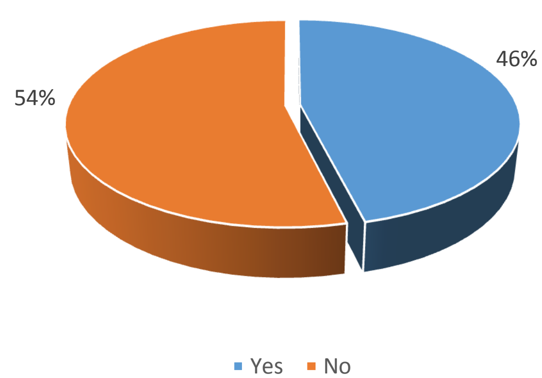


Figure 6.10. Result of participantõs answer for Q4 [Source: Own graph]

Q5. Did you know that using PV system in your place is feasible economically?

This question was asked to participants to test whether they have knowledge about economic benefits and payback investment cost of PV system. The results shows that 55% of participants have knowledge about that.

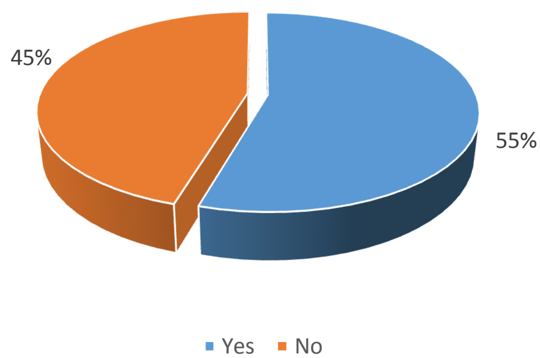


Figure 6.11. Result of participantơs answer for Q5 [Source: Own graph]

Q6. Did you aware about positive environmental impacts of PV system?

This question was asked to participants to test whether they have knowledge about ecological positive impacts of PV system as clean energy. The results shows that 65% of participants have knowledge about that.

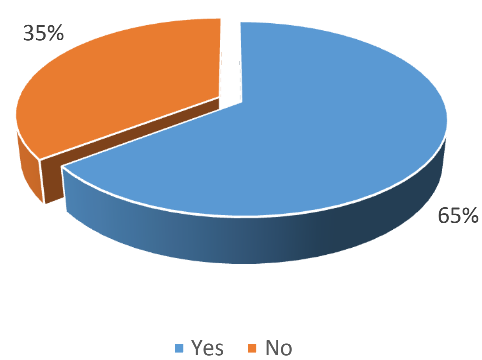


Figure 6.12. Result of participantơs answer for Q6 [Source: Own graph]

Q7. Knowing the ecological and economic benefits of PV system and if you have budget, are you interest to use PV system for produce electricity in your place?

This question was asked to participants to test whether they are interest to use PV systems for electricity produce in them place if they have budget and have clear information about ecologically and economic benefits of PV system. The results shows that 73% of participants are interested.

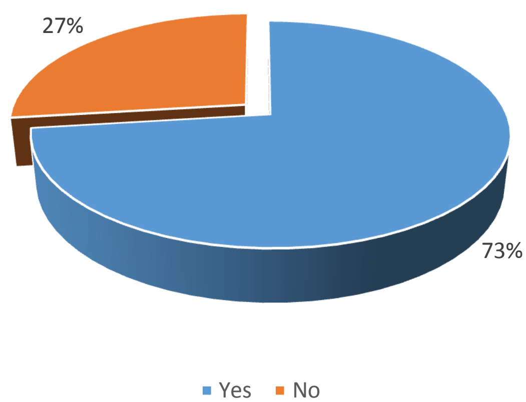


Figure 6.13. Result of participantš answer for Q7 [Source: Own graph]

6-3 Factors to develop PV Marketing in the Kurdistan region

Indeed solar technologies is not simple thus, in order to have more solar PV installations, solar programs need to address the key barriers to its market growth. In general, there are four primary barriers to solar PV market growth, and all four must be addressed to enlarge the market; PV Costs and long payback period, reliability of solar technology, time consuming and complex purchasing and installing solar energy systems. By learning from past years researches in the area of PV systems, the Consumers already understand the environmental benefits of solar technology, but it is not enough to spread market assumption. In order to understand consumer orientation and develop programs, it is essential to create a reputation about the product, Demonstrate and stand by the quality of the product, create pricing which convenient for public, make it as easy to make the purchase, and let the public know the offers. Actually the essential factors for an effective marketing plan are; Identify market barriers, detail marketing plans to address each barrier, and suggest the action steps to implement a successful marketing plan. Understanding what consumers believe both logically and emotionally about solar technology will help the direction of a solar marketing plan [Clean Energy group and Smart Power (2009)].

Investment cost or capital cost of PV systems is consider as the biggest barrier to purchasing solar products, therefore the value equation which is the relationship between the consumerõs outlook of the productõs benefits to the costs of solar systems need to improve in way to putting financing programs in place to overcome the high cost of solar PV systems and also must ensure that consumers are aware of those financial offerings. Another barrier to PV market growth is reliability of the PV technology, therefore augment the reliability of solar technology is needed by ensuring that solar is as visible as possible in the markets and is introduced as a strong source of energy, which can build a powerful economy. By the way must of people do not consider solar PV technology as an authentic source of energy for them house. Another factor which need to take in consideration is reducing the complexity of solar PV systems, as solar technology is not viewed easy for consumers to purchase and install also solar technology consider as intricate product and need a long decision-making process then requires research, financing, authorizing,. Motivation the customer is another factor which need to be aware about that.

7- PV application Case studies (Kurdistan)

In this chapter, in order to understand well the real situations of using PV technology in deferent applications such as off-grid connected PV system and On-grid connected PV system, two cases have been studied and the results are highlighted. For case Off-grid non-domestic, KOREK telecom has been selected as one of country mobile operator, has been selected, and for the Grid-connected distributed PV, a normal house in Erbil city has been selected. As the ecological effects are not considered in the region thus, only the technical and economical aspect are considered and studied in this section.

7-1- Case 1 (Off-grid non-domestic): PV application in Telecom sector (GSM Site) in Kurdistan – Technical and economic assessment

KOREK Telecom is the fastest growing mobile operator in Iraq. KOREK network covers the entire country. KOREK Telecom is a shared limited company registered in Iraq to operate and provide GSM services. KOREK started operating in Iraq in year 2000, notably in the north of Iraq (Kurdistan region) and it is the oldest Iraqi Telecom company. Since 2007 KOREK telecom have been expanding at a phenomenal rate, increasing the reach of them network and enhancing the quality of cutting-edge services. As the fastest growing mobile operator in Iraq they now service approximately 7 million customers. KOREK manages to do that by partnering with the worldǿs best telecom technology providers like GSM Telecom, and with the cooperation of well-known international companies including Ericsson, Nokia and Siemens amongst others.

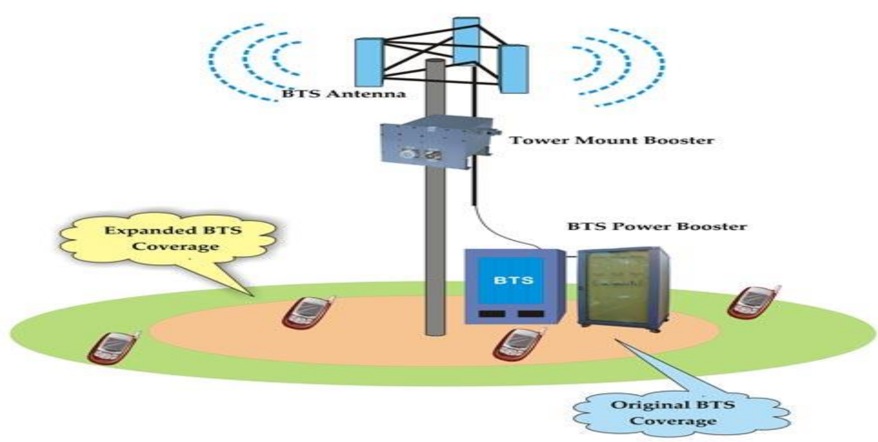


Figure 7.1. Topical GSM site [Source: ww.geeknizer.com]

Highlights

Currently **3,211** sites are under operation in KOREK network. KOREK network has been divided to 7 region as below:

- Erbil (Erbil + Soran)
- Dohuk (Dohuk + Akre)
- Sulymany
- Kirkuk
- Mosel (Musel + Shengal)
- CI&CII (Baghdad + Karbala + Babil + Najaf + Diyala + Salahaddin + Qadeseya + Mothana)
- South (Basra + Missan + Thi- Qar + Wasit)

Table 7.1. KOREK Telecom under operation sites details [Source: KOREK Telecom; Power department (2017)]

Region	Indoor Sites	Outdoor Sites	Total Sites
Sulyamani	167	236	403
Kirkuk	89	84	173
Musel	100	70	170
CI&CII	375	757	1,132
South	60	366	426
Erbil	190	396	589
Dohuk	102	216	318

Thus, from totally 3,211 sites under operation in KOREK telecom, 1,083 are indoor type which mean have higher power consumption because using cooling system in the site, and 2,128 outdoor sites with lower power consumption compare other type.

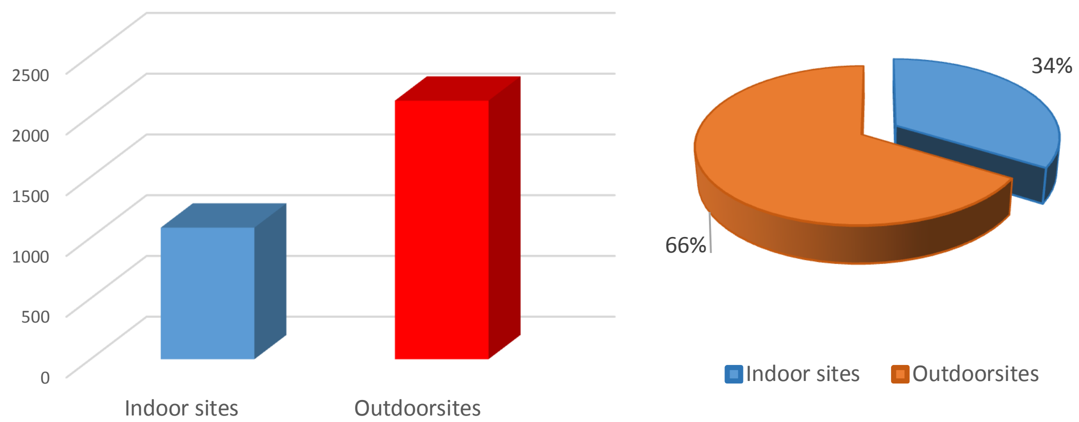


Figure 7.2. Type of Sites under operation in KOREK telecom [Source: KOREK Telecom; Power department (2017)]

Generators which used in KOREK network are 11KVA to 15 KVA capacity for the Outdoor type and 20 KVA to 33 KVA for indoor sites. As already explained due to higher power consumption in indoor site need to use bigger capacity in those sites. 3,955 generators are operating currently in the network from this amount 1,481 are in capacity range 11 KVA to 15 KVA and 2,474 generators are within 20 KVA to 33 KVA capacity.

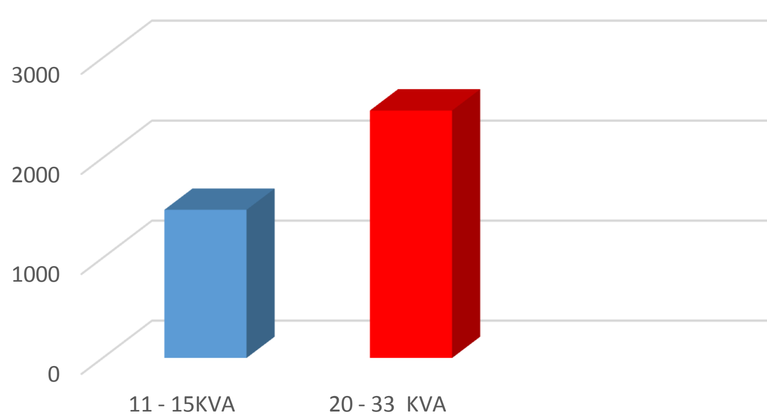


Figure 7.3. Generators use in KOREK telecom network [Source: KOREK Telecom; Power department (2017)]

74% of the sites, 2,378 sites are connected to the grid, it means they have two power sources (commercial power + Diesel generators). 830 sites are not connected to the grid yet. From this amount 494 sites are outdoor sites which are not connected to the commercial power and they are best option to use photovoltaic system in order to reduce the huge operational cost of the sites.

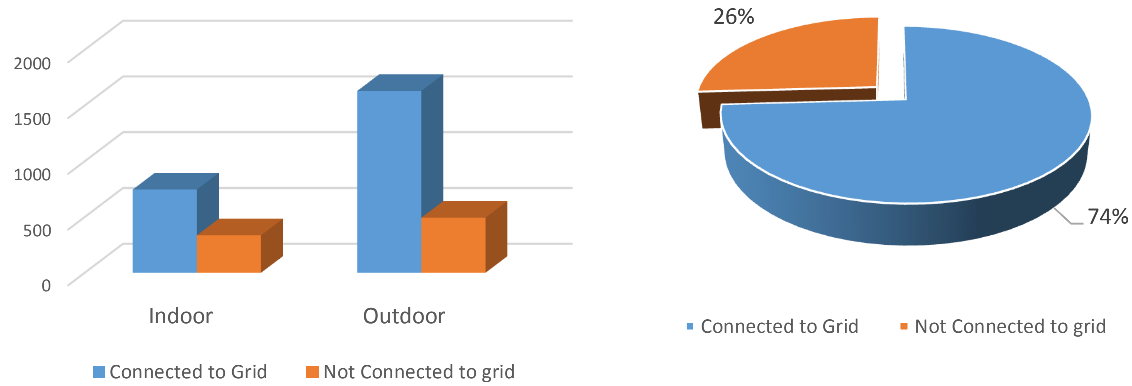


Figure 7.4. Connection sites to the Grid status in KOREK telecom network [Source: KOREK Telecom; Power department (2017)]

Case study

There is four category of sites under operation in KOREK network in terms connection to the grid and RBS type as below:

- Indoor site without commercial power
- Indoor site With commercial power
- Outdoor site with commercial power
- Outdoor site without commercial power

In this case study the most possible and feasible case is investigated which is the outdoor site without commercial power it called off-grid outdoor site. The number of sites in this category are around 500 sites. The aim of selecting this category are the low power consumption of the site compare with other category and the non-availability of the grid power on the site which mean working 24/7 generators on the site and due to high price of the fuel and hard access to the sites for fuel transportation.
The site has been selected for this case study is located in Erbil government in Kurdistan region with below details:

Site Name: Taweska

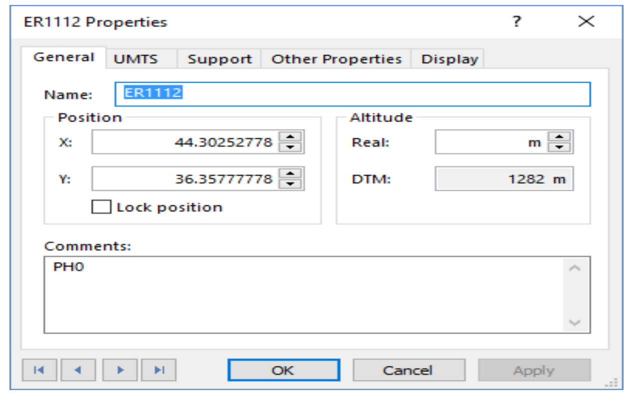
Site code: ER 1112

Site location: Erbil Government

Site Type: Outdoor Greenfield

RBS model: Ericsson 6102/ 48VDC

Connection to the Grid: NO (Off-Grid)



Sites contain of three main part which are power sources, power distribution and load, the main load of the site is the telecom equipment RBS (Radio base station). Site powered by two generators as main power source of the site and as distribution part it consist of automatic transfer switch and distribution board.

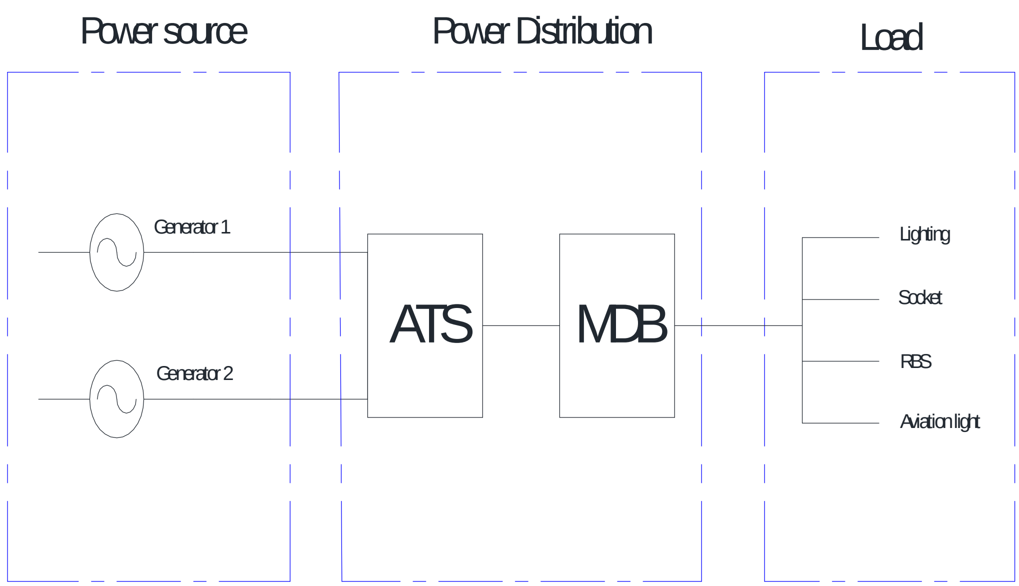


Figure 7.5. Site diagram -Outdoor off-grid site [Source: Own diagram]

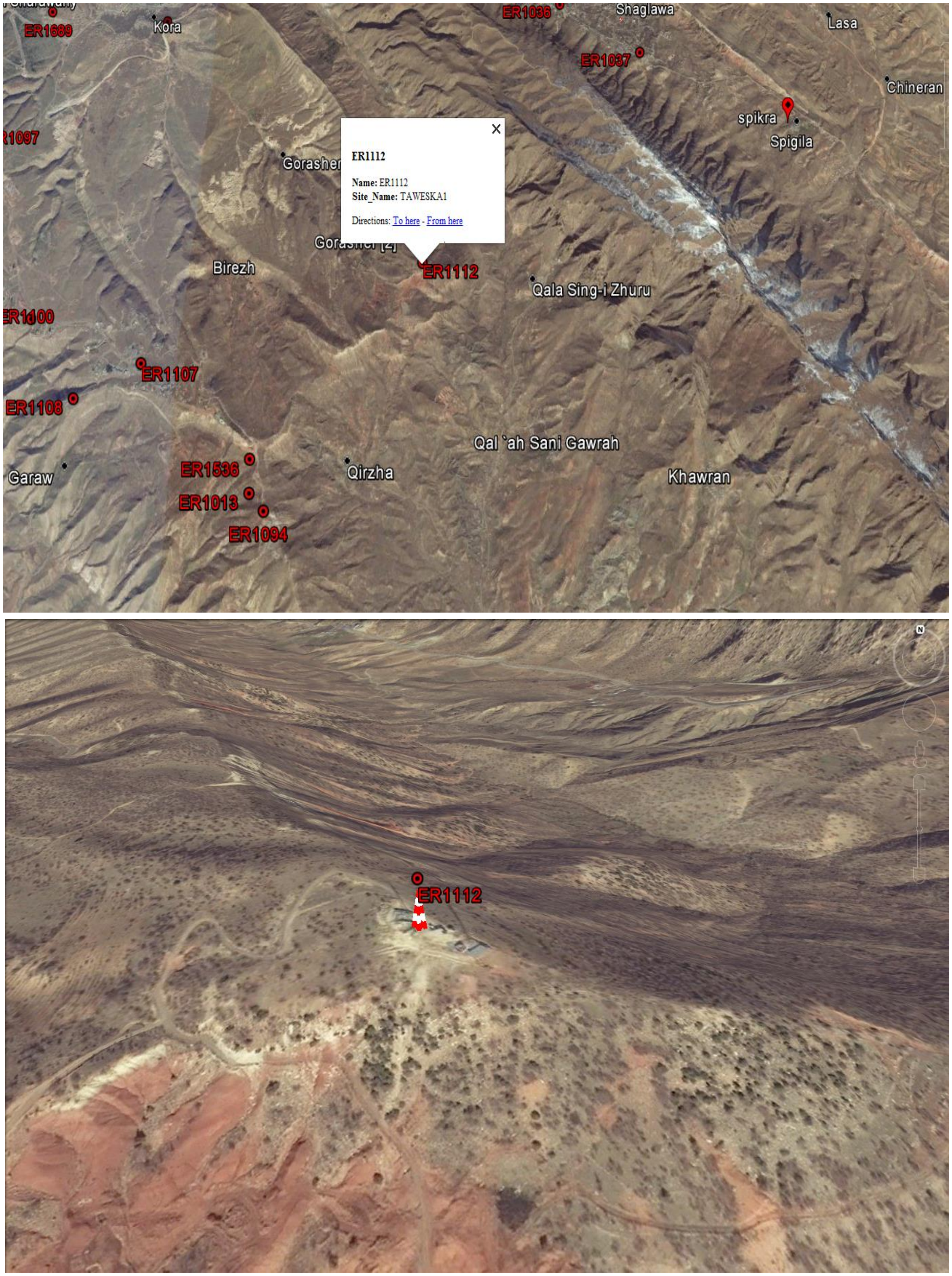


Figure 7.6. Tawska Site on the map [Source: KOREK telecom; Radio network planning department (2017)]

The total site power consumption for all electrical equipment is 1,500 Watt. It consist of the 6102 outdoor telecom Radio base station device with sample lighting on the site.

Power Operational costs of the site

In order to calculate the operational cost of the site, need to use the investigations and site background documents which prepared by the KOREK power department. As the site work with 2 generators as main power supply that working 24/7, Fuel consumption of the site can consider as the main operational cost of the site. The real fuel consumption illustrate in below chart. In our case for 24 hours working generator, the fuel consumption is 28.8 Lit/day or per 24 hours.

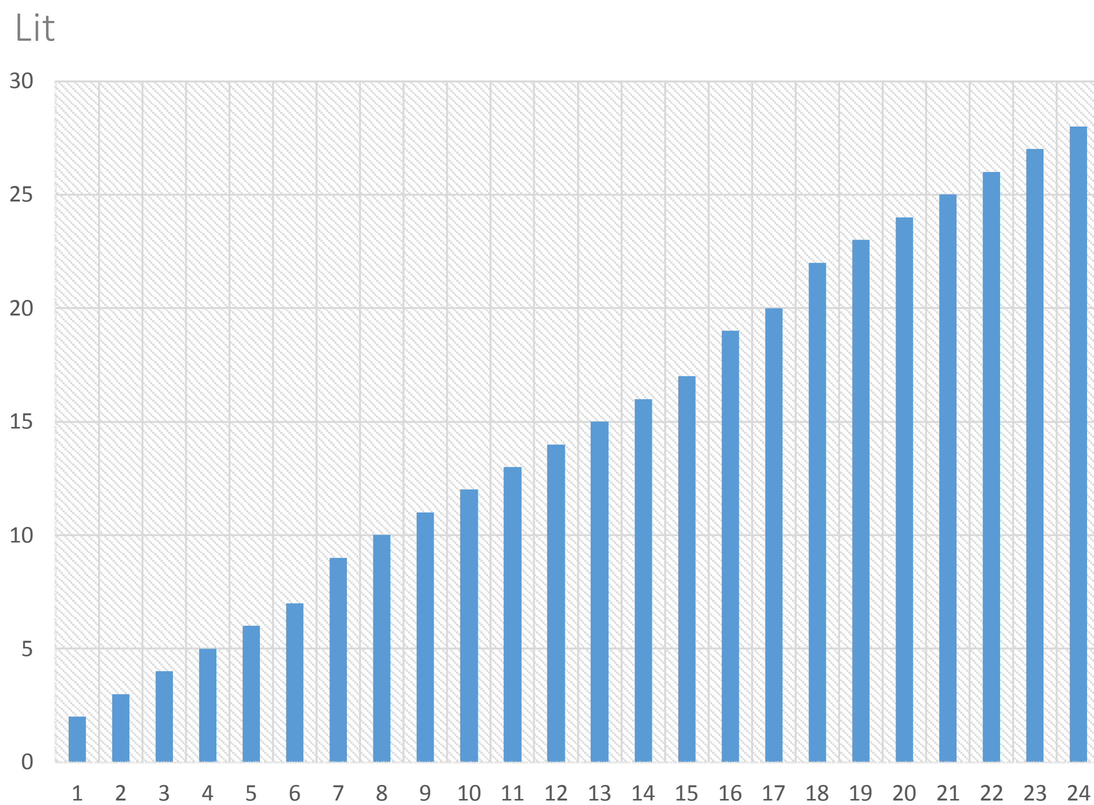


Figure 7.7. 11 ï 15 KVA generator fuel consumption per 24 hours [Source: KOREK Telecom; Power department (2017)]

Two deferent maintenance process is implement in the sites; Corrective maintenance (CM) and preventive maintenance (PM). Corrective maintenance when the problem happened in the site and depend on the level of the issue the action has been taken. Preventive maintenance is related to the consumable parts on the site and it impalement periodically base on time table.

For the case, as the site is not connected to the grid and work 24/7 on the generators, the generator monthly preventive maintenance cost of the site is 686$ per month which consist the Fuel, oil and filter cost. Monthly fuel consumption per month for the generators is 744 L/Month.

The total operational cost of the generator which consist the PM, CM and the technical action, is 926 $ per month.

Table 7.2. Total monthly operation cost of the Outdoor off-grid site [Source: KOREK Telecom; Power department (2017)]

Technical Information									
Fuel Consumption	Oil Change	Oil Filter Change	Fuel Filter Change	Fuel Price	Oil Price	Oil Filter Cost	Fuel Filter Cost	Month	Currency
1.2L/H	150 Hours	250 Hours	500 Hours	0.6 $	2.5 $/L	2.5 $	5 $	31 Days	1 $ = 1280 IQD

Preventive Maintenance (PM)							CM	Tech. action	Total Cost/Month
Gen. Working Hours		Fuel Consumption	Fuel Cost	Oil Cost	Filter Cost/Month	Total Cost/Month	CM Cost /Month	Tech. action Cost/Month	
Daily	Monthly	L/Month	$/Month	$/Month	Oil Filter				
6	186	224	135 $	35 $	4 $	174 $	100$	50 $	**324 $**
12	372	447	269 $	65 $	8 $	342 $	100$	80 $	**522 $**
18	558	670	402 $	104 $	12 $	518 $	100$	100 $	**718 $**
24	744	893	536 $	134 $	16 $	686 $	100$	140 $	**926 $**

The site has other technical environment costs which classified in, electrical, civil and management costs. According to the technical investigation and site operation history, the total costs under name other cost is 310 $ per month for outdoor site.

Table 7.3. Other operational cost of the outdoor site [Source: KOREK Telecom; Power department (2017)]

Item	Type of service	Cost ($ / Month)
Electrical	PM & CM	40 $
	Technical Action	50 $
Civil	PM & CM	30 $
	Technical Action	40 $
Management	Management	100 $
	Extra	50 $
Total		**310 $**

The energy consumption for the outdoor site in case there is no any generator working on site is 2,160 Kwh per month which is 108 $ per month. For the case which working 24 hour generator per day, it means no any commercial power or national power cost on site and it ignored from the site operational cost.

Total power operational cost of the outdoor off-grid site that generators are the main power supply with working 24 hours daily, is 1,236 $ per month. This cost consist the generators cost, telecom, Civil, electrical, and site management cost.

Table 7.4. Total monthly Site operation & maintenance Costs [Source: KOREK Telecom; Power department (2017)]

<table>
<tr><th colspan="8">Outdoor site operational cost / month</th></tr>
<tr><th rowspan="2">Gen. Working Hours</th><th colspan="2">Generator</th><th colspan="3">Other Cost</th><th rowspan="2">Grid power cost</th><th rowspan="2">Total ($ / month)</th></tr>
<tr><th>Fueling</th><th>PM&CM</th><th>Civil</th><th>Electrical</th><th>Management</th></tr>
<tr><td>6</td><td colspan="2">324 $</td><td colspan="3">310 $</td><td>81 $</td><td>715 $</td></tr>
<tr><td>12</td><td colspan="2">522 $</td><td colspan="3">310 $</td><td>54 $</td><td>886 $</td></tr>
<tr><td>18</td><td colspan="2">718 $</td><td colspan="3">310 $</td><td>27 $</td><td>1,055 $</td></tr>
<tr><td>24</td><td colspan="2">926 $</td><td colspan="3">310 $</td><td>0 $</td><td>1,236 $</td></tr>
</table>

Installation PV battery based system:

Technical Works:

The System voltage is 48 VDC with Load power consumption 1,500 W , Bright sunshine hours per day in Erbil is 6 h/day, Max discharge tolerated is assumed 80 % , the type of selected battery for this case is Gel battery, 12 VDC, 200 Ah , Incline = 45 / Horizontal with assuming Actual autonomy 3 days which means 72 hours.

In order to calculate the PV array, for this case Tenesul brand PV panel has been selected with below specification:

- Type: TE135-36P
- Nominal Power: 135 Wp
- Rated Voltage: 17.2 V DC
- Rated Current: 7.9 A
- Short Circuit Current (Isc): 8.2 A
- Open Circuit Voltage (Voc): 21.9 V DC
- Minimum power: 132.5 Wp

First need to know the daily energy consumption, then the system current in Ampere in order to obtain the number of parallel strings and number of panels per each string by using below equations:

Daily Energy consumption (Watt-hours) = Power consumption (W) x 24 [Equation 7.1]

Daily Ampere hour = daily Energy consumption (Watt-hours) ÷ System voltage [Equation 7.2]

System current (A) = Ampere hour per day ÷ daily sunshine hours [Equation 7.3]

Number of strings= system current (A) ÷ PV panel rated current [Equation 7.4]

Number of panels per string = system voltage (VDC) ÷ PV panel rated voltage [Equation 7.5]

By using equations 7.1, 7.2, 7.3, 7.4, and 7.5, the number of solar panels needed is 48, 16 parallel strings, each string of panels containing 3 in series. The voltage of the solar

array will be 51.6 V (3 in series x 17.2) but 25% is added to this since that value is for 25°C (standard test conditions) and actual temperatures may be colder at times (solar panels are more efficient when colder), giving a solar array voltage of 64.5 V. charge controller should be rated for this.
The current from solar array is 126.8 Ampere (16 parallel strings x 7.9) by adding 25% because of factors of reflected sunlight therefore the solar array current will be 158 Ampere as input. For battery bank calculation, the type of selected battery is Gel Battery with 12 VDC voltage and 200 Ah power capacity. 3 days (72 h) has been selected as actual autonomy and 80% as max discharge tolerated. To know the needed energy from batteries as system back up, need to obtain the battery banks and number of batteries per each bank or strings by using below equations:

System Current (A) = Power consumption (W) ÷ System voltage (V) [Equation 7.6]

Ampere hour per day = System Current (A) ÷ 24 [Equation 7.7]

Number of Battery Banks = Required Ampere hour ÷ Battery Voltage [Equation 7.8]

Number of Battery per Banks = System voltage (V) ÷ Battery Voltage [Equation 7.9]

System current is 31.25 ampere by using equations 7.6 and using equation 7.7 with 3 days as battery backup needed time, also by considering 0.8 as maximum discharge tolerated, 2,812 Ah is obtained as required battery backup. By using equations 7.8 and 7.9, number of battery banks is calculated as 14 battery banks with 4 batteries per each bank. Thus, the total batteries are 56 batteries. Space required for the system is (As per Fechner 2016: 8 -10 m^2 area use for 1KWel; in our case consider 8 m^2) therefore 52 meter square space needed for the system as the PV system size is around 6.5 KW. Maximum power output for our case 6.5 KW. Thus, the collector area for small PV array is 52 m^2 and the maximum efficiency (according to equation 4.1) of a PV panel is 12.5%.

Table 7.5. PV system yearly electricity generation base of FLH [Source; Own data]

6.5 KWel	January	February	March	April	May	June	Julay	August	September	October	November	December	Total Anuualy
Day	31	28	31	30	31	30	31	31	30	31	30	31	**365**
Sunshine Hours	319	309	374	390	434	429	437	416	375	341	318	313	**4,455**
FLH (80% of sunshine hours)	255	247	299	312	347	343	350	333	300	273	255	250	**3,570**
KWh	1,657	1,605	1,943	2,028	2,255	2,230	2,275	2,164	1,950	1,774	1,657	1,625	**23,163**

Financial Highlights

In order to evaluating the PV System on an economic basis or comparing the economics of different technologies, the factors which need to take in consideration are: Capital costs ($/KW), The initial cost of the system which include the cost of the PV module, battery banks, accessories, installation on the site is 16,500 $ (according to the Kurdistan local price). As investment horizon, for this case 15 years is assumed. In year 7, battery banks are replaced due to life times of the batteries which is 70% of the initial cost.

To calculate the operational cost, the generators which used before installation PV system on the site has been ignored. Therefor in this case, the generator monthly preventive maintenance cost of the site which was 686 $ per month is become zero and consequently the total operational cost of the generator which is 926 $ per month (According to the table 7.4) which consist the PM, CM and the technical action, is become Zero USD per month. The site has other technical environment costs which classified in, electrical, civil and management costs. According to the technical investigation and site operation history, the total costs under name other cost is 310 $ per month for outdoor site (according to the table 7.4).

Result and conclusions

By considering the data of table 7.4 (total operational cost of the outdoor GSM site) the total power operational cost is reduced from 1,236 $ /Month to 310 $/ Month. As result, the total cost of the site is 310 $ per month which mean 3,720 $ per year from year 0 to 6. Year 6, due to replace the battery banks, 12,500 $ add to the costs, and the total cost of the site in year 8 to 15 is 3,720 $ per year (with consider 1% operation and maintenance escalation as illustrate in table 7.7).

Table 7.6. OPEX & CAPEX of installation PV battery based system on GSM outdoor off-grid site (TAWESKA) in Erbil [Source; Own calculation]

TAWESKA Site (Total Power Cost)					
	Component	Installation Cost /$	Monthly OPEX	Yearly(Y0) OPEX	Total Cost (OPEX + CAPEX) for Y0
Typical site	2 x generators, ATS, MDB, fuel tank)	19,000 $	1,236 $	14,832$	33,832 $
Install PV battery based system	PV system and battery bank ,	16,500 $	310 $	3,720 $	20,220 $

The above table shows that the differences in site total cost in year zero, reducing operational cost from 14,832 $ per year to 3,720 $ per year. Which means by installing PV system on the site can save 11,112 $ per year by reducing fuel and generators cost to zero $ from the site. The positive effects of the PV system to the environment in terms reducing GHG has been ignored in this report. As KOREK telecom, with consider the number of sites with same situation as selected site (TAWESKA Site) are 494 sites. With considering same power cost of the site, the only yearly power operational cost of these site (in year zero) are 7,327,008 4. By installing the PV system on those sites the yearly operational cost of these sites will be 1,837,680 $. It means only in operational cost, and for those site (494 off-grid outdoor sites) KOREK can save 5,489,328 $. The question here that why KOREK do not implement this proposal? The possible answers are; The High initial cost (14,326,000 $ for 494 sites), lack of information about technology, trust the system, etc. the real economic assessment for the 15 years as investment horizon show the positive net present value as shown in the table 7.7, which mean it is economically feasible.

Table 7.7. Overview of the economic appraisal for 6.5 KW installed in outdoor GSM site [Source: Own calculated data]

Rated Capacity KW	6.5 KW
Initial investment cost $	16,500 $
Discount rate %	2%
Investment replacement (in year 6) $	12,500 $
O& M cost / Year $	3750 $
O& M escalation %	1%
Revenue / year $	11,112 $
CRF	0.0778

	Discount CF (PV	Nominal CF(FV)	O&M	Inv. Replacement	Revenue		Discount cost
			1%				
0	$ (16,500)	$ (16,500)	$ 3,720	$ (16,500)	$ -		$ 16,500
1	$ 7,247	$ 7,392	$ (3,720)	$ -	$ 11,112		$ (3,647)
2	$ 7,069	$ 7,355	$ (3,757)	$ -	$ 11,112		$ (3,611)
3	$ 6,895	$ 7,317	$ (3,795)	$ -	$ 11,112		$ (3,576)
4	$ 6,725	$ 7,279	$ (3,833)	$ -	$ 11,112		$ (3,541)
5	$ 6,558	$ 7,241	$ (3,871)	$ -	$ 11,112		$ (3,506)
6	$ (4,704)	$ (5,298)	$ (3,910)	$ (12,500)	$ 11,112		$ (14,571)
7	$ 6,236	$ 7,163	$ (3,949)	$ -	$ 11,112		$ (3,438)
8	$ 6,080	$ 7,124	$ (3,988)	$ -	$ 11,112		$ (3,404)
9	$ 5,927	$ 7,084	$ (4,028)	$ -	$ 11,112		$ (3,371)
10	$ 5,778	$ 7,043	$ (4,069)	$ -	$ 11,112		$ (3,338)
11	$ 5,632	$ 7,003	$ (4,109)	$ -	$ 11,112		$ (3,305)
12	$ 5,489	$ 6,962	$ (4,150)	$ -	$ 11,112		$ (3,272)
13	$ 5,350	$ 6,920	$ (4,192)	$ -	$ 11,112		$ (3,240)
14	$ 5,213	$ 6,878	$ (4,234)	$ -	$ 11,112		$ (3,209)
15	$ 5,079	$ 6,836	$ (4,276)	$ -	$ 11,112		$ (3,177)

NPV	$	64,075
Ann	$	4,987

NPV Cost	$	(78,706)
Ann Cost	$	(6,125)

7-2- Case 2 (Grid-connected distributed PV): Electricity generation by PV for normal house in Erbil - Technical and economic assessment

Erbil is the capital of Kurdistan Region, Coordinates: 36°11′28″N 44°0′33″E and the area 197 Km², The population of Erbil city is (1,000,000) and the whole population of the governorate is (1,500,000). "*The scientists have considered Erbil as the cradle of humanity, because Shanidar cave is located near Erbil has a special importance. The historical documents have disclosed, that life was found in this cave before 60-65 thousand years. The citadel of Erbil Goes back to 6000 years BC*"[Erbil chamber (2017)].

Figure 7.8. Erbil city [Source: www.ciphotels.com]

Erbil Climate

According to Köppen climate classification, Erbil's climate is hot-summer Mediterranean, with extremely hot summers and cool wet winters. January is the wettest month [Erbil climate info (2013)].

Table 7.8. Climate Data for Erbil [Source: Climate-Data.org]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	20	27	30	34	42	44	48	49	45	39	31	24	49
Average high °C	12.4	14.2	18.1	24.0	31.5	38.1	42.0	41.9	37.9	30.7	21.2	14.4	27.2
Daily mean °C	7.4	8.9	12.4	17.5	24.1	29.7	33.4	33.1	29.0	22.6	15.0	9.1	20.18
Average low °C	2.4	3.6	6.7	11.1	16.7	21.4	24.9	24.4	20.1	14.5	8.9	3.9	13.22
Record low °C	ī 4	ī 6	ī 1	3	6	10	13	17	11	4	ī 2	ī 2	ī 6
Average rainfall mm	111	97	89	69	26	0	0	0	0	12	56	80	540
Average relative humidity (%)	74.5	70	65	58.5	41.5	28.5	25	27.5	30.5	43.5	60.5	75.5	50.04

Electricity in Erbil

The national grid electricity is not stable in Kurdistan, the availability of grid is fluctuated in seasons. The less availably is in the winter (January) less than 10 hours per day to high availability in summer more than 18 hours per day. The price of electricity energy is started from 0.02 $ for energy consumption 0-600 KWh and 0.72 $ for over 5,000 Kwh electricity energy consumption. Like other government in Kurdistan, domestic generators are used to cover the deficiency of national grid to consumers. For normal house needed 6 ampere and the average daily time for electricity from domestic generators are 8 hours per day. As the price is fluctuated in seasonal basis from 6 $ per ampere to 12 $ per Ampere. 3 power plants are operating in Erbil with total capacity 2,129 MW. The main fuel is natural gas.

Solar irradiation in Erbil

Concerning solar irradiation in Erbil city, as shown in below figure the maximum solar irradiation is in June with 7,610 (Watt-hours /m2 /Day) and minimum irradiation in December with 2,160 (Watt-hours /m2 /Day).

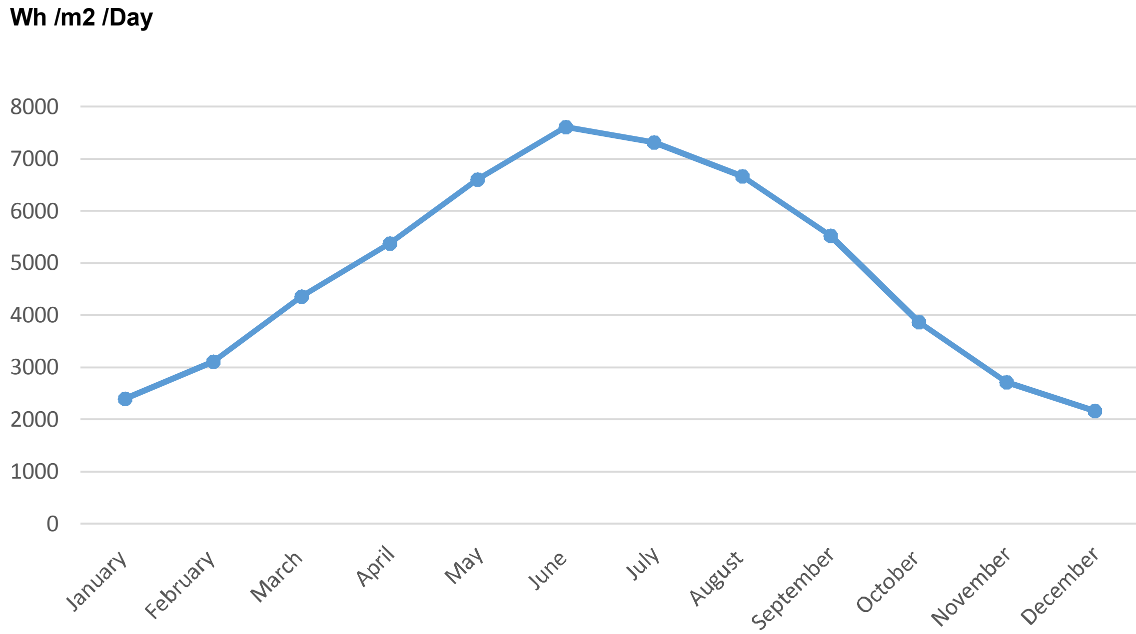


Figure 7.9. Solar irradiation in Erbil [Source: Boxwell (2016)]

Case study

Indeed as the availability of electrical power in Kurdistan is not stable which mean national grid power is not sufficient to cover all consumers demand, thus it had to seeking for another alternatives to cover the 24 hours consumer power demands. As energy measurement Kurdistan proceed the standards which is KWh, but for domestic generators is not proceeding the standards and it is base of any consumers request the amperes from the generator owner. This is special case which is applied in Kurdistan and other places in Iraq. The price of ampere is controlled by government and it is deferent in seasonal basis. For normal house needed 6 ampere and the average daily time for electricity from domestic generators are 8 hours per day. As the price is fluctuated in seasonal basis from 6 $ per ampere to 12 $ per Ampere. Thus, the 9 $ per ampere is assumed for this case study as the flat fee price per ampere. Therefore the flat fee for normal house that has 6 ampere is 54 $ per month. As already mentioned the normal power consumption (from generator) is 6 ampere for 8 hours per day, this will be the base of the PV battery based system in this case. In below table the energy consumption is illustrated. For this case, two option are studied, PV battery based system and dual input solar inverter with battery bank.

Table 7.9. Energy consumption of normal house in Erbil [Source: Own Data]

			Power Needs Table		
		(A)	**Power**	**(B) Hours**	**Watt-hours per week**
	Quantity	**Power**	**used at**	**used**	
Appliance/Loads	**(PS)**	**(watts)**	**one time**	**in a day**	
Refrigerator	1	90	160	8	720
TV	1	120	120	8	960
Fridge	1	100	100	8	800
Cooling System :					0.00
Water Cooler	2	660	660	8	5,280
Fan	1	40	40	8	320
Lighting : Bulbs					0.00
Kitchen	2	40	40	8	320
Living Room	2	40	40	8	320
Dining Room	2	40	40	8	320
Bedroom	1	20	20	8	160
Bathroom	1	20	20	8	160
Computer & Monitors	1	80	80	8	640
Highest power used at one time:			1,320 Watt	Total power per week:	10,000 Watt-hours/day

Option# 1 (PV + Solar inverter + battery bank)

The System voltage is 48 VDC with Load power consumption 1,320 W, which mean 6 ampere as power consumption, Bright sunshine hours per day in Erbil is 6 h/day, Max discharge tolerated is assumed 80 %, the type of selected battery for this case is Gel battery, 12 VDC, 200 Ah, Incline = 45 / Horizontal with assuming Actual autonomy 8 hours per day.

In order to calculate the PV array, same as previous case, Tenesul brand PV panel has been selected with below specification:

- Type: TE135-36P
- Nominal Power: 135 Wp
- Rated Current: 7.9 A
- Short Circuit Current (Isc): 8.2 A
- Open Circuit Voltage (Voc): 21.9 V DC
- Minimum power: 132.5 Wp

First need to know the daily energy consumption, then the system current in Ampere in order to obtain the number of parallel strings and number of panels per each string by using equations 7.1, 7.2, 7.3, 7.4, and 7.5, energy consumption per day is 10,000 Watt-Hours, 208.3 Ampere hours per day it means, the number of solar panels needed is 15, 5 parallel strings, each string of panels containing 3 in series. For battery bank calculation, the type of selected battery is Gel Battery with 12 VDC voltage and 200 Ah power capacity. 8 hours has been selected as actual autonomy and 80% as max discharge tolerated. To know the needed energy from batteries as system back up, need to obtain the battery banks and number of batteries per each bank or strings by using equations 7.8 and 7.9, Total energy required for one day is 220 ampere hours, with consider 80% Max discharge tolerated, it become 275 ampere hours per day. Total required battery are 8 Batteries and Space required for the system is 16 meter square space needed for the system as the PV system size is around 2 KW. The size of inverter is 4 KVA, and the Maximum efficiency of a PV panel (according to equation 4.1) the maximum efficiency is 12.5%.

Table 7.10. Energy production of the 2 KW system in normal house in Erbil city.
[Source: Own Data]

2 KWel	January	February	March	April	May	June	Julay	August	September	October	November	December	Total Anuualy
Day	31	28	31	30	31	30	31	31	30	31	30	31	**365**
Sunshine Hours	319	309	374	390	434	429	437	416	375	341	318	313	**4,455**
FLH (80% of sunshine hours)	255	247	299	312	347	343	350	333	300	273	255	250	**3,570**
KWh	510	494	598	624	694	686	700	666	600	546	510	500	**6,528**

Option # 2 (solar inverter + battery bank)

In this option, just use the solar dual input Inverter with below specification:

- GSA48-4KVA
- Built- in 60 A , MPPT controller
- Duel input (main AC ï Solar PV)
- Mains charging and bypass voltage stabilizing function
- Pure sine wave power frequency output

For battery bank calculation, the type of selected battery is Gel Battery with 12 VDC voltage and 200 Ah power capacity. 8 hours has been selected as actual autonomy and 80% as max discharge tolerated. To know the needed energy from batteries as system back up, need to obtain the battery banks and number of batteries per each bank or strings by using equations 7.8 and 7.9, Total energy required for one day is 220 ampere hours, with consider 80% Max discharge tolerated, it become 275 ampere hours per day. Total required battery are 8 Batteries.

Financial Result and conclusions

For option # 1 , The initial cost of the system which include the cost of the PV module, battery banks, inverter accessories, installation on the site is 3,300 $. As investment horizon, for this case 15 years is assumed. In year 7, battery banks are replaced due to life times of the batteries which is 50% of the initial cost.

For option # 2 , The initial cost of the system which include the cost of the dual input solar inverter, battery banks, accessories, and installation on the site is 2,250 $. As investment horizon, for this case 15 years is assumed. In year 7, battery banks are replaced due to life times of the batteries which is 75% of the initial cost.

To evaluate the operational cost of the case, by ignoring the national grid power costs, which mean only considering the generator power costs for 6 ampere which mean 54 $ per month, 648 $ per year as flat fee. This cost will reduced to zero USD per month for both options.

Thus, the generator power cost 54 $ /Month is transferred to 0 $/ Month. The capital cost of the project in 15 years as time horizon is 5,050 $ for option# 1 and 4,000 $ for Option# 2 which mean the payback time of this capital cost is 8 years for option # 1 and 6 year for option #2.

In this case, using the system consist only the solar inverter with battery banks is more feasible with short payback time in compare with using system consist PV panels. Because there is no Feed-in-Tariff in Kurdistan, there is no room for consumers to sale the surplus of electricity generation of the PV panels to the grid.

Table 7.11. Financial results of two options for Normal House in Erbil city (option# 1: 2 Kilo Watt PV battery based system installation, option# 2: 4 KVA solar inverter with battery bank [Source: Own data]

Option	Investment Cost ($)	Investment Horizon (Year)	Energy Production (KWh/Year)	O& M Cost ($ / Year)	Revenue ($ /Year)	Solar Irradiation in Kurdistan (Kwh/m2/Year)	Payback Time
2KW, PV battery based system	5,050	15	10,710	0	648	1,760	8 Years
Solar inverter + battery bank	4,000	15	-	0	648	1,760	6 Years

8-Conclusions and recommendations

In this part the main question which highlighted in introduction part must be answered;

- What is the technical strength and barriers of using PV systems in the region?
- In economical aspect, what is SOWAT analysis of PV market in Kurdistan region?
- Does using PV technology as alternative energy in Kurdistan has impact on region economic situation?
- Which sector (Industrial, Agriculture, residential, etcé) has more potential for using PV technology?
- Is it financially feasible using Photovoltaic systems for electricity production in the region?
- What is possible suggested strategies to emphasize PV market in the region?

Kurdistan region of Iraq is consider as optimal region for PV installation with high annual solar irradiation (1,754 Kwh/m²/year). Those environment and technical potential also by increasing energy demands in the region, renewable energy technologies, especially PV systems can be sue as alternative energy.

In contrast with that lack of public educational and technical knowledge levels, high initial photovoltaic module costs, , absent of FIT (Feed ï In-Tariff) in the region, not sufficient government support (subsidies) , Lack of specialist or organization in the renewable energy sector in Kurdistan, are the main issues with PV technology in the region. By the way, Kurdistan region has a great potential for solar energy but utilization of this technology is not so easy.

Concerning utility-scale PV power plants study in Kurdistan, by considering the average cost of grid connected PV packages < 1000 KW is 2.55 ú/W installation, 2 ú/W for grid connected PV plants between 1MWel to 5 MW, and 1.8 ú/W for grid connected PV plants > 5MW, investment horizon is considered 20 years and the current price of electricity sale in the region 0.03 ú / KWh. The results shows that installation of the small scale PV power plants are economically not feasible due to low price of electricity and high investment cost. For the scale > 5MW, it economically feasible as shows the positive net present value amount due to higher electricity power generation by the plant and lower initial cost (per power unit). By the way, utility-scale solar PV plant to generate electricity is complicated process and need a more investigation in the long term. Thinking about solar PV Park in Kurdistan is important as there is lack of electric power generation and increasing the demand. It can be a suitable alternative for the domestic generators which are now using as alternative power supplies for the inhabitants. Those generators are in the range 400 KVA to 750 KVA, by doing some modification in the electricity price it will be a convenient option for the investors.

Indeed, in Kurdistan can use PV technology in all sectors, industrial, agriculture, residential, commercial, etc. currently more interesting is using in residential sector with considering all barriers such as high cost, low knowledge, etc. in the case which has been studied in this paper it shows that in off-grid non domestic application (GSM site), using PV system battery based is more feasible economically due to high price of diesel fuel and maintenance issue and it will save a substantial cost for the GSM operator companies. For residential application, using PV system is good option as well. But because the price of commercial power is low thus, using solar inverter with battery banks is better. Concerning agriculture sector, most of Kurdistan farm land are in rural areas and not connected to the grid power network, thus for irrigation works and water pumping, using PV modules or solar water pumps will be a good option, again the reason behind of that is the price of diesel fuel in case using diesel generators for producing electric power.

There is no any PV module manufactures in Kurdistan and all solar products are imported to the region, not clear price for photovoltaic modules or packages in the region so the customers have an issue for select the product with desirable price, and due to lack of knowledge and trust about the technology, the feasibility study of the PV technology is somewhat complicated. The region PV market occupied by chines products which have less price and low quality in compare with European brands, also European solar products are available as well but with higher price in compare with chines brand.

Below are the some possible recommendation to emphasize using PV technology in the Kurdistan region:

- To motivate investor, in order to install the PV power plants (small, medium, and large scale) also make it feasible economically, need modification in electricity price by government. (KRG is planning to increase price from 0.025 $/Kwh to 0.08 $/Kwh)
- More government financial support to the customers by running the bank loan system, or support private banks to proceed this system.

- It is recommended to have a proper policy for renewable energy particularly solar energy management to find out a best channel to use this energy source as the potential of solar energy in Kurdistan is wide and could have a substantial effect in power generation to reach a desired power demands.
- Running special policies related to the on-grid PV systems particularly for residential application, such as Feed in tariff, subsidies, etc.
- Concerning PV market improving it is recommended to; Educate citizens and commercial customers especially in terms financing, looking for opportunities to increase perspectives of solar installations, create positive solar images and increase installation of solar systems in public places.

Finally, Kurdistan region of Iraq is in developing steps and due to population growth and increasing energy demand thus, need producing more electricity, for this purpose any of the renewable energy particularly Photovoltaic technology can help to produce more power and to become more independent from fossil fuels, like natural gas, which is impacting environment and to be safe in future in case depleting conventional fuel sources of the region and obviously, from this paper that Kurdistan region has abundant source of solar which deserve to take in consideration.

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List of abbreviations and symbols

ASDC	Atmospheric Science Data Center
AGPS	Arbil Gas Power Station
AC	Alternating Current
AM	Air Mass
BOS	Balance Of System
BIPV	Building Integrated Photovoltaic
bpd	Barrel Per Day
C.U.F	Capacity Utilization Factor
DNI	Direct normal Irradiation
DGPS	Dohuk Gas Power Station
DC	Direct Current
EPBT	Energy Pay Back Time
FIT	Feed In Tariff
GHG	Green House Gas
GHI	Global Horizontal Irradiation
GDP	Gross Domestic Production
GW	Giga Watt
IEA	International Energy Agency
IC	Integrated Circuit
KWh	Kilo Watt Hour
KIB	Kurdistan Investment Board
KRG	Kurdistan Region Government
KWel	Kilo Watt Electrical
LRGC	Long Run Generation Cost
MOE	Ministry of Electricity
MOP	Ministry of Electricity
MONR	Ministry of Natural Resource
MOF	Ministry of Finance
MWel	Mega Watt Electrical
NPV	Net Present Value

OPVC	Organic Photovoltaic Cell
PV	Photovoltaic
PR	Performance Ratio
RBS	Radio Base Station
REN	Renewable Energy
STC	Standard Temperature and Conditions
SWOT	Strength ï Weakness ï Opportunity ï threats
TFSC	Thin Film Solar Cell
UNDP	United nations Development Program

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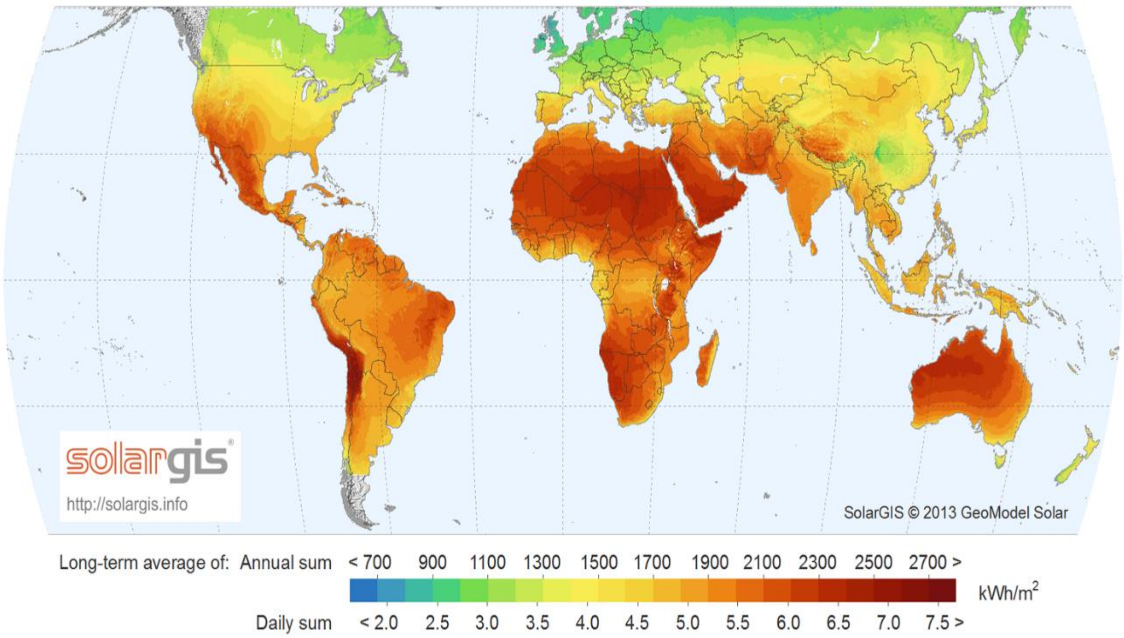
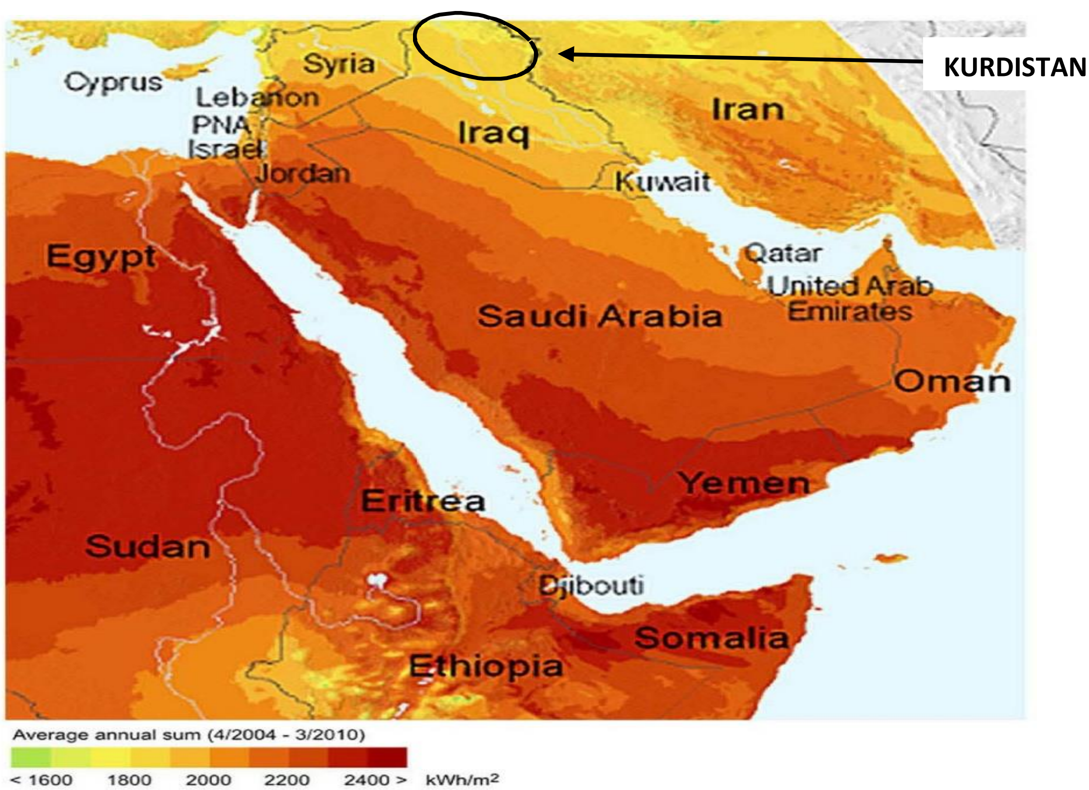
Appendix 1: World Map of global horizontal irradiation





Appendix 2: Energy, Time, and solar irradiation conversions

Energy and Power Conversions

1kWh	3.6×10^6 J
1 hp (horsepower)	746 W
1 Btu	1.055 kJ

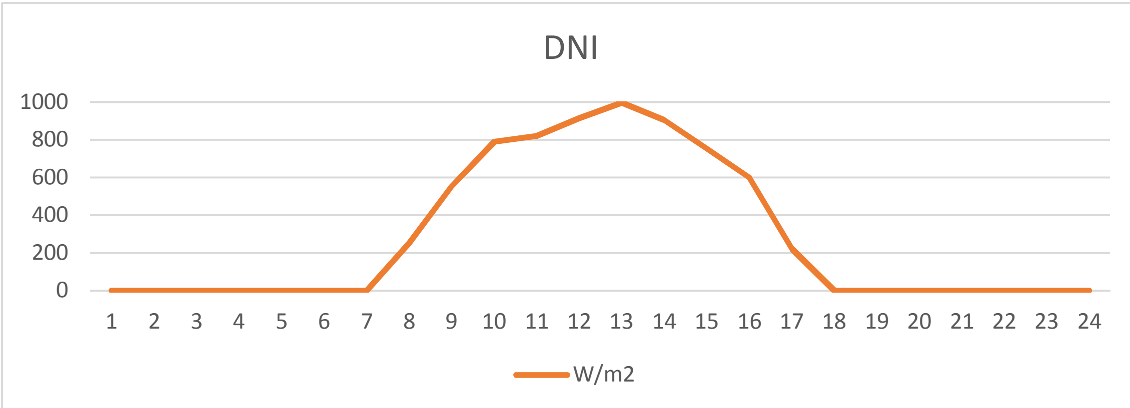
Time Conversions

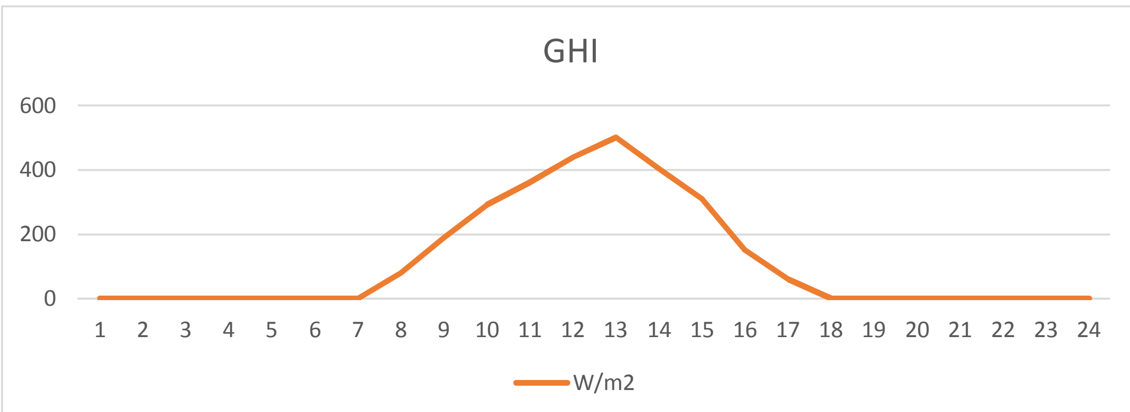
1 year	8765.8 hours
1 hour	3600 sec
1 year	3.157×10^7 sec

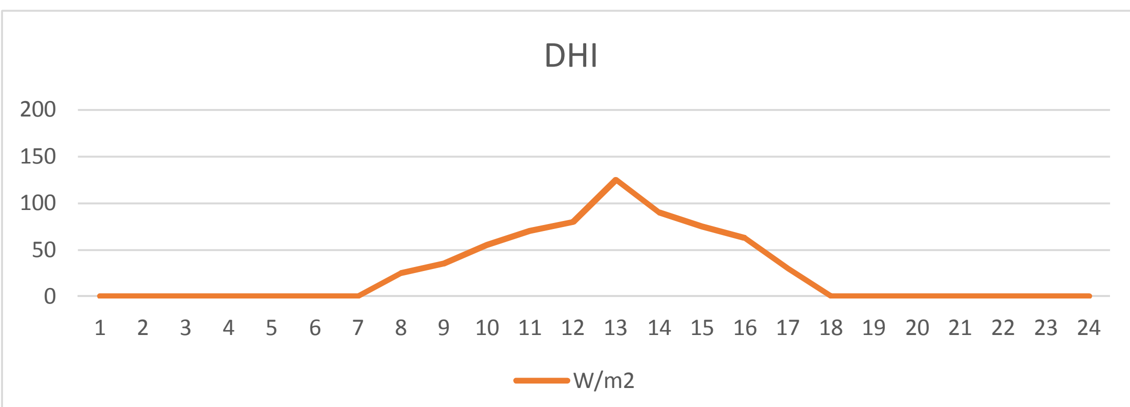
Solar Radiation Conversions

1 kWh/m^2	1 Peak Sun Hour
1 kWh/m^2	3.6 MJ/m^2
1 kWh/m^2	0.0116 Langley
1 kWh/m^2	860 Cal/m^2
1 MJ/m^2/day	0.01157 kW/m^2

Appendix 3: DNI, GHI, and DHI in Erbil / W/m2 (Own Measurement in 15 December, 2016)







Appendix 4: Kurdistan electric power generation 2016 (Source: KRG; Ministry of Electricity)

KURDISTAN REGION P

Date	Kurdistan Region Local Generation														Imported Power (MW)		Grand Total Power (MW)
	HPS		Gas PP				CCCPP	SCCPP	HPPP		Deisel PP						
	DOK (MW)	DBK (MW)	Erbil (MW)	Duh(MW)	Suly (MW)	Kh.J MW)			Baadre (MW)	Taslıja (MW)	Erbil (MW)	Duk (MW)	Suly (MW)		Iran	Turkey	
January	48	86	678	406	642	216	323	0	117	41	0	0	0		12	0	2569
Februry	44	107	588	248	629	294	294	0	138	41	0	0	0		11	0	2394
March	57	97	603	240	573	176	309	0	133	34	0	0	0		10	0	2299
April	55	208	666	139	527	17	340	193	134	36	0	0	0		1	0	2323
May	59	110	618	50	568	259	240	288	139	39	0	0	0		0	0	2368
June	132	132	644	142	537	228	288	272	135	39	0	0	0		0	0	2549
July	143	170	597	172	539	350	309	277	135	38	0	0	0		0	0	2731
August	178	197	586	171	570	298	304	301	130	35	0	0	0		0	0	2771
September	118	105	583	125	579	255	314	312	127	28	0	0	0		0	0	2546
October	49	37	581	88	521	319	298	272	122	32	0	0	0		0	0	2316
November	87	51	601	138	593	277	255	258	125	31	0	0	0		0	0	2416
December	76	31	596	112	593	368	296	249	127	39	0	0	0		0	0	2486
Ave.	87	111	612	169	572	255	297	202	130	36	0	0	0		3	0	2481

Appendix 5

Electricity generation – PV Plant – Kurdistan region of Iraq

500 KW

Economical Appraisal

Input Data

Rated Capacity (MW)	0.5
WACC	2%
FLH hr/y *	3,570
Initial Inv. Cost €	-1,275,000
O&M Costs €/Year	6,375
O&M Price escelation	0%
Electricity sale €/MWh	30
Electricity sale escelation	2%
Fuel Cost €/Year	-
Fuel Price escelation	0%
Inv. Horizon (year)	20
CRF	0.061156718
Electricity sale €	53,550
Yearly elect. Production MWh	1,785

Specific investmnet cost €/MWh 714.3
Specific O & M Cost €/MWh 3.6

* Due to dust and other factors, assume 80% of sunshine hours as FLH

	Discount CF (PV)	Nominal CF(FV)	O&M	Fuel Cost	Electricity Sale	Discount cost
			0%	0%	2%	
0	-€ 1,275,000	-€ 1,275,000	€ -	€ -	€ -	-€ 1,275,000
1	€ 46,250	€ 47,175	-€ 6,375	€ -	€ 53,550	-€ 6,250
2	€ 46,373	€ 48,246	-€ 6,375	€ -	€ 54,621	-€ 6,127
3	€ 46,493	€ 49,338	-€ 6,375	€ -	€ 55,713	-€ 6,007
4	€ 46,610	€ 50,453	-€ 6,375	€ -	€ 56,828	-€ 5,890
5	€ 46,726	€ 51,589	-€ 6,375	€ -	€ 57,964	-€ 5,774
6	€ 46,839	€ 52,749	-€ 6,375	€ -	€ 59,124	-€ 5,661
7	€ 46,950	€ 53,931	-€ 6,375	€ -	€ 60,306	-€ 5,550
8	€ 47,059	€ 55,137	-€ 6,375	€ -	€ 61,512	-€ 5,441
9	€ 47,166	€ 56,367	-€ 6,375	€ -	€ 62,742	-€ 5,334
10	€ 47,270	€ 57,622	-€ 6,375	€ -	€ 63,997	-€ 5,230
11	€ 47,373	€ 58,902	-€ 6,375	€ -	€ 65,277	-€ 5,127
12	€ 47,473	€ 60,208	-€ 6,375	€ -	€ 66,583	-€ 5,027
13	€ 47,572	€ 61,539	-€ 6,375	€ -	€ 67,914	-€ 4,928
14	€ 47,669	€ 62,898	-€ 6,375	€ -	€ 69,273	-€ 4,831
15	€ 47,763	€ 64,283	-€ 6,375	€ -	€ 70,658	-€ 4,737
16	€ 47,856	€ 65,696	-€ 6,375	€ -	€ 72,071	-€ 4,644
17	€ 47,947	€ 67,138	-€ 6,375	€ -	€ 73,513	-€ 4,553
18	€ 48,036	€ 68,608	-€ 6,375	€ -	€ 74,983	-€ 4,464
19	€ 48,124	€ 70,108	-€ 6,375	€ -	€ 76,483	-€ 4,376
20	€ 48,210	€ 71,637	-€ 6,375	€ -	€ 78,012	-€ 4,290

NPV	-€ 329,240.39
Ann	-€ 20,135

NPV Cost	-€ 1,379,240
Ann Cost	-€ 84,350

47.25

Appendix 6

Electricity generation – PV Plant – Kurdistan region of Iraq

5 MW

Economical Appraisal

Input Data	
Rated Capacity (MW)	5
WACC	2%
FLH hr/y *	3,570
Initial Inv. Cost €	-8,925,000
O&M Costs €/Year	44,625
O&M Price escelation	0%
Electricity sale €/MWh	30
Electricity sale escelation	2%
Fuel Cost €/Year	-
Fuel Price escelation	0%
Inv. Horizon (year)	20
CRF	0.061156718
Electricity sale €	535,500
Yearly elect. Production MWh	17,850

* Due to dust and other factors, assume 80% of sunshine hours as FLH

	Discount CF (PV)	Nominal CF(FV)	O&M	Fuel Cost	Electricity Sale	Discount cost
			0%	0%	2%	
0	-€ 8,925,000	-€ 8,925,000	€ -	€ -	€ -	-€ 8,925,000
1	€ 481,250	€ 490,875	-€ 44,625	€ -	€ 535,500	-€ 43,750
2	€ 482,108	€ 501,585	-€ 44,625	€ -	€ 546,210	-€ 42,892
3	€ 482,949	€ 512,509	-€ 44,625	€ -	€ 557,134	-€ 42,051
4	€ 483,773	€ 523,652	-€ 44,625	€ -	€ 568,277	-€ 41,227
5	€ 484,582	€ 535,017	-€ 44,625	€ -	€ 579,642	-€ 40,418
6	€ 485,374	€ 546,610	-€ 44,625	€ -	€ 591,235	-€ 39,626
7	€ 486,151	€ 558,435	-€ 44,625	€ -	€ 603,060	-€ 38,849
8	€ 486,913	€ 570,496	-€ 44,625	€ -	€ 615,121	-€ 38,087
9	€ 487,660	€ 582,799	-€ 44,625	€ -	€ 627,424	-€ 37,340
10	€ 488,392	€ 595,347	-€ 44,625	€ -	€ 639,972	-€ 36,608
11	€ 489,110	€ 608,147	-€ 44,625	€ -	€ 652,772	-€ 35,890
12	€ 489,813	€ 621,202	-€ 44,625	€ -	€ 665,827	-€ 35,187
13	€ 490,503	€ 634,518	-€ 44,625	€ -	€ 679,143	-€ 34,497
14	€ 491,180	€ 648,101	-€ 44,625	€ -	€ 692,726	-€ 33,820
15	€ 491,843	€ 661,956	-€ 44,625	€ -	€ 706,581	-€ 33,157
16	€ 492,493	€ 676,087	-€ 44,625	€ -	€ 720,712	-€ 32,507
17	€ 493,130	€ 690,502	-€ 44,625	€ -	€ 735,127	-€ 31,870
18	€ 493,755	€ 705,204	-€ 44,625	€ -	€ 749,829	-€ 31,245
19	€ 494,368	€ 720,201	-€ 44,625	€ -	€ 764,826	-€ 30,632
20	€ 494,969	€ 735,497	-€ 44,625	€ -	€ 780,122	-€ 30,031

NPV	€ 845,317.29
Ann	€ 51,697

NPV Cost	-€ 9,654,683
Ann Cost	-€ 590,449

33.08

Appendix 7

Electricity generation – PV Plant – Kurdistan region of Iraq

20 MW

Economical Appraisal

Input Data

Rated Capacity (MW)	20
WACC	2%
FLH hr/y *	3,570
Initial Inv. Cost €	-35,700,000
O&M Costs €/Year	178,500
O&M Price escelation	0%
Electricity sale €/MWh	30
Electricity sale escelation	2%
Fuel Cost €/Year	-
Fuel Price escelation	0%
Inv. Horizon (year)	20
CRF	0.061156718
Electricity sale €	2,142,000
Yearly elect. Production MWh	71,400

* Due to dust and other factors, assume 80% of sunshine hours as FLH

	Discount CF (PV)	Nominal CF(FV)	O&M	Fuel Cost	Electricity Sale	Discount cost
			0%	0%	2%	
0	-€ 35,700,000	-€ 35,700,000	€ -	€ -	€ -	-€ 35,700,000
1	€ 1,925,000	€ 1,963,500	-€ 178,500	€ -	€ 2,142,000	-€ 175,000
2	€ 1,928,431	€ 2,006,340	-€ 178,500	€ -	€ 2,184,840	-€ 171,569
3	€ 1,931,795	€ 2,050,037	-€ 178,500	€ -	€ 2,228,537	-€ 168,205
4	€ 1,935,094	€ 2,094,608	-€ 178,500	€ -	€ 2,273,108	-€ 164,906
5	€ 1,938,327	€ 2,140,070	-€ 178,500	€ -	€ 2,318,570	-€ 161,673
6	€ 1,941,497	€ 2,186,441	-€ 178,500	€ -	€ 2,364,941	-€ 158,503
7	€ 1,944,605	€ 2,233,740	-€ 178,500	€ -	€ 2,412,240	-€ 155,395
8	€ 1,947,652	€ 2,281,985	-€ 178,500	€ -	€ 2,460,485	-€ 152,348
9	€ 1,950,639	€ 2,331,194	-€ 178,500	€ -	€ 2,509,694	-€ 149,361
10	€ 1,953,568	€ 2,381,388	-€ 178,500	€ -	€ 2,559,888	-€ 146,432
11	€ 1,956,439	€ 2,432,586	-€ 178,500	€ -	€ 2,611,086	-€ 143,561
12	€ 1,959,254	€ 2,484,808	-€ 178,500	€ -	€ 2,663,308	-€ 140,746
13	€ 1,962,014	€ 2,538,074	-€ 178,500	€ -	€ 2,716,574	-€ 137,986
14	€ 1,964,719	€ 2,592,405	-€ 178,500	€ -	€ 2,770,905	-€ 135,281
15	€ 1,967,372	€ 2,647,824	-€ 178,500	€ -	€ 2,826,324	-€ 132,628
16	€ 1,969,972	€ 2,704,350	-€ 178,500	€ -	€ 2,882,850	-€ 130,028
17	€ 1,972,522	€ 2,762,007	-€ 178,500	€ -	€ 2,940,507	-€ 127,478
18	€ 1,975,022	€ 2,820,817	-€ 178,500	€ -	€ 2,999,317	-€ 124,978
19	€ 1,977,472	€ 2,880,803	-€ 178,500	€ -	€ 3,059,303	-€ 122,528
20	€ 1,979,875	€ 2,941,990	-€ 178,500	€ -	€ 3,120,490	-€ 120,125

NPV	€	3,381,269.15
Ann	€	206,787

NPV Cost	-€ 38,618,731
Ann Cost	-€ 2,361,795
	33.08

Appendix 8: Questionnaire form

Age

- 16- 25 26-35 36-45 > 45

Education level

- Illiterate Primary school High School Diploma BSc Msc PhD

Occupation

- Unemployed Government Employee Private sector employee Self-employment

Monthly income

- Less than 500,000 IQD
- 500,000 to 1,000,000 IQD
- 1,000,000 to 2,000,000 IQD
- 2,000,000 to 3,000,000 IQD
- 3,000,000 to 4,000,000 IQD
- More than 4,000,000 IQD

Q1. Did you know that sunlight can convert directly to the electricity energy?

Yes **No**

Q2. Have you heard about ôPhotovoltaic ô?

Yes **No**

Q3. Did you know that you can install PV system in your own house in order to produce electricity?

Yes **No**

Q4. Have you thought about installing PV system in your own house?

Yes **No**

Q5. Did you know that using PV system in your place is feasible economically?

Yes **No**

Q6. Did you aware about positive environmental impacts of PV system?

Yes **No**

Q7. Knowing the ecological and economic benefits of PV system and if you have budget, are you interest to use PV system for produce electricity in your place?

Yes **No**