Master Thesis

Project of photovoltaic power plant and economical calculations

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Contents

Preface:

This thesis is one of the fruits of my labor at Czech university of life sciences Prague over the past year. This thesis would not have been a possibility if it did not have the guidance and support of some people. The people I am going to name have one way or the other added life to the work.

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My family has been a cornucopia of support for me and I would like to extend my thanks and love to them for their understanding and endless love, throughout the duration of my studies.

Abstract:

The purpose of this project is to make a comparison of different construction possibilities of photovoltaic system in two different countries including Pakistan and Czech Republic and to make an economical calculation for both of the countries. We determined the data for solar irradiation by reliable sources for different cities of both of the countries and calculated the energy production for 3 kW photovoltaic system throughout the year under different constructions. The results evaluated that PV system in Pakistan have capability to produce electricity double than Czech Republic and then we calculated the difference in energy payback time for both of the countries which is also showing the same behavior where PV system in Pakistan showing the energy payback time around 6-7 years and 3-4 years for Czech Republic for same photovoltaic system but there is a difference in price payback time according to grid connected power supply as both of the countries have different price of electricity per kWh. Czech people are paying more as compared to Pakistan's people for grid connected supply and photovoltaic panel prices are also lower in Czech Republic, so it shows a little difference in price payback time approximately 2-3 years higher in Czech Republic than Pakistan but price payback time will be lower as the time will pass and there will be an improvement in technology with the shortage of fossil fuels will make it more and more feasible and affordable for both of the countries.

1.0 Introduction:

Conventional energy resources are running out from the world very rapidly and renewable energy resources are replacing them because it is the time of the need to go for other resources who not only have the ability to cope with the reduction of conventional fuel but also environment friendly so that we will live in a better world. Electricity is no doubt a major energy sector in the whole world to make a significant contribution in the every field of life either it is an education sector or industrial, health sector or corporate, we will find this impossible to grow without electricity.

Photovoltaic has become an increasing alternative energy source for electricity all around the world due to the availability of solar energy universally. Photovoltaic involves the process of making electricity directly from sunlight by semiconductors. It does not involve any other process that is why it is becoming more and more popular on domestic and international level due to its simplicity to install and making it more feasible for home users. There are many research institutes who are trying to find out more efficient ways to get benefits from photovoltaic system as it is an expensive system to adopt throughout the world.

According to World Bank energy facts (“Energy- The facts,” 2011), 1.2 billion people, which is 20 % of world’s population, are living without electricity and majority of them are from developing countries including 500 million people in Africa and 400 million people in India. They are using candles, kerosene lanterns and fire wood to enlighten the house and other buildings. This type of lighting is not only expensive but also a big problem for air pollution which causes the severe long term diseases e.g., lungs cancer, breathing problems etc. It is estimated that delivering the electricity to the whole world will cost 35-40 billion dollars per year which is in addition to 450 billion dollars which is needed to sustain the electricity to current level. Economics is the most important parameter for adopting any technology. Economical profits and social benefits are the key challenges and rewarding for any sustainable project planning. Commercial projects usually fails because increasing the profits always overcome the aim of reducing the poverty. In this research work, we will try to find the feasibility of PV system in two different countries Pakistan and Czech Republic which are from two different regions, one is in Europe and other is in Asia with totally different climate conditions. We will try to find the energy production, energy payback time and price payback time as well for current scenario.

2.0 Aim, Goals and Objectives:

The main aim of this research is to make a project of the photovoltaic power plant and economical calculation of electric energy price. To achieve this, we will compare two countries of different regions Pakistan from Asia and Czech Republic from Europe and we will discuss the different possibilities of photovoltaic system in each of the country and describe the individual performance and individual economics of both of the countries that how feasible is the photovoltaic system in both countries with energy payback time and price payback time as well.

2.1 keywords

Photovoltaic, solar energy, power plant, Economics

3.0 Present Status:

The sun supplies immense amount of energy to our earth. On average basis, it supplies $1.2 * 10^{17}$ W of solar power to earth. It clearly shows that it supplies enough energy within one hour so that it satisfies the whole energy demand of human population for the whole year. Earth's average temperature is maintained near 15ºC due to infrared radiations absorption in the atmospheric gases which is later on reemitted to the surface. Photovoltaics history is 150 years old, when Alexandre-Edmund Becquerel in 1839 observed that some chemical reactions produce electric current called photo galvanic effect. The same effect also observed by Adams and Day in 1876 in selenium. (Markvart, 2000). Russel Ohl found the first silicon solar cell unintentionally in 1940. He was amazed to calculate a large electrical voltage from what he thought was a pure rod of silicon when he sparkled a flashlight on it. Focused studies showed that small application of impurities were giving some piece of the silicon properties classified "negative" (n-type). These characteristics are now known to be due to an excess of moving electrons with their negative charge. Other regions had "positive" (p-type) properties, now known to be due to a shortage of electrons, causing an effect similar to an excess of positive charge. William Shockley accomplished the theory of the devices composed from junctions between "positive" and "negative" regions (p–n junctions) in 1949 and soon used this theory to model the first practical transistor. The semiconductor uprising of the 1950s followed, which also followed in the first efficient solar cells in 1954. This generated vast excitement and attracted front-page headlines at the time. (Green, 2000).

In 2005, India and china with one third of world's population consumes 18 % of world's energy whereas North America consumes 26 % of world's energy. Worldwide primary energy consumption in 2000 was 397.40 quads which is then increased to 462 quads in 2005 while 75 % of this energy is used by developed countries. (R. A. Messenger & Ventre, 2010). If we see from the past then we will know that in 1995, United States of America were the major producer of photovoltaic modules producing 45% of the total world's photovoltaic modules but in 2002, Japan, Europe and rest of the world were producing 80 % and in 2007 this percentage was increased to 93 %. This clearly shows that decrease in production in United States due to changing the policy in business sector and letting them move to outside United States. (R. A. Messenger & Ventre, 2010).

3.1 Benefits and environmental concerns:

Among all the alternatives available, solar energy classifies in high rank. This system contains many advantages, not least of which is its availability irrespective of location. It is also free of charge and environmentally friendly. (Bugaje, 1999). Photovoltaic system is very desirable in obsolete regions and in rural areas due to its no fuel cost and there is no fuel supply problems in addition to this system requires very little maintenance and it has quite a long life (20-30 years). (Markvart, 2000). If we considers the power supply of isolated area, there are two aspects from which the conversion of solar energy into electricity can be utilized. One way is photovoltaic conversion and the second is the use of solar-heat/solar thermal engines. Direct conversion using photovoltaics is the easiest, especially when its major edge of being service free is taken into account since it has no moving parts. The technology included in the production of the cells is, however, high and so are the initial major costs. Photovoltaic cells were originally utilized for space applications. In recent years, the price of the photovoltaic modules has decreased and they are now considerably used for many other applications. The individual photovoltaic module can convert solar energy into electricity with quite reasonable efficiency of more than 10%. The life time of the module is generally supposed to be 20–25 years. However, current research have shown that photovoltaic modules have surpassed this life period while working in very hard conditions. (Herwig, 1997)

Now a days, many camp grounds stopping RV owners from running their engines to generate electricity for the electrical appliances. Noise and exhaust gases not only pollute the environment but also disturb the other people especially at night. Photovoltaic panels providing the electricity without disturbing others and without problem of carrying fuel. (Perlin, 2002). Throughout the time of the solar energy conversion, the cells do not gain constant radiation's intensity. On a sunny day, it increases from minimum at sun rise to a maximum at the solar noon. Thereafter it is consistently decreasing, falling to zero at sunset. Throughout these times, the appearance of cloud cover could decrease this intensity. The favorable fact about solar cells is that their open voltage continues to be fairly constant with changing intensity of radiation. Thus contrast is only found in the current output, which is almost continuous with respect to intensity of solar radiation. This makes photovoltaic systems quite worthy for storage using batteries. The stored energy could then be used at night or when needed. (Bugaje, 1999). Light emitting diodes which are revolutionary lighting elements can produce the light with very little amount of power, so it will increase the suitability of photovoltaic power and decreasing the number of panels for same work to be done at the same place. (Perlin, 2002).

Photovoltaics also increasing in the developed world with that of developing world. Photovoltaics can also work as a building material like windows, skylights, facades or any other type of covering on a home, as it is favorable for owners who are getting both building material and electrical generator. (Perlin, 2002). Energy input is the main requirement for all production processes so the production of photovoltaic systems is also associated with emissions of greenhouse gases and acidic gases but in the present situation of photovoltaic industry, these emissions are very low as compared to fossil fuels. (Markvart, 2000).

Life cycle assessment (LCA) is usually used as a technique to compare and analyze the environmental impacts and energy using associated with the evolution of products during the whole life-cycle. The whole LCA usually consists of four stages, like goal and scope definition, impact assessment, inventory analysis and evaluation. (J. Peng, Lu, & Yang, 2013). There is zero or no public health issues were observed with crystalline silicon technology. Many efforts have done to decrease the waste which includes recycling of stainless steel wires, retrieving the SiC from the slurry and to neutralize the acid and alkali solutions produced during the manufacturing. One crystalline silicon cell (x-Si) producer is using Pb free solders which is also encouraging others to develop and use the environmental friendly technologies. (Hankins, 2012). The enviro-economic investigation is based upon cost of CO_2 emission into the air, which is very convincing mechanism to popularize the implementation of renewable energy technologies that does not release carbon to the air space. The average CO_2 equivalent intensity for electrical energy production from coal is roughly 960 g CO_2/kW h. while transmission and delivery losses are 40 % and 20% loss is due to the ineffectual electric equipment used are supposed.(Agrawal & Tiwari, 2013). Then the total figure comes to be 2.0 kg CO_2/kWh. In amorphous silicon solar cell (a-Si) production, SiH_4, hydrogen is flammable but bilk storage can be used to avoid any type of accident as trailer changes are very less and it happens usually in a well-controlled manner in a presence of management, fire department officials and the gas supplier and it is used at very low rate for glow discharge deposition. (Hankins, 2012). During the life cycle of an energy system, emissions related to system spread in the environment and create disturbance in an ecological system and also to the structures and buildings which are of great importance. The emissions generated by energy systems create problems for human health and on other living organisms and so this charges cost to all the society. These costs include natural resources management, national security consideration (security of supply and safety). (Miquel, 1998).

The very well-known GHG is carbon dioxide (CO2), many other gases, such as CH_4, NO_x, SO_2, etc. are also memorable greenhouse gases. The greenhouse effect of a specific gas is usually called as its global warming potential (GWP) relative to CO2, therefore it can be expressed as a CO_2-equivalent amount for convenience. (J. Peng et al., 2013). Toxic doping gases like GeH_4, AsH_3, usually used in very small quantities to avoid any environmental hazards. Besides all the preventive measures, compressed gas association (CGA) of USA have defined distances between production and public places which is ranging from 80 ft. to 450 ft. depending on the amount of silane and pressure used in production process. There is no environmental issues observed with this technology so far. (Hankins, 2012). Hydrogen selenide (H_2Se) is highly toxic which is used in production of copper indium selenide (CIS) solar cells but its hazards can be controlled or decreased by inventory limitation, introducing flow restricting valves and other safer alternative. Hydrogen selenide emission usually controlled by dry or wet scrubbing. (Hankins, 2012).

The greenhouse-gas (GHG) emissions during the life-cycle steps of a photovoltaic system are calculated as an analogous of CO_2; the major emissions, expressed in terms of global warming potential (GWP), included as GHG emissions are chlorofluorocarbons (GWP = 4600–10,600), N_2O (GWP = 296), CH_4 (GWP = 23), CO_2 (GWP = 1), and Electrical energy use during the PV components and module manufacturing are the main sources of the GHG emissions for PV cycles. If we see GHG emission factor of the average Western European (UCTE) grid is lower than the average US electricity grid by 40% while emission factors of fossil-fuel burning are nearly same, resulting in higher GHG emissions for the US manufactured PV modules. (V.M. Fthenakis & Kim, 2011). Photovoltaic system does not produce any harmful substances or emissions in the environment. The harmful substances used in photovoltaic production can only be a problem if they will enter the body crossing the dangerous limit. The photovoltaic layers are solid and stable in a much better extent and are captured in a glass or plastic. Unless they have broken or have been ground to fine particles, dust cannot be generated s inhaling photovoltaic substances are near to impossible. Photovoltaic material emissions can only be generated if they have been caught by large fire and in this case the fire will be more dangerous than the photovoltaic emissions. (Hankins, 2012). If we Burn one ton (2,000 pounds) of coal then it generates 2500 kWh of electrical energy which produces about 5000 pounds of carbon dioxide emission, which enters the earth's atmosphere. Thus, a one-kilowatt PV system working in a very sunny location for one year can reduce the carbon dioxide emissions in the air by more than two metric tons per year compared to producing the equivalent amount of electricity from coal. Or a one-megawatt PV system operating for a year could decrease the carbon dioxide emissions by more than 2,000 metric tons per year. (Herwig, 1997). As far as the photovoltaic waste and expiration management is concerned, the best available solutions is to recycle the useful materials or substances. It has been clear by present studies that recycling of the materials is feasible on current emerging recycling technologies. (Hankins, 2012).

Most GHG emissions were related to the energy consumption during the PV systems' life-cycle. Emissions unrelated to energy use were only found in aluminum and steel production (for the frames and supports) and in silica reduction (for silicon solar cells), but the total proportion is less than 10%. (J. Peng et al., 2013). If we compare the CO_2 emissions of conventional energy supply (which is 50 % by hydroelectric and nuclear, 20 % by coal, 10 % by gas fired plants and 10 % by oil) with photovoltaic systems then we will see the CO_2 emission factor is about 0.57 Kg/KWh whereas CO_2 emissions by photovoltaic technology is in between 0.04-0.05 Kg/KWh which is significantly lower than fossil fuel plants. With improving technology, it may decrease to 0.02-0.03 Kg/KWh in near future. Solar lighting installation will also help to reduce greenhouse gas emissions about 480 Kg/year if this system replaces just two kerosene lamps. (Hankins, 2012). Posorski made a contrast of SHS with conventional lighting system using petroleum lamps and dry cell batteries as baseline case. The study depicts a GHG reduction of 9 tonnes of CO_2 within 20 years of use of one single 50 W_p SHS compared to the baseline case. (Posorski, Bussmann, & Menke, 2003)

(Tezuka, Okushima, & Sawa, 2002) showed a new way for calculating the amount of CO_2-emission decrease in specific case where the carbon-tax earnings is used as the allowance to encourage photovoltaic installations and figure out that the sum of CO_2-emission reduction grows by advertising the PV system with subsidy policy even under the same tax-rate and the CO_2-payback time of the PV system reduces by half if the GDP is supposed not to alter after the introduction of carbon taxation. Thin film silicon solar cells have the same impact on environment as that of wafer solar cells but the magnitude is low as there are minor volume of Si is used. CO_2 emissions during the life cycle of photovoltaic system occurs from the beginning of production till the decommissioning and waste management. Photovoltaic modules produce 1500 KWh/m^2 during the life time period and CO_2 emission is 400,000 tonnes/GWyr for same module whereas if we will consider the thin film Si and thin film polycrystalline materials on same scale production as crystalline Si, CO_2 output will be 130,000 tonnes/GWyr and 100,000 tonnes/GWyr respectively which clearly shows the huge amount of reduction in CO_2 output if we will use thin film Si.(Miquel, 1998).(Vasilis M. Fthenakis & Kim, 2007) calculated the greenhouse gas (GHG) emissions due to materials and energy flows during all phases of the life cycle of commercial technologies for photovoltaic and nuclear power generation. Their investigation is based on the material and energy catalogue for solar technologies obtained from 12 PV companies in the Europe and the United States of America. They presented that GHG emissions in the life of solar electric and nuclear-fuel technologies fluctuate, depending mainly on the performance of upstream energy, regional conditions, and other assumptions. Although, the study forecasted 40–50% decrease of GHG emissions in the crystalline-Si PV cycle.

A relative study on the reduction effect of carbon dioxide CO_2 for solar PV systems installed in different locations was organized. Three cases (A: made in Japan and used in Japan, B: made in Indonesia and used in Indonesia, C: solar PV modules were made in Japan but used in Indonesia) were analyzed and compared. It was found that the case C had the best effect to reduce carbon dioxide CO_2, which was due to that on the one hand the PV modules' manufacturing country has relatively high efficiency in thermal power plant and thus the GHG emission caused by producing PV modules was less, on the other hand the PV modules' using country has better solar energy resources, which could made the same PV system generate more electricity power during its life time. Thus the authors suggested that it was essential to make cooperation between developed countries which have good technologies and developing countries which have better solar energy resources to eliminate carbon dioxide by PV technology in future.(J. Peng et al., 2013). Silicon photovoltaic modules do not create any environmental problems during decommissioning process. It is just like constructional waste but the situation is different for other substances which are used instead of Si e.g. $CuInSe_2$ (CIS), CdTe modules. (Miquel, 1998).

The direct emissions of Cd are much lower than the indirect emissions due to energy used in the life cycle of CdTe PV systems. CdTe PV systems need low energy input in their production than other commercial PV systems, and this results into less emissions of heavy metals including Cd as well as SO_2, NO_x, PM, and CO_2 in the CdTe cycle than any other PV technologies. However, in spite of the specific technology, these emissions are extremely small in contrast to the emissions from the plants which are using fossil fuels that PV will replace in future. (Vasilis M. Fthenakis & Kim, 2007). If we increase the module production scale and optimizing the production process, there can be 30 % decrease in environmental interferences. Material use reduction and recycling of materials should be done as much as possible. (Miquel, 1998). Photovoltaic systems are less vulnerable to electric shocks as it generates in DC by 12-24 volts and fire chances are also much less as compared to generators (Hankins, 2010). Top producers of SO_2 in United States in 1999 were electric utilities which were producing 4.672 million tons per year SO_2 (R. A. Messenger & Ventre, 2010). Energy consumed in western countries is almost 40% which is produced by the built environment. (Kaan & Reijenga, 2004).

3.2 Applications:

Billions of persons around the globe are benefiting notably from the impact of photovoltaic power systems generating power for space communication systems. But, generally a much more particular effect is resulting from the supply of PV-generated electricity in small amounts by an estimated 500,000 photovoltaic systems installed in rural areas of developing countries around the world. It is evaluated that several million persons are now experiencing enhanced living conditions as an outcome of the availability of PV-generated electrical power. Over the next few years, the continued expansion of these systems can affect the lives of approximately one to two billion persons around the world through electrification of countryside areas. (Herwig, 1997). Photovoltaic system highlights the self-rule of building. It clearly shows that user of the building is somewhat independent from the energy supplier. (Kaan & Reijenga, 2004). Photovoltaic systems can easily be installed according to power requirement e.g. for pumping the water or lighting the house and if needed its output capacity can be increased accordingly. Solar home systems, solar photovoltaic systems are generally used for providing electricity for lighting and other electrical appliances e.g. computers, television and other communication devices etc. (Hankins, 2010). The context and color of the PV system according to building will make the system more adoptable and it will be pleasing to eyes as well. (Kaan & Reijenga, 2004). A Solar Engineering Program carried out by University of Massachusetts Lowell (2002) entitled Design of a Standalone Portable Solar-Powered Thermoelectric Vaccine Refrigerator using Phase Change Material as Thermal Backup to design a compact vaccine refrigerator for remote villages. (Xi, Luo, & Fraisse, 2007). Solar PV panels can also be used for electric water pumps which is used to pump water for irrigation and for drinking purposes but it can be used for small scale irrigation. Large scale irrigation is not cost effective which the main discussion is for commercial purposes. Public institutes can also use photovoltaic systems as they are often in need of electricity during the day like schools, GOVT offices and small industries which usually work on days only. Electric fences are usually used to keep wild animals outside and keep domestic animals inside the house. (Hankins, 2010). The integration of photovoltaic system in non-building structures have been done successfully. This is used to do on public urban spaces to provide additional facilities such as shading or sheltering paths. This will not only help to improve the environment but it will make familiar to people as well. (Kaan & Reijenga, 2004). Space age beginning was also happened due to solar cell development at bell laboratory in 1953. The first ever satellite powered by solar cells, Vanguard 1, was launched by US in 1958. (Easton & Votaw, 1959). Vanguard 1 had 8 small panels and every panel power output was 50 mW with a cell efficiency of near about 8 %. The largest ever photovoltaic system which are present in space can produce 110 kW power with an average efficiency 14.2 % on 8 US solar arrays. (Hague, Metcalf, Shannon, Hill, & Lu, 1996). In the early 30 years, space solar cell developed with a total focus on silicon solar cells however it was known that some other efficient materials also existed. (Loferski, 1956). Thin film cells in military applications have marked interest. Large specific power (kW/kg) and Lower cost is also in planned missions of NASA and thin film solar cells is fulfilling this criteria somehow with additional characteristics of light weight substrate with a suitably light weight support structure but currently thin film solar cells are lower in efficiency however there are some other prospective applications have been recognized. (Murphy, Eskenazi, White, & Spence, 2000). Equator-S and COMETS satellite data analyzed using solar array verification and analysis tool (SAVANT). $CuInSe_2$ and GeAs/Ge solar cells degradation have been identified successfully in the equator-S mission model. This model was first time applied to thin film technology. SAVANT modeled the power output of arrays correctly for the mission bulk life time for GeAs/Ge solar cells which were used as the main source for COMETS mission. (S. Messenger et al., 2000). Naval research labs of NASA are developing a monolithically grown devices that combines lithium ion energy storage with micro sized solar arrays both into single device. A first practical concept has flown on star shine 3 satellite in 2002. (Jenkins et al., 2002).

Buildings are extensive users of energy and use the energy for different applications. Energy production is expensive as well as polluting the environment. Solar energy use in these buildings is attractive addition to energy supply which we get from grid stations but also some time abolish. These incorporations of solar system will make the grid supplier balancer for energy rather than supplier. (Hankins, 2012). In Singapore, the building sector utilizes about one third of its total electricity production. To upgrade the working efficiency of buildings, passive strategies like energy efficient facades can be used. Enhancing facade element's energy performance is the main role as they are the interface between the indoor and outdoor environments. The world renowned aim on reducing fossil fuel consumption has resulted in the push for adopting renewable technologies such as solar photovoltaic to generate clean energy. As such, building-integrated photovoltaic (BIPV) windows are considered one of the arising technologies for building facade materials. (Ng & Mithraratne, 2014). BIPV system takes short fitting time, and the absence of movable parts decreases the need for servicing. As Japan and some other countries in Europe have low specific land use per capita, for example for Switzerland, German, Japan, Netherlands, have 6000, 4450, 3060, 2680m^2 area per capita as compared to 37,040 m^2 per capita for the USA, locating PV on buildings is advantageous to specifically devoting land. (Norton et al., 2011). Power user sector is mostly lies in buildings in Europe around 40 %. This definitely increasing a lot of attention towards building self-sufficiency. Passive solar energy use is practiced from centuries but now a days there should be more focus on energy production which the building needs itself. Photovoltaics is no doubt the technology to use in building envelope as compared to other technologies. (Mercaldo et al., 2009). Building integrated photovoltaics (BIPV) are not only increasing in new building but existing buildings can also modernize with BIPV modules. To achieve the maximum efficiency of BIPV system many factors are considered like photovoltaic module temperature, shading and orientation etc. The most important factor is photovoltaic module temperature which is not only affecting the electrical efficiency but also energy performance of the buildings where modules have been installed. (C. Peng, Huang, & Wu, 2011). From a utility point of view, the cost of BIPV electricity depends on its potential to meet maximum demand. Saving peak load demand removes the need for major, and repeated investment in additional energy systems such as exorbitant gas turbines or hydro storage. This presents a chance to optimize economic performance by saving high building-load demand for a BIPV system. (Koner, Dutta, & Chopra, 2000).

(Wang, Tian, Ren, Zhu, & Wang, 2006) used four different roofs to analyzed the effects of building integrated photovoltaic (BIPV) on heating and cooling loads of building. It was found that a PV installed roof with a ventilated air-gap was acceptable for use in summer season because this combination led to a low cooling load and high PV conversion efficiency. A PV installed roof with a ventilated air-gap had a high delay and small declining factor and had the identical heat gain. In winter season, a BIPV with a non-ventilated air-gap was more suitable due to the integration of the low heating-load through the PV roof and high PV electricity output. Thin film technology is the most worthy which satisfies all architectural theories. New PV thin film modules will be able to match with conventional architecture and also with most contemporary tendencies that will be in favor of envelops characterized by free arrangement. (Mercaldo et al., 2009).

BIPV and BAPV are the main photovoltaic mounting systems. BIPV are integrated into the building structure whereas BAPV (building applied photovoltaics) are just an addition to the architecture of building. Standoff which are mounted parallel on the slope of the roof and rack mounted arrays which are mounted on the flat roof are typical examples of BAPV. (C. Peng et al., 2011). BIPV system have many benefits but there are three main benefits which are of main concerns. PV systems integrated into or mounted onto buildings can be refrained the cost of fencing, access roads, land acquisition and major support structures for the modules. And it would avoid some cabling costs which in case is essential in remote PV sites. PV system attached with the building removes the transmission and electricity losses due to near point of use. PV systems that are integrated into building are also a source of protecting the building from weather and replacing the building material use for weather proofing. (Oliver & Jackson, 2001).

(Xi et al., 2007) submitted the development and uses of two solar-driven thermoelectric technologies (i.e., solar-driven thermoelectric power generation and solar-driven refrigeration) and the currently existing drawbacks of the solar-based thermoelectric technology and methods to upgrade and assess the working of the solar-driven thermoelectric devices. Where BIPV heat transfer uses water or in some cases glycol solution as the working fluid, the price is much greater due to the demand of more complex operations like plumbing, more complex facade and hydronic systems combination. Protective system output development of water- heating systems (PV-T) is thus required to defend the initial major cost expenditure however they have been anticipated to be feasible in terms of incorporated energy payback time (EPBT) under Indian conditions with EPBT ranging from 4 to 14 years. (Tiwari, Raman, & Tiwari, 2007).

Solar parks which are also called solar farms like wind farms in which the sole purpose is to generate electrical power for on grid or off grid system. Atlantic Rich field subsidiary Arco Solar installed a first solar park in 1982 in California. Later on Arco solar again installed a solar park in 1983 whose production was 5 MW at Carrizo plain. (Hankins, 2012). Geographical information systems (GIS) provides a very efficient tool for solving different problems in site selection for solar farms. GIS integrated with multi criteria decision analysis (MCDA) to solve problems in renewable energy facilities. GIS have been used in different parts of world to study the location of solar farm like Janke in Colorado USA, Charabi & Gastli in Oman and Aran-Carrion in Andalusia, Spain and many others who have engaged in GIS study in renewable energy sector. (Sánchez-Lozano, Henggeler Antunes, García-Cascales, & Dias, 2014). Mono and poly crystalline silicone PV technology is mostly used in solar parks. Thin films PV have also been used in solar parks. Different types of arrays used in solar parks/farms according to location e.g. fixed arrays, tracking arrays and array mountings. (Hankins, 2012). Solar farms alone cannot satisfy the energy needs for 24 hours. The hybrid system contain solar farm, wind farm and diesel based power generation is becoming feasible. It is the most cost effective approach for remote located communities. Borowy and Salameh developed a methodology for PV array for a stand-alone hybrid Wind/Solar farms and the optimum size of a battery bank. Correct size of a battery bank is necessary for any system to satisfy load demand at any time. (Shaahid, 2011). (Miyazaki, Akisawa, & Kashiwagi, 2005) studied a PV window to supply natural light transmission and electrical energy production and analyzed the effect of the photovoltaic window on heating and cooling, day lighting, and electricity output. It was clear that the solar cell transmittance is of 40% and a window wall ratio of 50% achieved the minimum electricity use.

Solar home systems have wide range of benefits like for the operation of communication systems, TV sets and fans with that of lighting. Studies have shown that 50 of users of solar home systems stated that SHS was beneficial for children and 43 % expressed their comments on benefiting from different entertainment possibilities. (Gustavsson & Ellegård, 2004). Despite the fact of GHG reduction and rural growth benefits of SHS, there are not much in number SHS projects that appear to have been benefited from carbon finance. According to the statistics at that time reported by the UNFCCC, 594 of the 1105 registered clean development mechanism (CDM) projects till June 2008 belong to large-scale project category having GHG reduction potential in excess of 20,000 tonnes of carbon dioxide per year (tCO_2/yr.). Remaining 511 CDM speculations are in small-scale projects that lies in the developmental needs of rural area in developing countries by supplying people with latest energy services and upgrading their living areas. (Chaurey & Kandpal, 2009). Energy statistics of UK government in 2004 showed average household electricity consumption 4068 kWh on annual basis while English house condition survey (EHCS) collected data in 2001 on 7370 households in England which showed annual average electricity consumption 5282 kWh. This energy consumption includes the uses of hot water, space heating and electrical appliances as well. (Firth, Lomas, Wright, & Wall, 2008). Research studies have shown that solar photovoltaic water pumping system is an appropriate technology that is technically, environmentally and economically feasible in developed countries. Chandratilleke tested the performance of water pumping system with PV 1.14 kW and 860 W of centrifugal pump and found that it is quite good for medium delivery flow rate (1-4 m^3/h) but operating efficiency was lower around 1-6 %. (Parida, Iniyan, & Goic, 2011). Solar irrigation is an efficient and reliable method to irrigate farm land where electric power is in short or farm land is in obsolete regions where grid connected power cannot be available. (Xu, Liu, Qin, Gao, & Yan, 2013). Different solar energy operated pumps have been successfully installed throughout the world. A 50 hp. Pump is working at Gila Bend, Arizona with parabolic tracking collectors of 510 m^2 area. Another system of 25 kW capacity with parabolic trough collectors of 624 m^2 area was developed at Willard, New Mexico. (Krishna, Rap, & Soin, 1980). High solar insolation/irradiation makes the photovoltaic powered (PVP) irrigation technically feasible. If there is an enough land available for photovoltaic array then there is no technological barrier to implement photovoltaic powered irrigation. (Kelley, Gilbertson, Sheikh, Eppinger, & Dubowsky, 2010).

Pakistan is located in a very suitable location as far as solar radiation is concerned with long sunshine hours and high irradiance levels. In most areas of the country the sun shines for 7 to 8 h on daily basis and solar energy is accessible for roughly 2300–2700 h per annum and sunshine is available for more than 300 days per year. (Sheikh, 2009). Presently PV technology is being used in Pakistan for stand-alone rural telephone exchanges, highway emergency telephones, cathodic protection, repeater stations, refrigeration systems for vaccine and medicines in hospitals, and many others. Initiatives have been taken for use of solar energy traffic signal lamp, solar energy street lamp, solar energy sight lighting and solar energy lawn lamp. Siemens Pakistan is also actively participating in Photovoltaic advancement for more than 10 years. They have installed complete solar PV systems in approximately all parts of the country, mainly for water pumping, house electrification, highway communication, telecommunication, oil and gas fields, navigation and street lighting. (Bhutto, Bazmi, & Zahedi, 2012).

3.3 Economics:

Solar PV technology's market prices are of considerable attention and it is always difficult to have a well-organized picture of price shifting across the country or region around the whole world due to many reasons like complexity of PV supply chain, rapidity of costs and price changes, installation costs associated with complete PV systems, balance of system and choice of different distribution channels. (Bazilian et al., 2013). Cost evaluation of electricity produced by PV and other services done by this energy like the value of water delivered by PV pump can be validated by the economic competition between on grid and off grid energy sources but stakeholders and investors wants to have a clear profit on their investments. Hence PV developers and investors need to have simple tools to assess their feasibility and profitability of projects. Sometimes to make a project feasible, incentives in different forms is also needed.(Chabot, 1998). Energy consumption of a household is effected by many considerable factors including climate, size of the house and size of the family. It has been estimated that electricity consumption varies from 0.33 kWh/day/household to 0.84 kWh/day/household for lighting purposes. (Kamalapur & Udaykumar, 2011).

For a BIPV system, the economic feasibility is obtained by the produced electrical energy cost in competition with that of other sources of electricity usually from grid. Traditional energy sources usually contain small initial costs as compared to large operating costs whereas BIPV systems have higher initial expenses but lower operating costs. (Goswami, Kreith, & Kreider, 2000). PV technology have now been in use for around 50 years in some specific applications and for grid connected systems around twenty years. Its use for such a long time was only possibly due to two main factors. One is its renewable energy resource that is sun and the second is its delicate and elegant use without any moving parts and without much maintenance. Despite of all these facts, the high initial costs of PV technology prevented wide spread commercial deployment. (Bazilian et al., 2013). Bugaje found in results that PV solar power system gives the least energy cost per annum among all the others including diesel generator and NEPA (National Electric Power Authority) power grid supply. Its operation costs are imperceptible as it is almost maintenance free. This is its greatest feature for an obsolete region. Stand-alone solar powered photovoltaic power system is therefore the most feasible power supply system for remote locations in countries like Nigeria. (Bugaje, 1999). Feasibility and profitability of a photovoltaic projects on a specific site can be assessed by global profitability analysis which is taking into account operating and maintenance (O&M) costs, discounting parameters and considering the average selling price (ASP) of delivered kWh or energy service as the main parameter to obtain a targeted profitability. This analysis gives the global economic view as it does not considers inflation rate during the period and other financial parameters such as taxes on sale and profit or balance between debt and equity and all variations of other parameters are supposed to evolve at a fixed rate equal to constant inflation rate. (Chabot, 1998).

Energy payback time (EPBT) is the energy equivalence to money payback. It evaluates the time which it takes for the energy produced after system installation to same energy required to produce that system e.g. manufacturing, collection and disposal. The refining which is necessary to achieve a minimum purity essential for excellent performance is one of the main factors to increase the burden of PV materials. (Goe & Gaustad, 2014). If we set aside the local conditions in any area then we can easily see that future cost reduction’s magnitude will have remarkable effect on photovoltaic cost competitiveness. Cost reduction’s potential can easily be assess by common way in an industry which is application of learning curves, which for the solar photovoltaic sector anticipate a decrease in cost of 20 % for each doubling of cumulative capacity. (Mitscher & Rüther, 2012). An economic study of energy supply options including PV-diesel, wind-diesel, PV-wind-diesel and diesel only indicates that applications with high consumption of sustainable energy have the minimum net current cost and the same are previously cost productive without CDM. Although, deficiency of investment capital, restricted technical capacity, limited recognition, and ineffective renewable product service and supply systems make it hard to implement such cost-efficient projects. The fact that renewable energy projects face such barriers magnify the additionality of the projects and may support in validating their registration under CDM. (Gilau, Van Buskirk, & Small, 2007).

Gusdorf points out that in the last two decades, there has been a considerable improvement in energy payback time for PVs (Gusdorf, 1992) whereas if we look back in 1970s, authors had suggested that solar energy was not feasible economically as they claimed that energy which is required to produce the PV system is much greater than its output energy which it produces in its whole life time but now recent research have clearly showed that energy payback time is in fact a very small fraction of the actual life time of the Photovoltaic systems. (Oliver & Jackson, 2001). Oliver presented some of the main technological factors that have helped to minimize the cost of PVs in economic and energy terms. Recent attempts to improve the feasibility of PVs have been broadened to include consideration of the way technology is applied. (Oliver & Jackson, 2000) Energy payback time of PV systems in a particular region is quite difficult because it is affected by many parameters such as electricity mix of PV modules, place of origin, lifecycle energy requirement and local weather conditions with life time of system as well. (J. Peng et al., 2013). Energy payback time of thin film modules declining linearly as recycling of material increases for same efficiency. The lesser the module efficiency, the steeper the decrease of energy payback time with recycling rate. Exhaustive recycling (ER) of all materials decreases energy payback time by 0.5, 0.7, 1.1 and 1.1years for CdTe, CIGS, a-Si and c-Si respectively at baseline efficiency. Municipal solid waste recycling rate of frame and roof mounting materials has the capability to reduce energy payback time by 0.2-0.5 years. (Goe & Gaustad, 2014)

According to Kaldellis results, energy payback period in Rhodes island approaches to 2.35 years for the grid connected system whereas this reaches to 4.6 years for the optimum photovoltaic battery (PV-Bat) stand-alone system. The higher energy payback time for stand-alone system as compared to grid connected system depicts the individual character which requires an energy storage capacity e.g. a lead acid (PbA) battery and presents a significant energy excess during the high solar insolation period. (Kaldellis, Zafirakis, & Kondili, 2010). An accurate measure of Gross energy requirement (GER) of the modules is required to determine the precise value of energy payback time and energy return factor (ERF). The calculated GER value are as described further. Amorphous silicon = 2064 MJ/m^2, CdTe cells = 2281 MJ/m^2, CIS cells = 4053 MJ/m^2, polycrystalline silicone cells = 4000 MJ/m^2, monocrystalline silicone cells = 5200 MJ/m^2. The energy demand for the structure is 500 MJ/m^2. (Bayod-Rújula, Ortego-Bielsa, & Martínez-Gracia, 2011). Ng et al, found in his studies that the energy payback period (EPBT) was less than two years while energy return on the investment (EROI) could be as much as 35 times. However buying photovoltaic materials including batteries from a surrounding country can decrease the transport energy demand to the much extent, it can also direct to increased greenhouse gases emissions, depending on the electricity mix of the country. Thus buying choices should include an integrated view. The silhouette created by surrounding buildings and infrastructure can reduce the overall performance of semi-transparent BIPV which should be examined during design stage. (Ng & Mithraratne, 2014).

(Bhuiyan, Asgar, Mazumder, & Hussain, 2000) studied photovoltaic power system's economics for stand-alone construction to test its suitability in rural areas of Bangladesh and differentiate between renewable and non-renewable generators by estimating their life cycle cost using the method of net present value analysis (NPV analysis) and showed that life cycle cost of photovoltaic energy is much lower than the cost of energy produced by diesel or petrol generators in Bangladesh and so it is economically suitable in remote rural areas of Bangladesh. Producing cost of Photovoltaic cells and modules have been reduced by 30 to 50% over the past five years due to the efforts of industry in collaboration with the U.S. Department of Energy's Photovoltaic Manufacturing Technology (PVMaT) program. Also, throughout the same period, U.S. industry's production capacity and module sales proportion have grew by more than a factor of two. However, salts prices per watt have not lessened much more than an estimated 10% because of the continuous heavy demand by customers and excessive sales. More considerable decrease in sales prices awaits further capacity growth and cost decrease based upon economies-of-scale, and on the developing of thin-film technologies and their producing capacity growth. With future sales prices expected to be reduced steadily, hopefully with increasing industry benefits in hand which is already going on throughout the world. The present situation of cost reductions heading to volume increases should continue and accelerate. (Herwig, 1997).

(Alsema & Nieuwlaar, 2000) have attempted to predict the EPBT for a mono-crystalline solar cell for the year 2020, considering the upgraded and refined technology and the effectiveness of the solar cell; they reached to the result that the current EPBT, which presently is 5–6 years, will be decreased to 1.5–2 years. (Yamada, Komiyama, Kato, & Atsushi, 1995) have estimated that energy pay-back time (EPBT) was near about 6 years even if the yearly cell production rate was 0.01 GW/year and the price for decreasing CO_2 emissions estimated from the difference of electricity production costs by a photovoltaic energy system and a coal-fired power plant were in a range of 30,000–200,000 yen/t-C. Provincial or local PV market evolution programs that cover both buy down initiatives and non-pricing plans to increase the efficiency of PV markets will often be desirable to more centralized efforts, particularly since the best markets will be concentrated locally. Program designers in key regions will typically be better positioned than program designers in central government. Such local programs contain auxiliary benefits by: (i) allowing states or provinces separately or even localities to take leadership positions in commercializing PV; (ii) decreasing the threat to producers that overall sales levels will crash if any single program is prematurely removed and (iii) facilitating educating about alternative execution approach. (Duke, Williams, & Payne, 2005). Van der Zwaan concluded in his studies that due to high costs of PV system, Photovoltaic powered systems before 2020 is quite unexpected to play a big role in world energy supply and CO_2 emission reduction. PV should be encompassed in long-term energy scenarios, hence beyond 2020 it can produce electricity very significantly and given its supposed learning potential, photovoltaic costs are expected to reduce notably in near future, so that a substantial energy contribution from PV world-wide could arise after 2020. In addition to that, external costs due to environmental pollution emitted by conventional fuels are significantly important, especially for older fossil-fuelled power plants e.g. by a pollution tax, would improve the economic feasibility of photovoltaics, while it is not enough to close the current cost gap. (van der Zwaan & Rabl, 2004). (Gaiddon & Jedliczka, 2006) have shown the relative evaluation of selected environmental indicators of photovoltaic generated electricity in OECD cities. They observed that the EPBT of a complete PV system was in the range of 1.6–3.3 years for a roof mounted PV system and from 2.7 to 4.7 years for a PV-facade and energy return factor (ERF) was between 8-18 for roof mounted systems and between 5.4 and 10 for PV facades considering 30 years long commercial PV life cycle.

At present the described efficiency of traditional Si modules ranges between 12 and 14%, with some of the modern commercial monocrystalline cells present in the market having efficiencies of approximately 18%. In relation to the all-inclusive efficiency of the PV system, several attributes decrease the aggregate of electricity transferred to the building. Losses due to inverter and mismatch losses due to maximum power point tracker calculated to be between 10 and 15 % respectively. Small Balance of System losses from cables like Ohmic losses, fuses diodes, and switches, calculated not to exceed 1.5%. These jointly describe the total losses within the system and can be shown as a PR, or Performance Ratio. (Wilson & Young, 1996). The comprehensive energy efficiency of photovoltaic systems may accordingly be enhanced not only by increasing their electrical energy output, but by reducing their encompassed energy which is utilized not only in the manufacturing of PV modules, but also in the other balance-of-system constituents such as supporting structures. The deployment of the PV system as a building-integrated structure, requires little or no additional support, or positioned in the open field may therefore have significant importance for its net energy yield. (Halasah, Pearlmutter, & Feuermann, 2013). (Chaurey & Kandpal, 2009) have evaluated to estimate the CO_2 reduction potential of solar home system (SHS) in India by studying the potential for their dissemination and the proper baseline. They observed that carbon finance could decrease the productive load of SHS to the user by 19% if carbon costs are \$10/t CO_2 without transaction cost.

Khalid has found in his results that RETScreen simulation showed that the PV power plant with south facing arrays of 30.2° tilt produced 17.713 GWh/yr. AC electric power while the one axis tracking plant produced 23.206 GWh AC electricity in a year. Against this value the farm with a two axis tracking arrays generated 23.922 GWh/yr. This means that power obtainable from a one axis tracking PV farm is 31% higher than the power from a similar sized farm with south facing 30.2° tilt arrays. On the other hand power generation improvement from one axis tracking to two axis tracking is marginal and is only 3.08%. (Khalid & Junaidi, 2013)

4.0 Methodology:

The fact that an advanced, innovative and advantageous technology like photovoltaics is being used in an inappropriate way can be demonstrated by the following map (Fig. 1), where the map shows the average annual sum of global horizontal irradiance from data gathered for many years. Dark colors like red are designating the locations most suitable for PV installations, the contradiction being that the areas with the best irradiance conditions are without electricity, while photovoltaic is booming all over Europe, where the insolation conditions are far from ideal and more convenient energy sources exist. The major reason why solar is suitable in Europe are the governments incentives and feed-in tariffs, that assured the purchasing price for solar energy for 20+ years. It is arguable that a government with an authority for a few years can responsibly make such a long term decision. Recent news show it cannot, as the governments of Czech Republic and Spain faced the increasing budget shortage and decided to cut the future cost of PV subsidization by decreasing the promised buying price. This action has been subject to many disputes and provoked multiple international lawsuits.

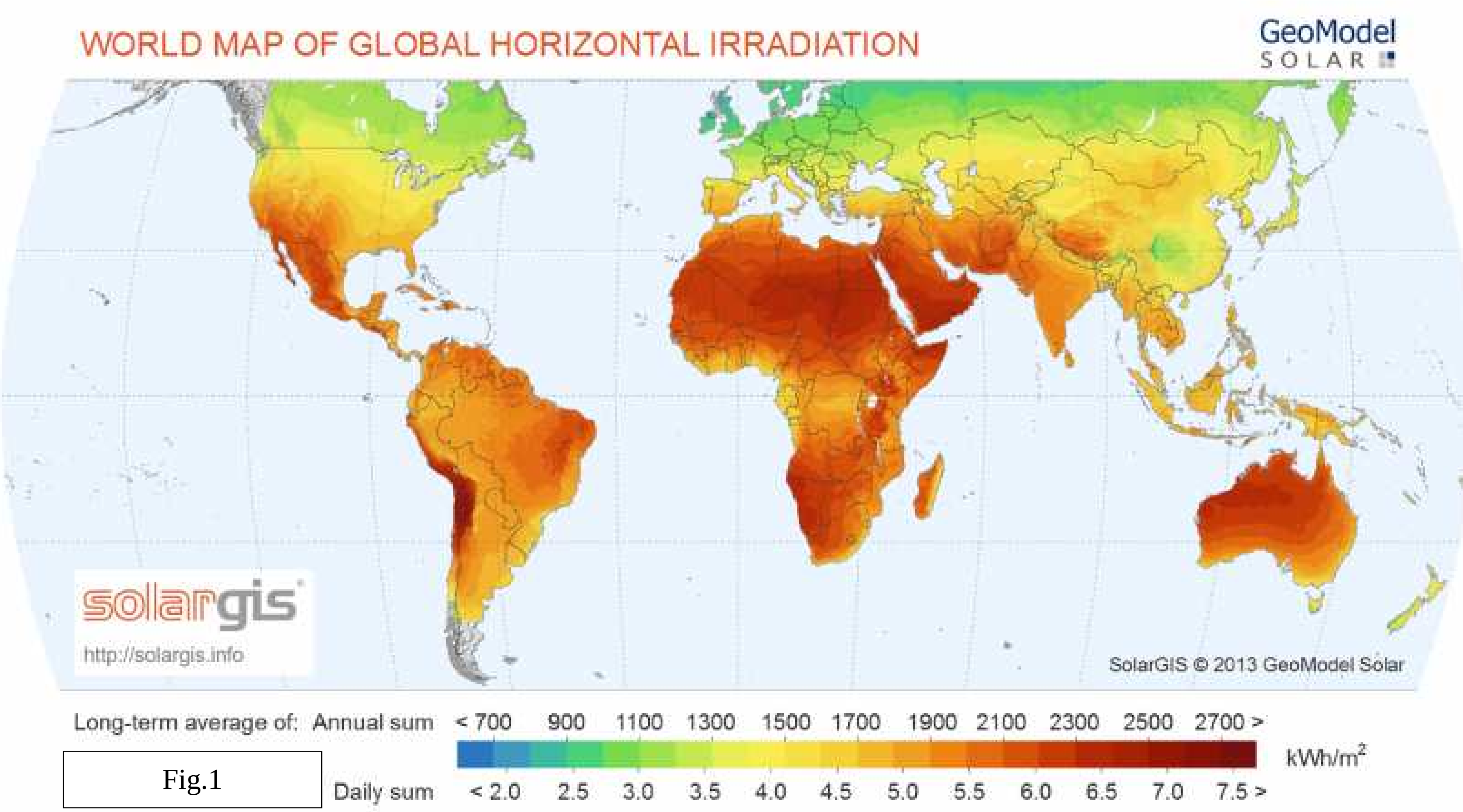


Fig.1

Nevertheless presently, the solar power marketplace is concentrated in countries which have government incentives, subsidies, and easy financing options targeting electricity generation using solar power. EU has the most favorable legal and fiscal incentives and remains the global regional leader, having a total installed solar PV generation capacity of 68.64 GW in 2012 as compared to total world installed photovoltaic capacity which is 102 GW in 2012.

4.1 Pakistan:

World Energy Outlook report for the year 2010 indicated that China & East Asia accounts for a population of 186 million without electricity and a level of 85.6% of rural electrification, whereas South Asia including Pakistan and its 612 million without electricity falls short of the results of the former, regarding the 51.2% rural electrification level. Pakistan is the sixth most populous country of the world with area coverage of 796096 km^2. Being in the most ideal region having various abundant resources available including hydropower in the form of river and sea, natural gas, coal mines, solar and wind resources. Total installed capacity for electricity generation in Pakistan is 21,103 MW from various sources including 65 % from fossil fuels, 31 % from hydro power and 4 % from nuclear resources. Electrical energy production in Pakistan has reduced by up to 50% in recent years due to an over dependency on conventional fossil fuels. There is a severe shortage of electricity in the whole country. Load Shedding and power cutoff have become acute in Pakistan in recent years. The shortfall of electricity was reached to 6000 MW until May 2012 (Kessides, 2013), resulting in increase of power cutoff times. There is a power cutoff of 14 hours in urban areas while it reaches to 20 hours in rural areas which is not only disturbing the day activity but it is also causing considerable damage to the economy of the country as many of the industries have been shut down due to power shortage.

In these adverse conditions of energy shortfall, Pakistan needs to move to other sources of energy which must be consistent and can accommodate the growing population with their basic needs of energy. Pakistan needs to move to renewable energy resources and among all of them, solar energy is quite abundant throughout Pakistan and solar irradiation is also quite high in most of the areas except northern region. US National Renewable Energy Laboratory developed solar maps of Pakistan which shows that most of the regions of the country are blessed with higher solar insolation levels averaging from 5 kW h/m2*day to 7 kW h/m2*day (NREL, 2010), shown in Fig. 2 and Fig. 3. Solar PV technology has good potential in the country but due to high cost of electricity generation from solar energy, it is burdensome to widely deploy this technology on large scale.

Fig. 2

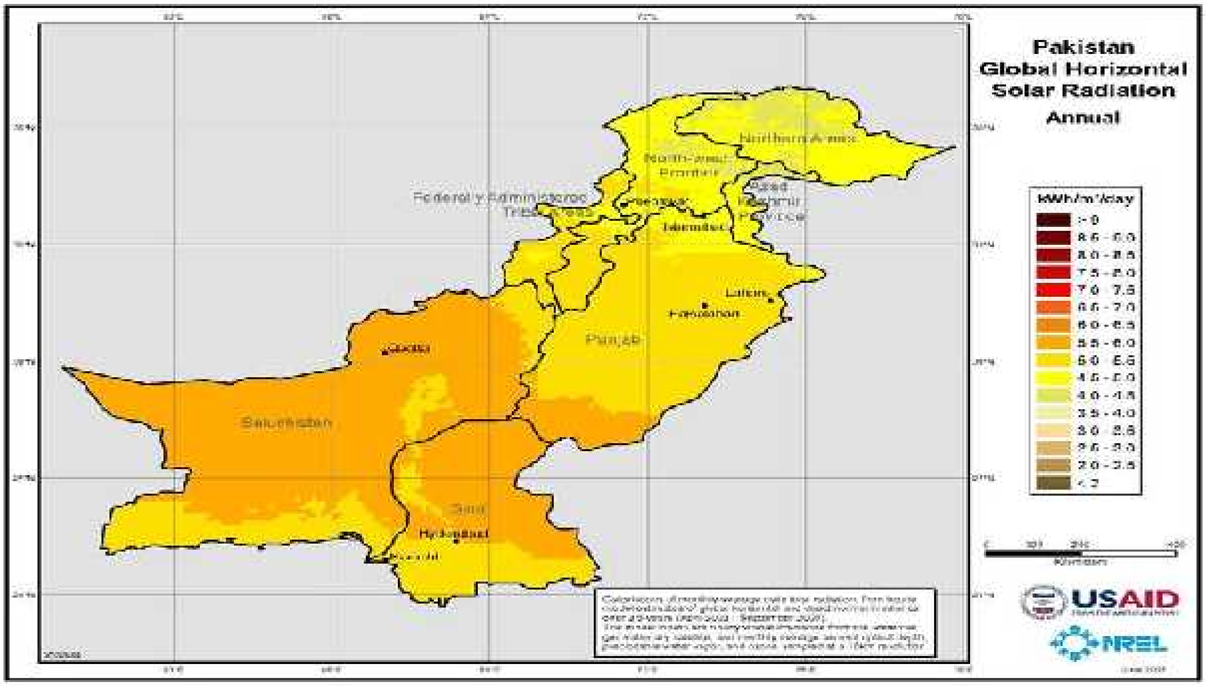
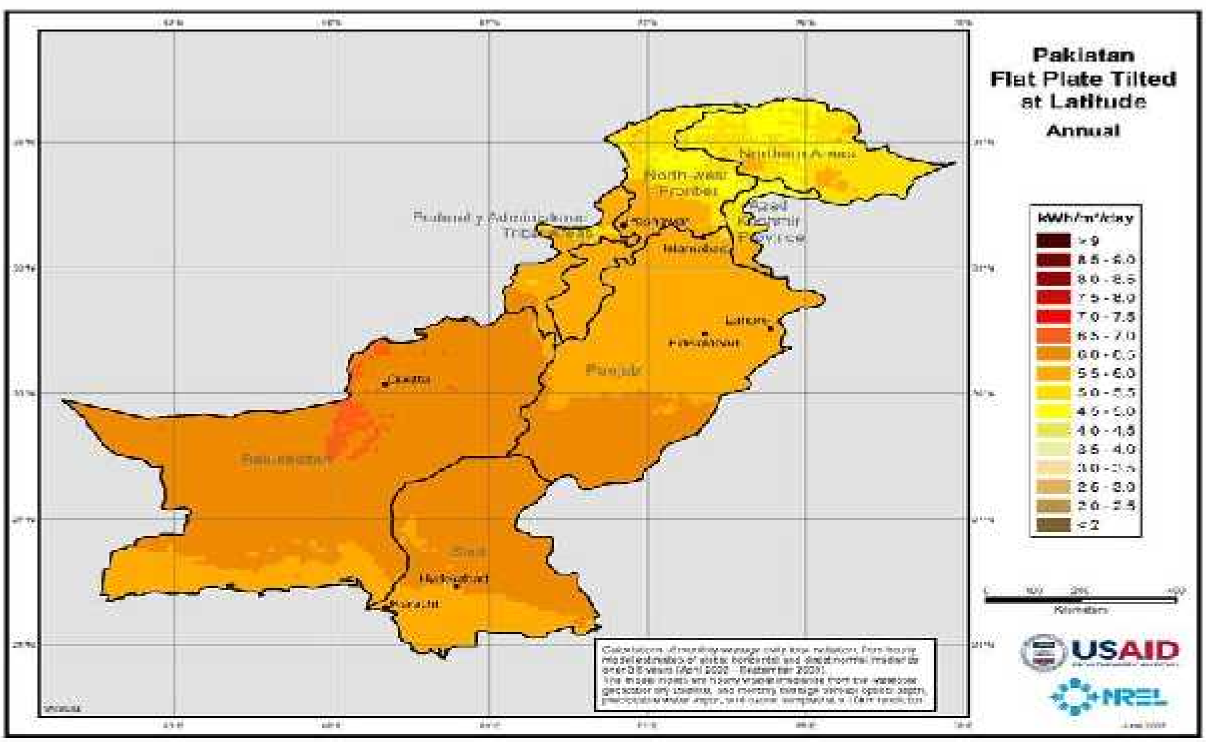


Fig. 3



4.2 Czech Republic:

Czech Republic is a central European country with a population of total 10.5 million until 2012. Its capital is Prague with a major population as compared to whole country of 1.3 million. Czech is no doubt a fast growing country in the field of generating electricity by photovoltaics. Czech has installed a 2022 MW capacity photovoltaic panels until 2012 leaving the United Kingdom, Austria, Sweden and many other leading countries far behind. Opatov photovoltaic plant is the largest photovoltaic plant till now having an annual installed capacity of 60 MW solar panels. There is going to be another big plant in consideration which is going to be made in future called kadan photovoltaics plant. This plant will have an annual capacity of 150 MW of solar cells. It had happened because of their attractive feed in tariffs in spite of low solar radiation. The first edition of Feed-in Tariff for Renewable Energy Sources was announced in 2002 by Notice of Ministry of Industry and Trade No. 252/2001 Coll. about buying of electricity from alternative energy and combined heat power production. Preference connection, transmission and supply of electricity from alternative sources were done by Energy Act (No. 458/2000 Coll.). For photovoltaic electricity generation, the Feed in tariff was fixed to futile level 6.00 CZK/kWh (about 0.21 /kWh depending on stock exchange rate CZK/EUR). That is why besides several off-grid systems, until the end of 2005, near about all photovoltaic systems were installed only under allowance programs such as Sun to Schools or Operational Program Environment and in many cases by municipal subsidies. e.g., capital city Prague provided investment subsidies up to 4,000 CZK/m^2 in 2008. Actually, all such allowances are stopped regarding too profitable FiT.

Besides of fastest growing technology, the Photovoltaic technology in The Czech Republic, like in many other European countries, are facing planned suspension of financial support, valid from 1st January 2014, without presenting any other funding tools or tariffs. The Czech Republic had an aim to achieve the 2.167 GWh of electricity from photovoltaics. But they achieved this goal by 2011 crossing the 2097 MW of installed capacity. Solar GIS (2014) GeoModel Solar have developed solar map for Czech Republic for average annual global horizontal radiation for year 2004 to 2010 shown in Fig. 4.

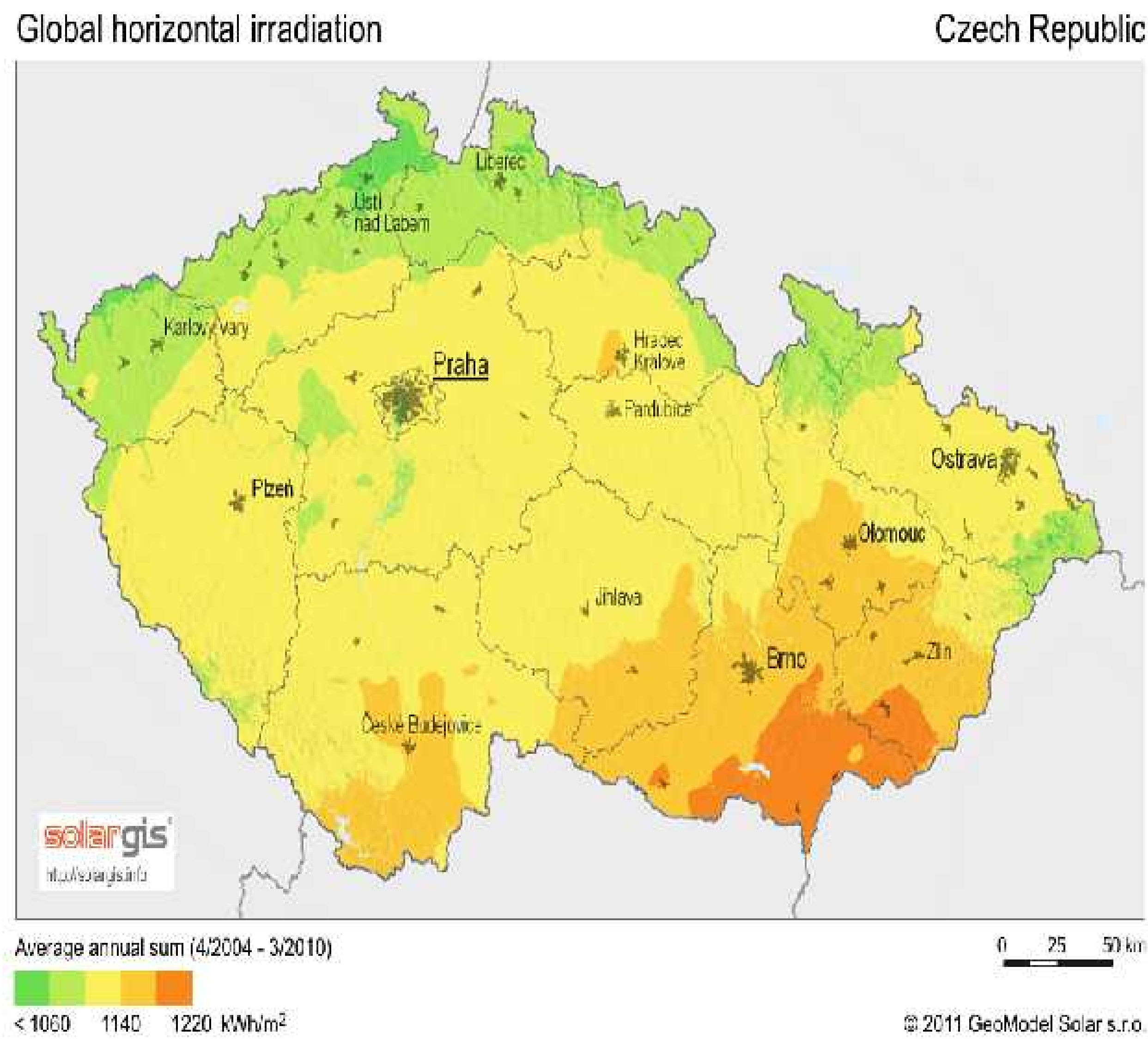


Fig. 4

4.3 Data collection:

We gather the data[1] about solar irradiation of different cities of Pakistan (including Lahore, Quetta and Karachi) and Czech Republic (including Praha, Brno and Ostrava) and compare the data of Pakistan and Czech Republic and draw different graphs to distinguish the difference between both of the countries. Then we calculated the energy output of 3 kW_p photovoltaic system for each of the city with different types of construction including fixed flat panel

[1] http://www.solarelectricityhandbook.com/solar-irradiance.html

(horizontally), inclined at a fixed optimum angle and one at adjusted angle throughout the year according to summer and winter season by the formula.

$$E = A*r*H*PR$$

Where E = Energy output in kWh for a given system,

A = Total solar panel area in m^2

r = Solar panel yield in %

H = annual average solar irradiation on panel (shadings do not included)

PR = performance ratio, coefficient for losses usually ranges 0.5 to 0.9 and we choose the 0.75 which is quite fair value.

Losses in energy output of PV system depends upon the site, technology and sizing of the system. We consider following losses during our calculations

Inverter losses = 8 %

Temperature losses = 8 %

DC cable losses = 2 %

AC cable losses = 2 %

Shadings = 3 %

Losses due to dust, snow etc. = 2 %

We determine the cost of photovoltaic system including panel, battery and inverter for both of the countries including Pakistan and Czech Republic. Then we determined the average price of electricity per kWh for grid connected supply for each of the country and then compare the energy output price with the cost of the photovoltaic system to calculate the money payback time in years. Then we also compare the energy output with the energy input to the PV system to determine the energy balance time in years and then compare the results by graphs to see results more effectively.

5.0 Results:

We gather the data of solar irradiation for different cities of Pakistan and Czech Republic and draw table for each of the country separately

Lahore solar irradiation for south direction (kWh/m^2*month)

Month	At Fixed flat plate (horizontally)	At Optimum inclination angle 32°	At adjusted inclination throughout the year	Optimum angle for particular month (degrees)
January	100.75	146.32	156.24	48°
February	119.84	158.48	164.08	40°
March	165.85	190.96	190.96	32°
April	191.7	195	199.2	24°
May	226.61	207.08	222.58	16°
June	216.6	190.2	216.6	8°
July	189.41	171.12	184.76	16°
August	175.46	169.26	177.63	24°
September	165	180	180	32°
October	155	199.33	203.98	40°
November	117.6	171.9	183.6	48°
December	98.89	152.21	168.64	56°
TOTAL	1922.71	2131.86	2248.27	

Table. 1

On the 21st December, the sun rises 75° east of due south and sets 75° west of due south. On the 21st March and 21st September, the sun rises 91° east of due south and sets 91° west of due south. On the 21st June, the sun rises 107° east of due south and sets 107° west of due south.

Whereas in Quetta, On the 21st December, the sun rises 77° east of due south and sets 77° west of due south. On the 21st March and 21st September, the sun rises 91° east of due south and set 91° west of due south. On the 21st June, the sun will rise 106° east of due south and set 106° west of due south. As you see there is a little variations in angle for sun rise and sun set in both of the cities which are from different provinces.

Quetta solar irradiation for south direction (kWh/m^2*month)

Month	At Fixed flat plate (horizontally)	At Optimum inclination angle 30°	At adjusted inclination throughout the year	Optimum angle for particular month (degrees)
January	109.74	158.1	169.26	46°
February	124.04	161.28	167.16	38°
March	163.68	185.69	185.69	30°
April	183	184.5	188.7	22°
May	214.21	195.92	210.49	14°
June	213	187.2	213	6°
July	205.84	184.76	200.26	14°
August	191.58	184.14	193.44	22°
September	170.4	184.5	184.5	30°
October	153.45	192.51	196.54	38°
November	119.4	169.8	180.9	46°
December	104.16	156.86	173.91	54°
TOTAL	1952.5	2145.26	2263.85	

Table. 2

Islamabad solar irradiation for south direction (kWh/m^2*month)

Month	At Fixed flat plate (horizontally)	At Optimum inclination angle 34°	At adjusted inclination throughout the year	Optimum angle for particular month (degrees)
January	97.03	149.11	159.65	50°
February	106.12	141.68	145.88	42°
March	151.59	176.39	176.39	34°
April	186.6	190.5	195	26°
May	224.44	205.53	221.03	18°

June	224.7	196.8	224.7	10°
July	198.4	178.87	193.44	18°
August	176.39	171.12	179.49	26°
September	168	187.5	187.5	34°
October	155.93	209.56	215.14	42°
November	114.3	177.3	189.9	50°
December	91.76	148.49	164.61	58°
TOTAL	1895.26	2132.85	2252.73	

Table. 3

Comparison of flat plate solar irradiation for three cities (Lahore, Quetta and Islamabad).

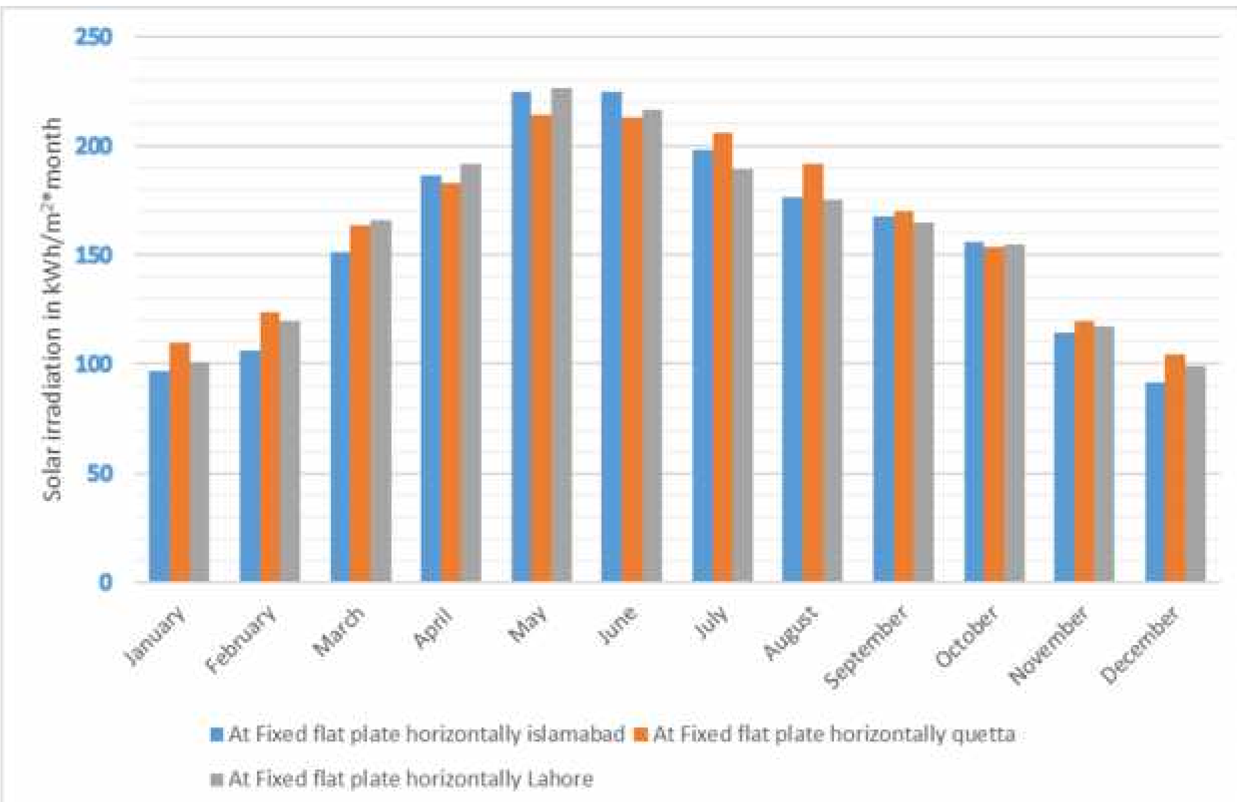


Fig. 5

Comparison of solar irradiation at fixed optimum inclination throughout the year for three cities of Pakistan (Islamabad, Quetta, and Lahore).

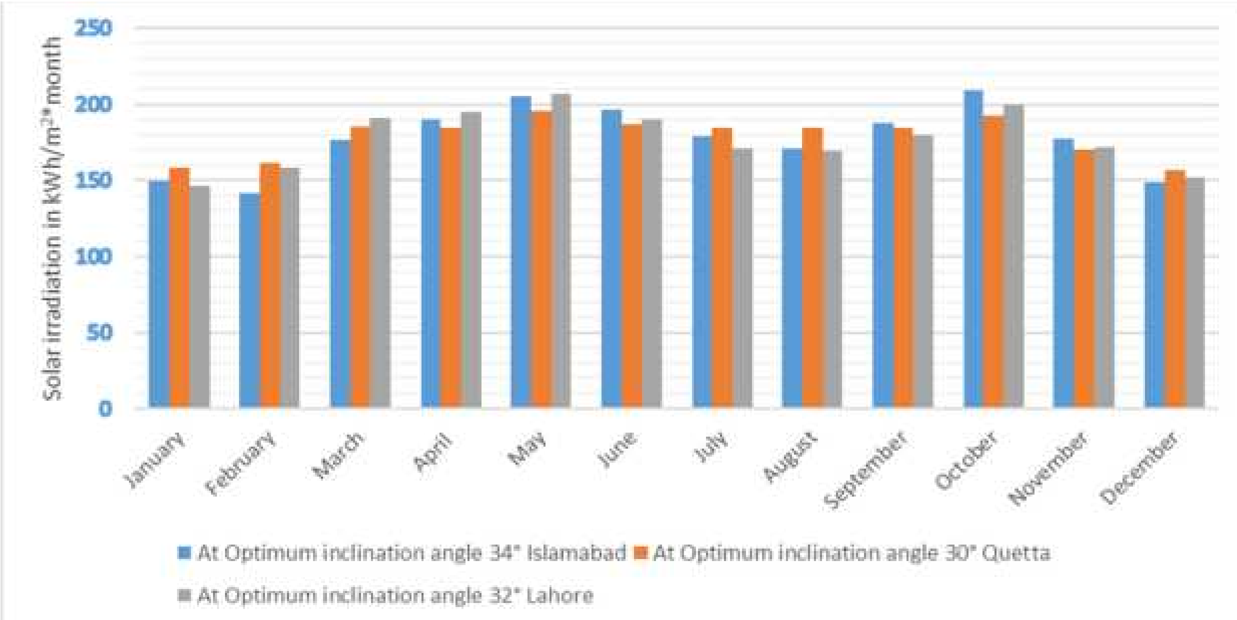


Fig. 6

Comparison of solar irradiation for adjusted inclination throughout the year for three cities of Pakistan (Islamabad, Quetta, and Lahore).

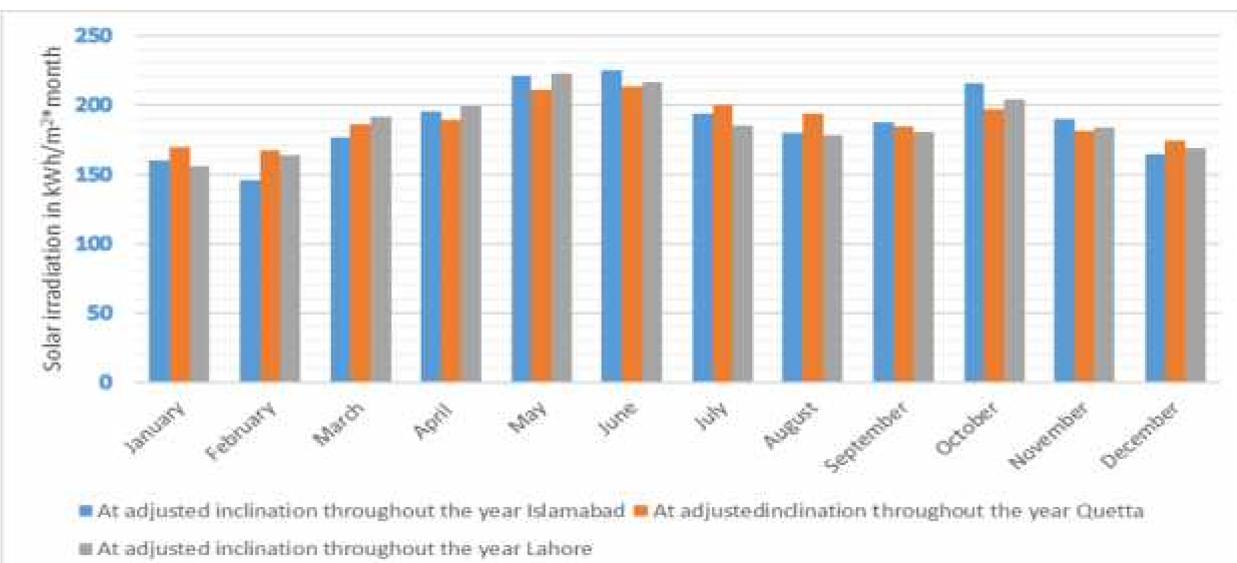


Fig. 7

Comparison of annual average solar irradiation for three cities of Pakistan

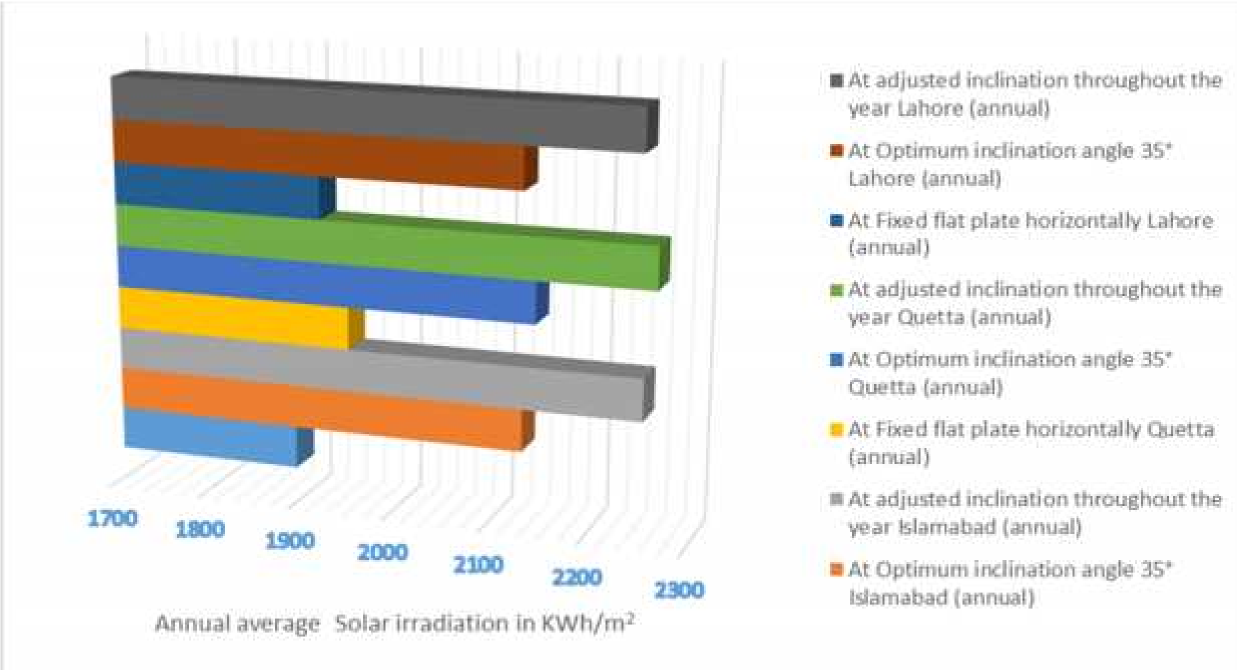


Fig. 8

Prague solar irradiation for south direction (kWh/m^2*month)

Month	At Fixed flat plate (horizontally)	At Optimum inclination angle 35°	At adjusted inclination throughout the year	Optimum angle for particular month (degrees)
January	28.52	48.98	50.22	66°
February	47.6	71.68	72.24	58°
March	79.36	95.79	95.79	50°
April	114.3	117.9	123.6	42°
May	146.94	133.3	144.46	34°
June	144.3	124.5	145.8	26°
July	150.66	132.68	145.39	34°
August	137.02	135.78	145.39	42°
September	85.8	98.4	98.4	50°
October	52.7	73.78	73.78	58°

November	27.3	42.6	42.9	66°
December	21.7	38.13	39.37	74°
TOTAL	1036.2	1113.52	1177.34	

Table. 4

Brno solar irradiation for south direction (kWh/m^2*month)

Month	**At Fixed flat plate (horizontally)**	**At Optimum inclination angle 35°**	**At adjusted inclination throughout the year**	**Optimum angle for particular month (degrees)**
January	32.24	55.18	56.73	65°
February	51.8	77.84	78.4	57°
March	87.11	106.02	106.02	49°
April	120.3	124.5	130.5	41°
May	156.55	142.91	154.38	33°
June	149.4	129	150.9	26°
July	155	136.71	149.73	33°
August	139.19	137.95	147.56	41°
September	90.9	104.4	104.4	49°
October	55.18	76.57	76.57	57°
November	30.6	47.7	48.3	65°
December	25.11	43.71	45.26	72°
TOTAL	1093.38	1182.49	1248.75	

Table. 5

Ostrava solar irradiation for south direction (kWh/m^2*month)

Month	**At Fixed flat plate (horizontally)**	**At Optimum inclination angle 35°**	**At adjusted inclination throughout the year**	**Optimum angle for particular month (degrees)**
January	32.24	55.49	57.04	66°
February	50.68	76.72	77.28	58°

March	84.01	101.99	101.99	50°
April	111.3	114.3	119.7	42°
May	146.63	133.61	144.46	34°
June	142.2	123.6	143.4	26°
July	149.42	132.37	144.77	34°
August	135.16	133.92	143.22	42°
September	88.8	102.3	102.3	50°
October	54.56	75.95	76.26	58°
November	30.9	48.9	49.8	66°
December	25.73	46.19	47.74	74°
TOTAL	1051.63	1145.34	1207.96	

Table. 6

Comparison of flat plate solar irradiation for three cities of Czech Republic (Prague, Brno and Ostrava).

Fig. 9

Comparison of solar irradiation at fixed optimum inclination throughout the year for three cities of Czech Republic (Prague, Brno and Ostrava).

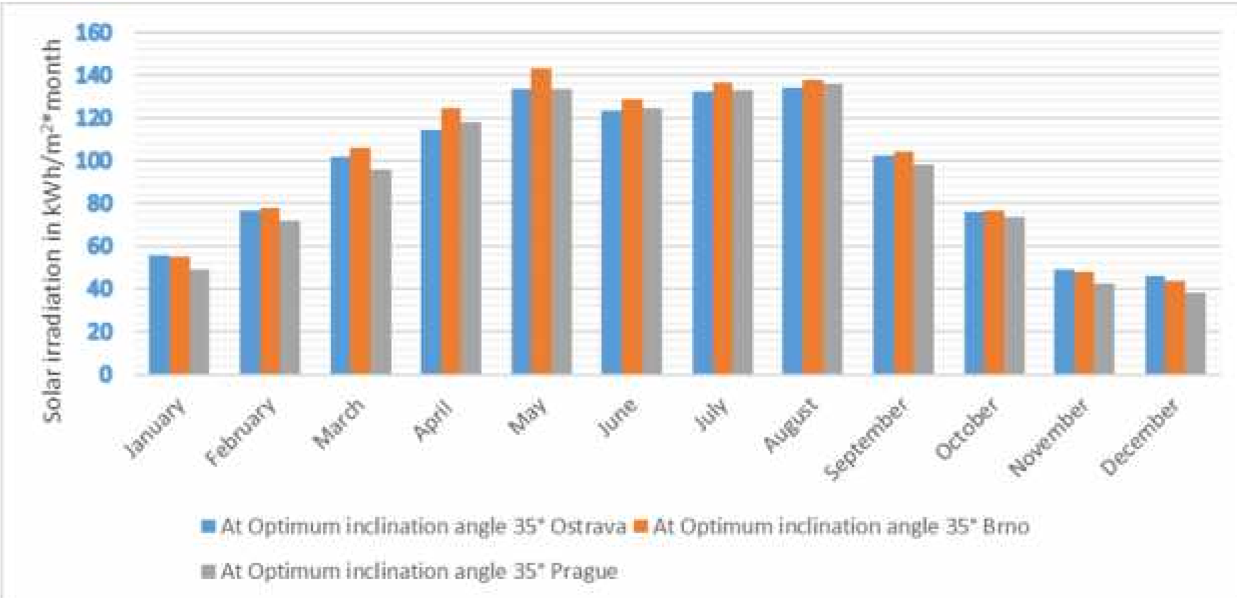


Fig. 10

Comparison of solar irradiation for adjusted inclination throughout the year for three cities of Czech Republic (Prague, Brno and Ostrava).

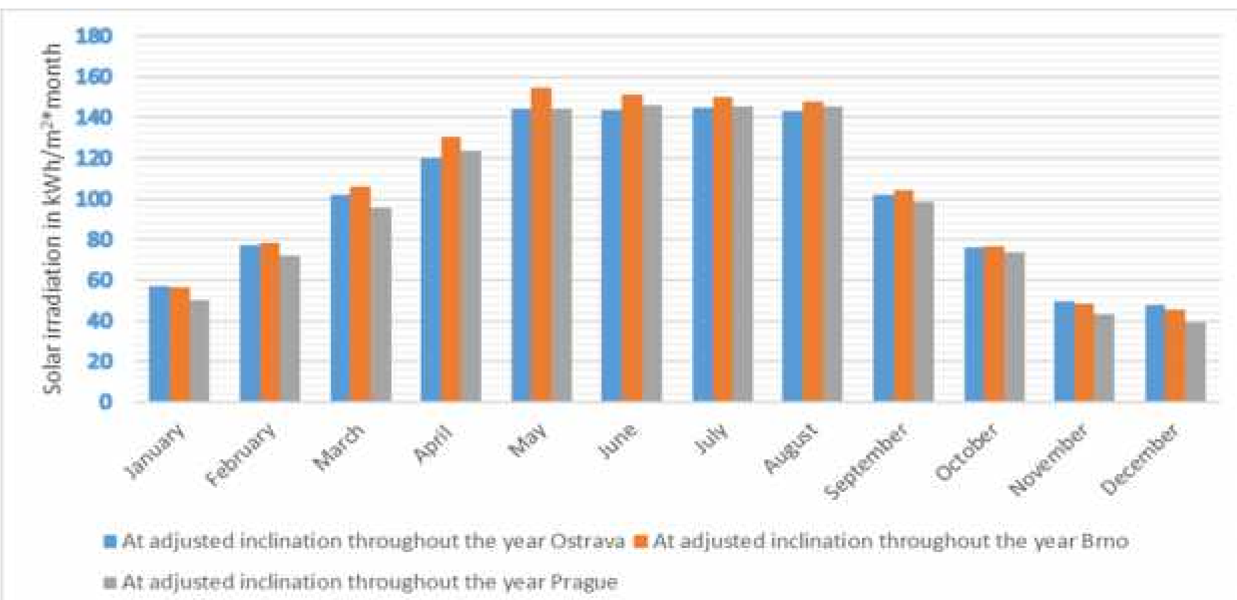


Fig. 11

Comparison of annual average solar irradiation for three cities of Czech Republic

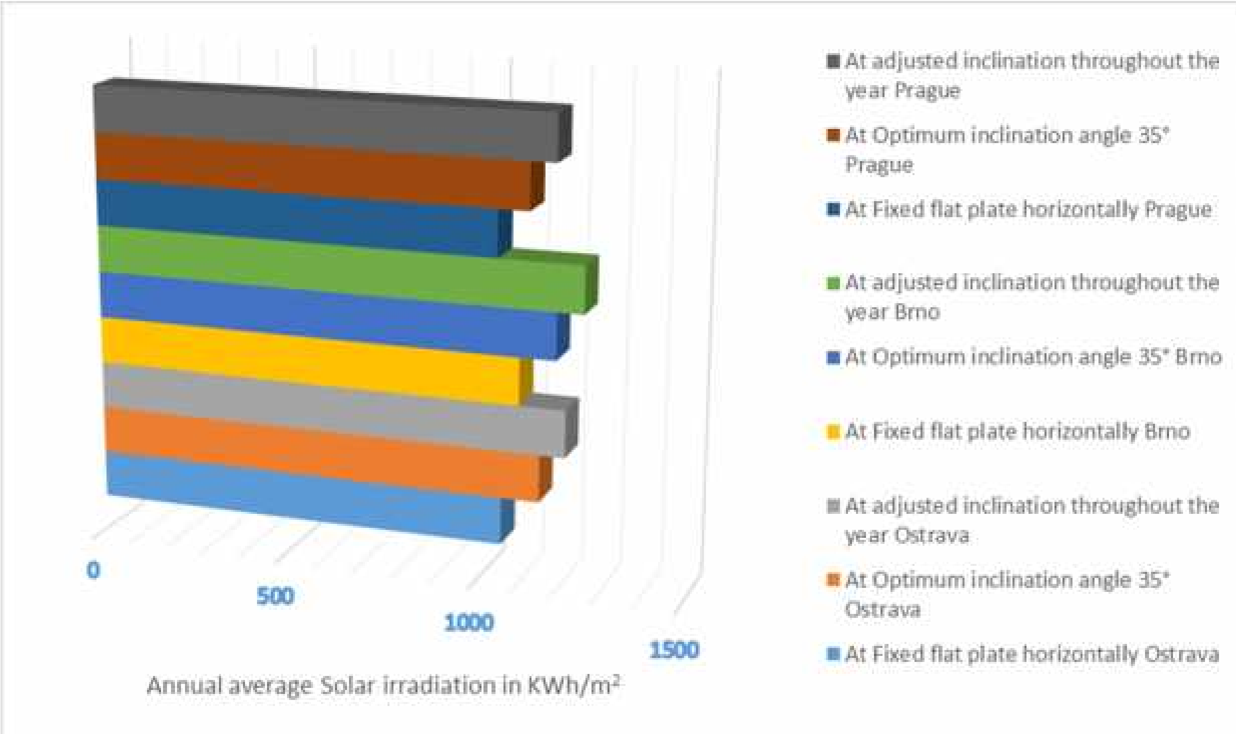


Fig. 12

5.1 Energy Production:

Energy Output of 3 kW photovoltaic system for Lahore (kWh/month).

Month	At Fixed flat plate (horizontally)	At Optimum inclination angle 32°	At adjusted inclination throughout the year
January	227	329.22	351.54
February	269.64	356.58	369.18
March	373.16	429.66	429.66
April	431.33	438.75	448.2
May	509.87	465.93	500.81
June	487.35	427.95	487.35

July	426.17	385.02	415.71
August	394.79	380.84	399.66
September	371.25	405	405
October	348.75	448.49	458.96
November	264.6	386.78	413.1
December	222.50	342.47	379.44
TOTAL	4326.41	4796.69	5058.61

Table. 7

Energy Output of 3 kW photovoltaic system for Quetta (kWh/month).

Month	**At Fixed flat plate (horizontally)**	**At Optimum inclination angle 30°**	**At adjusted inclination throughout the year**
January	246.91	355.73	380.84
February	279.09	362.88	376.11
March	368.28	417.80	417.80
April	411.75	415.13	424.58
May	481.97	440.82	473.60
June	479.25	421.2	479.25
July	463.14	415.71	450.59
August	431.05	414.32	435.24
September	383.4	415.13	415.13
October	345.26	433.15	442.22
November	268.65	382.05	407.03
December	234.36	352.94	391.30
TOTAL	4393.11	4826.86	5093.69

Table. 8

Energy Output of 3 kW photovoltaic system for Islamabad (kWh/month).

Month	**At Fixed flat plate (horizontally)**	**At Optimum inclination angle 34°**	**At adjusted inclination throughout the year**
January	218.32	335.50	359.21
February	238.77	318.78	328.23
March	341.08	396.88	396.88
April	419.85	428.63	438.75
May	504.99	462.44	497.31
June	505.58	442.8	505.58
July	446.4	402.46	435.24
August	396.88	385.02	403.85
September	378	421.88	421.88
October	350.84	471.51	484.07
November	257.18	398.93	427.28
December	206.46	334.10	370.37
TOTAL	4264.35	4798.93	5068.65

Table. 9

Comparison of electricity production of 3 kW PV system in Lahore.

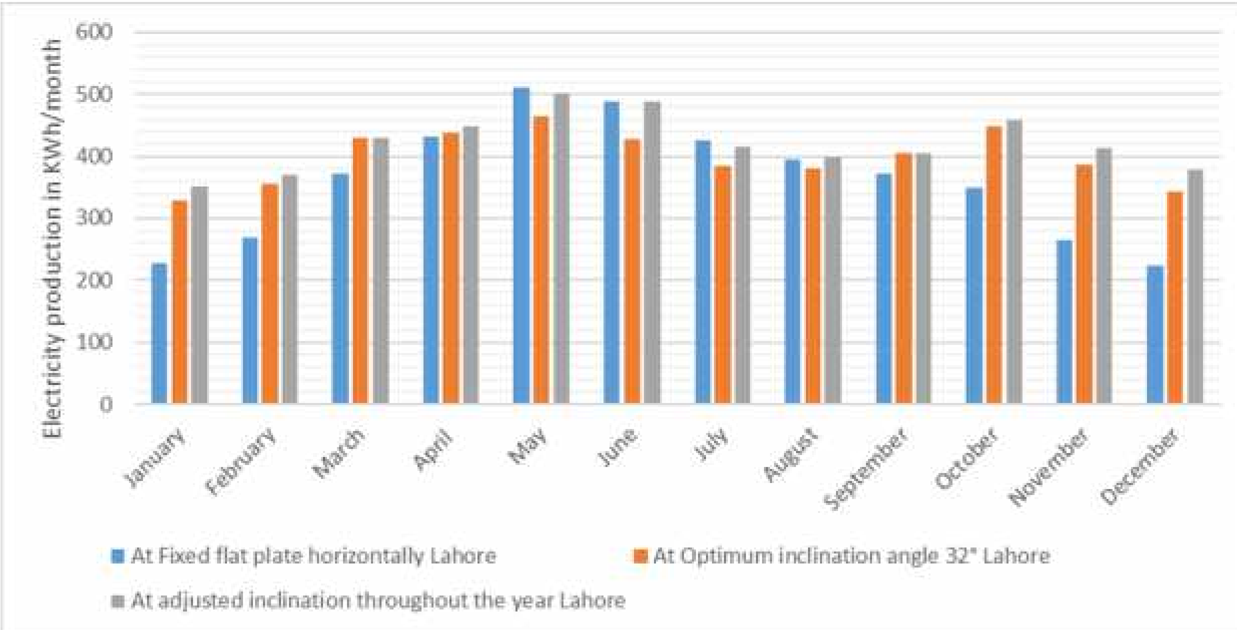


Fig. 13

Comparison of electricity production of 3 kW PV system in Quetta.

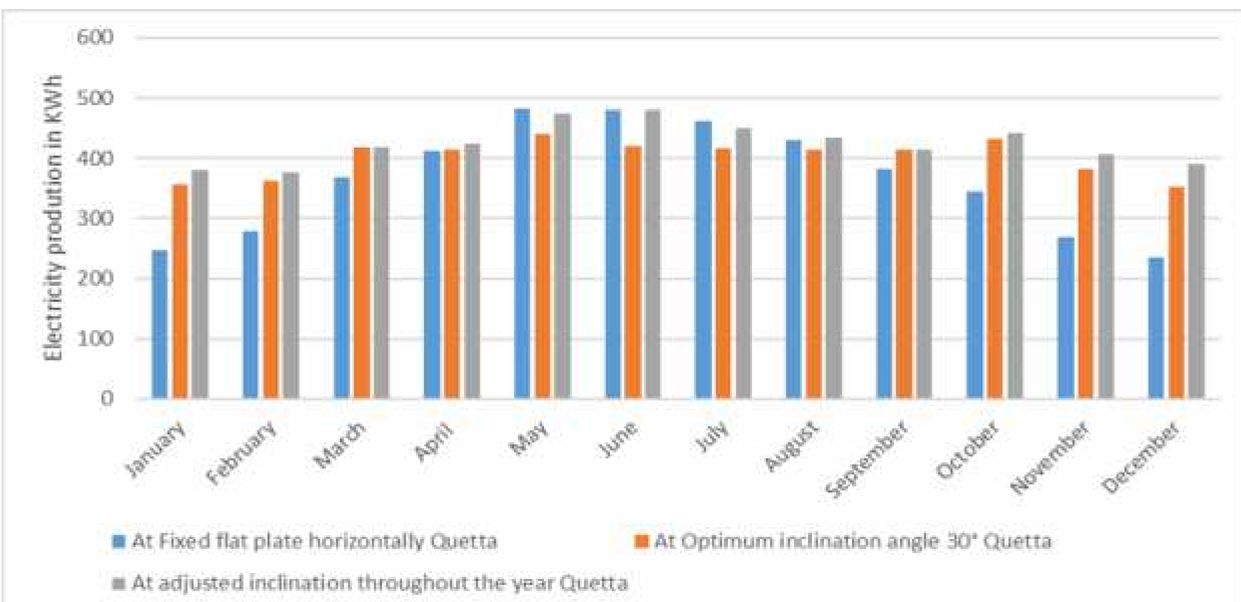


Fig. 14

Comparison of electricity production of 3 kW PV system in Islamabad.

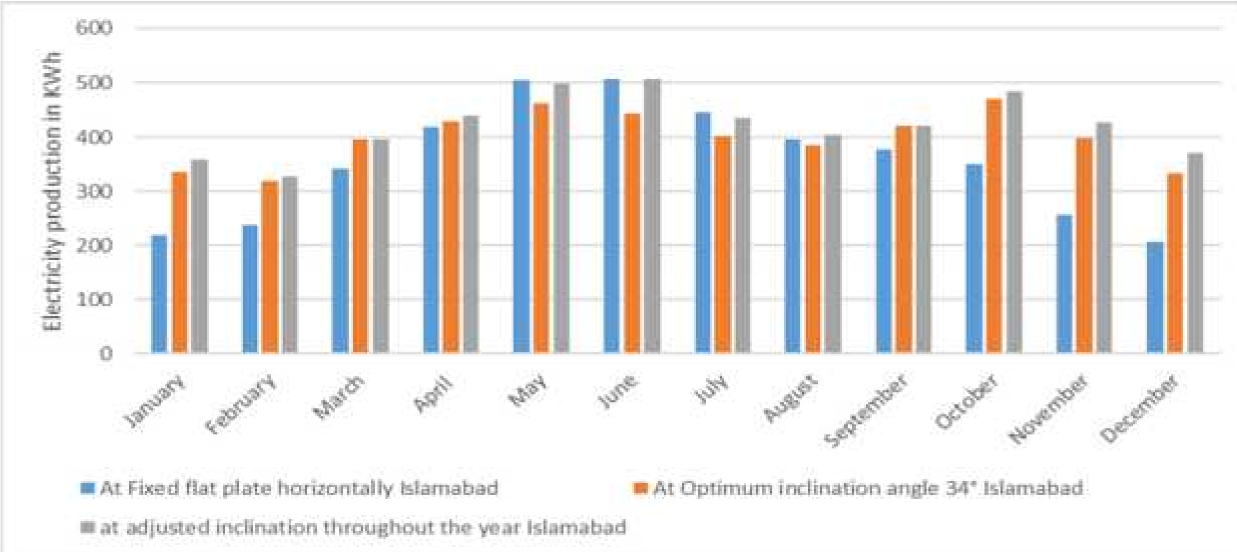


Fig. 15

Comparison of annual production of electricity by 3 kW PV system in three cities of Pakistan

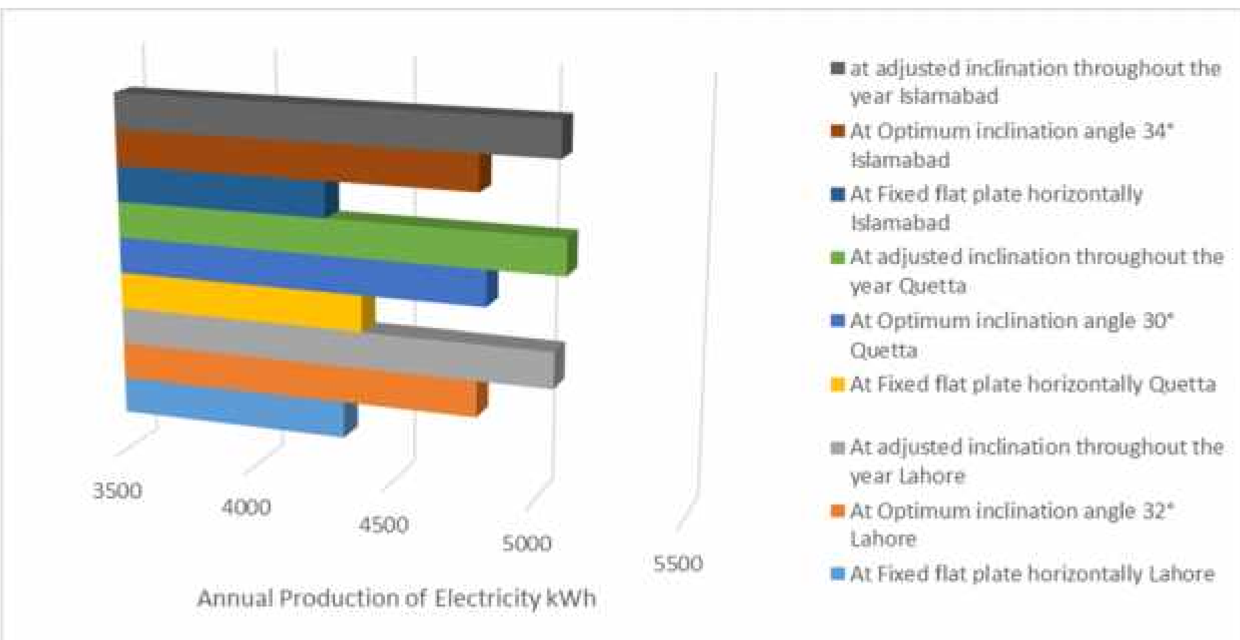


Fig. 16

Energy Output of 3 KW photovoltaic system for Prague (kWh/month).

Month	**At Fixed flat plate horizontally**	**At Optimum inclination angle 35°**	**At adjusted inclination throughout the year**
January	64.17	110.21	113
February	107.1	161.28	162.54
March	178.56	215.53	215.53
April	257.18	265.28	278.1
May	330.62	299.93	325.04
June	324.68	280.13	328.05
July	338.99	298.53	327.13
August	308.30	305.51	327.13
September	193.05	221.4	221.4
October	118.58	166	166
November	61.43	95.85	96.53
December	48.83	85.79	88.58
TOTAL	2331.49	2505.44	2649.03

Table. 10

Energy Output of 3 KW photovoltaic system for Brno (kWh/month).

Month	**At Fixed flat plate horizontally**	**At Optimum inclination angle 35°**	**At adjusted inclination throughout the year**
January	72.54	124.16	127.64
February	116.55	175.14	176.40
March	196.00	238.55	238.55
April	270.68	280.13	293.63
May	352.24	321.55	347.36

June	336.15	290.25	339.53
July	348.75	307.60	336.89
August	313.18	310.39	332.01
September	204.53	234.90	234.90
October	124.16	172.28	172.28
November	68.85	107.33	108.68
December	56.50	98.35	101.84
TOTAL	2460.11	2660.60	2809.69

Table. 11

Energy Output of 3 KW photovoltaic system for Ostrava (kWh/month).

Month	**At Fixed flat plate horizontally**	**At Optimum inclination angle 35°**	**At adjusted inclination throughout the year**
January	72.54	124.85	128.34
February	114.03	172.62	173.88
March	189.02	229.48	229.48
April	250.43	257.18	269.33
May	329.92	300.62	325.04
June	319.95	278.10	322.65
July	336.20	297.83	325.73
August	304.11	301.32	322.25
September	199.80	230.18	230.18
October	122.76	170.89	171.59
November	69.53	110.03	112.05
December	57.89	103.93	107.42
TOTAL	2366.17	2577.02	2717.91

Table. 12

Comparison of electricity production of 3 KW PV system in Prague

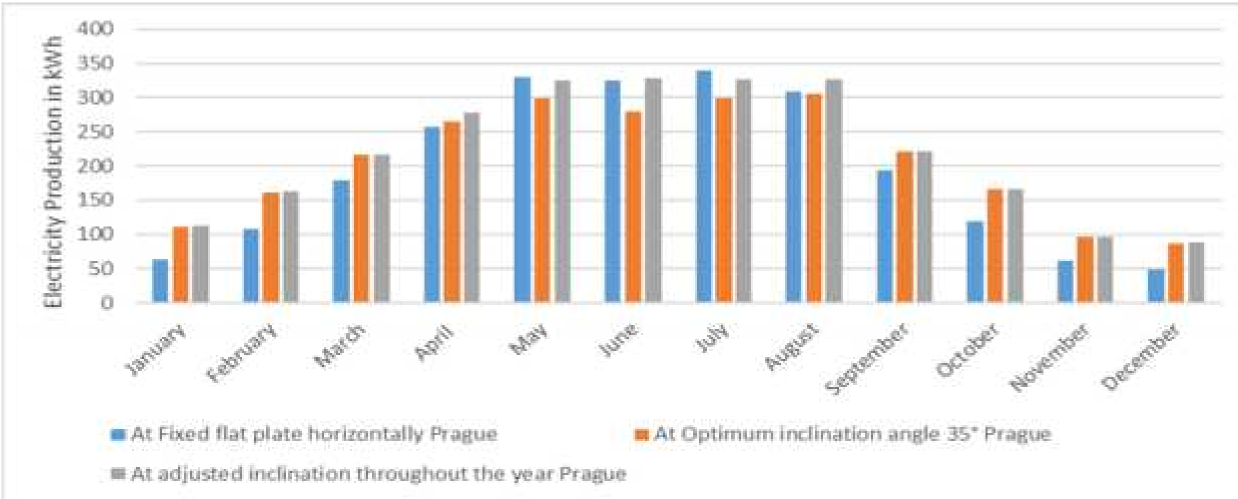


Fig. 17

Comparison of electricity production of 3 KW PV system in Brno

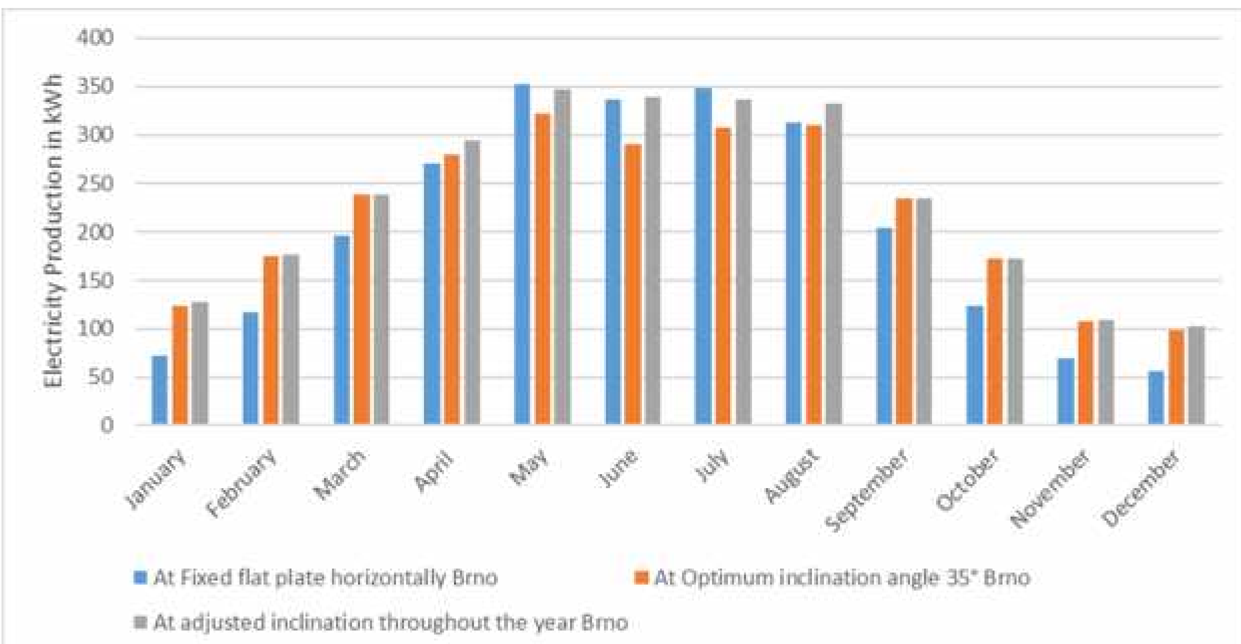


Fig. 18

Comparison of electricity production of 3 KW PV system in Ostrava

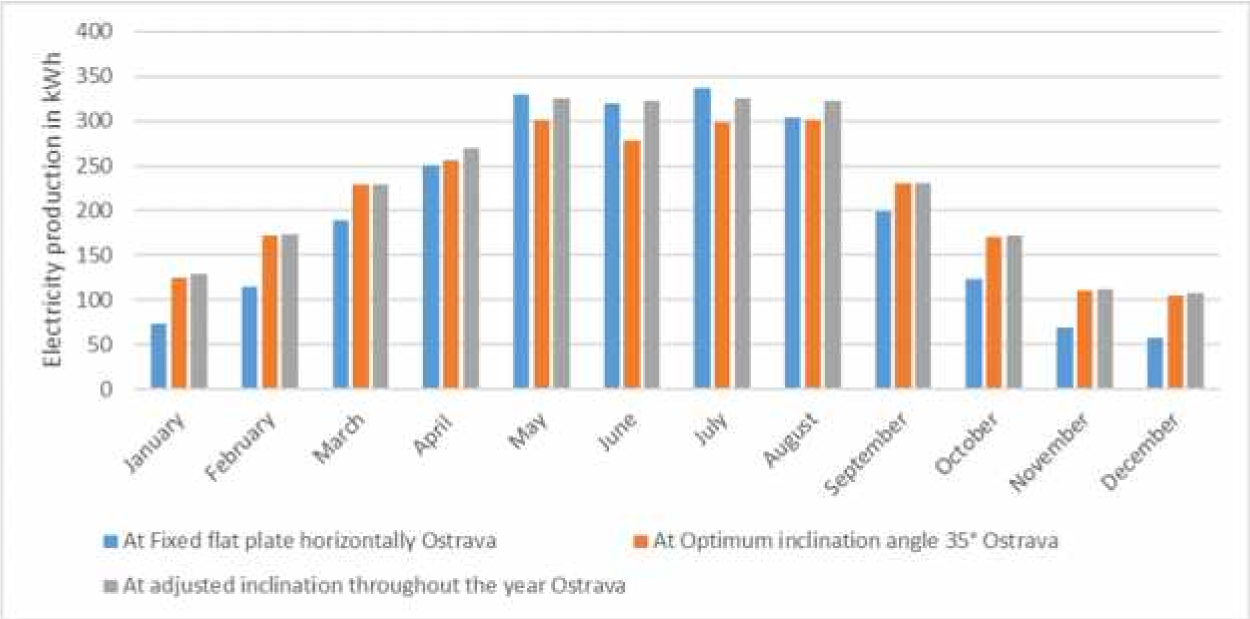


Fig. 19

Comparison of total annual production of electricity of 3 KW PV system in three cities of Czech Republic

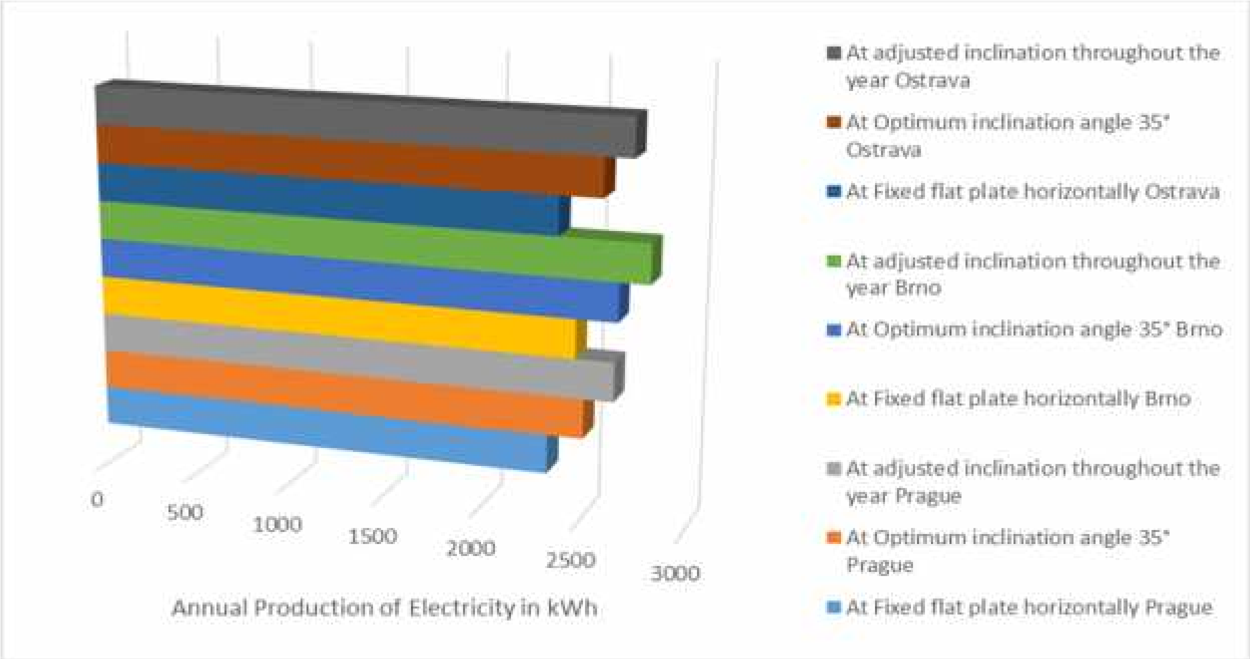


Fig. 20

If we compare the graphs of electricity production of 3 kW PV system on monthly basis, it is clear that the maximum production of electricity in Pakistan reaches to nearly 500 kWh during May and June months for all construction possibilities whereas maximum production in Czech Republic is nearly reaching to 350 kWh during summer. However lowest production of electricity in any month in Pakistan is exceeding 200 kWh for all of the construction possibilities whereas the lowest production of electricity in Czech Republic reaches to 50 kWh for all construction possibilities. The average production of electricity at adjusted inclination, which is the best construction possibility for both of the countries, in Pakistan is approximately 400 kWh and 200-250 kWh for Czech Republic. If we have a look at the annual production of electricity graph then we can easily see that the maximum production of electricity in all of the three cities of Pakistan is exceeding 5000 kWh/year whereas in Czech Republic it reaches to 2800 kWh/year for Brno and 2600 and 2700 for Prague and Ostrava respectively which is roughly half of the production of Pakistan. This shows the huge difference in electricity production in both of the countries by same PV system.

5.2 Energy Payback Time:

Balance of energy necessary for manufacturing photovoltaic panels based on polycrystalline silicon with the maximum output of 3 kW is 16800 kWh (LIBRA & POULEK, 2010). Among these 8571 kWh for material consumption and 8229 kWh for manufacturing processes. We calculated the energy required to balance this energy to measure the feasibility of 3 kW photovoltaic system and determined the time in years. The below table describe the time required to balance this energy consumption for all above mentioned construction types.

Time required to balance the energy consumed during production in years

Cities	**At Fixed flat plate horizontally**	**At Optimum inclination angle 35°**	**At adjusted inclination throughout the year**
Lahore	3.88	3.50	3.32
Quetta	3.82	3.48	3.30

Islamabad	3.94	3.50	3.31
Prague	7.21	6.71	6.34
Brno	6.83	6.31	5.98
Ostrava	7.10	6.52	6.18

Table. 13

Comparison of time required to balance the energy consumed during production for different cities of Pakistan and Czech Republic

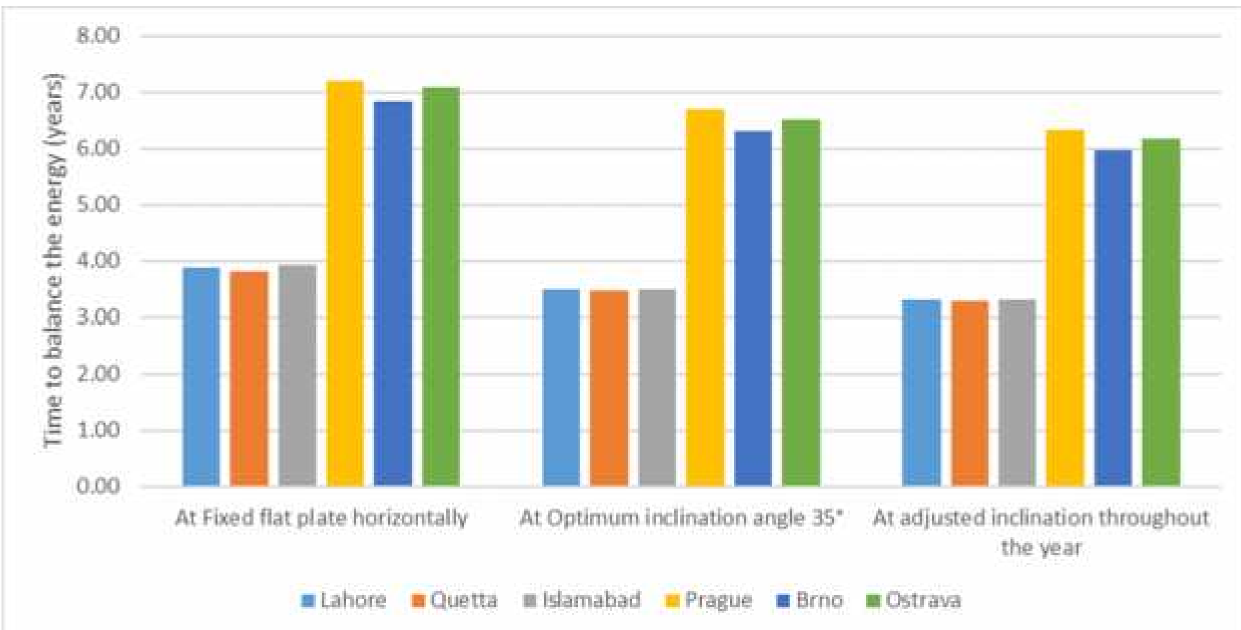


Fig. 21

As we can see in Fig. 21 that time required to balance the energy for cities of Pakistan ranges from 3-4 years whereas for Czech Republic it ranges between 6-7 years and even more in some cases for all types of construction.

5.3 Price payback time:

Cost[2] of 3 kW photovoltaic system including panels, battery and inverter is approximately 10000 US $ for Pakistan[3] whereas in Czech Republic it is 9153 US $. Price of electricity by grid is approximately 0.15[4] US $ per kWh for Pakistan and 0.21[5] US $ per kWh for Czech Republic. We calculated the price recovery per year price payback time in years for above mentioned cities of Pakistan and Czech Republic under different construction possibilities. This calculation is based on the current tariff of electricity the people are paying in their respective countries.

Price payback time (years)

	price recovery per year ($)			Price payback time (years)		
Cities	**At Fixed flat plate horizontally**	**At Optimum inclination angle 35°**	**At adjusted inclination throughout the year**	**At Fixed flat plate horizontally**	**At Optimum inclination angle 35°**	**At adjusted inclination throughout the year**
Lahore	648.96	719.50	758.79	15.41	13.90	13.18
Quetta	658.97	724.03	764.05	15.18	13.81	13.09
Islamabad	639.65	719.84	760.30	15.63	13.89	13.15
Prague	489.61	526.14	556.30	18.69	17.40	16.45
Brno	516.62	558.73	590.03	17.72	16.38	15.51
Ostrava	496.90	541.17	570.76	18.42	16.91	16.04

Table: 14

2 As of March 17, 2014 conversion rate.
3 http://solarpower.pk/prices.html
4 http://tribune.com.pk/story/591588/cost-of-production-high-electricity-rates-spread-panic/
5 http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Electricity_and_natural_gas_price_statistics

As you can see that there is a little difference in price payback time for both of the countries despite of being lot of difference in their average annual irradiation. This is due to the fact that people in Czech Republic is paying more money for electricity per kWh as compared to people of Pakistan in the current scenario. If we consider the life of photovoltaic panel 25 years which is quite fair then its energy production price for whole life cycle according to current rate will be 18000 US $ approximately for Pakistan and 13500 US $ approximately for Czech Republic which will not only cover the cost of the system but also have the ability to gain the profits and in future when there will be a shortage of fossil fuels and price of electricity will increase then it will cover its price more rapidly and will provide more cheaper electricity.

5.4 Discussion:

As we saw that Pakistan is despite of being an energy rich country, price payback time is very high, this is just because of high panel prices in Pakistan and low electricity prices as compared to Czech Republic. Czech Republic have done a significant work on attaining the desired target of energy production by renewable energy resources by offering high feed in tariff prices by government which not only helped to gain the target early as compared to desired time but also it helped to familiarize the people with the importance of renewable energy and its benefits which definitely will help in long term scenario. But Pakistan is far behind in adopting renewable energy especially photovoltaics as they have installed the 300 kW of photovoltaic plant only in Islamabad until 2012 which looks like a small fraction as compared to more than 2 GW of installed photovoltaic system of Czech Republic until 2012. Government of Pakistan is now planning to install more photovoltaic system until 2014. It is expected that they will install 300 MW of photovoltaic system in different parts of country. One major factor in success of Czech Republic in the field of renewable energy resources is their subsidy policy which should be adopted by Pakistan to make the people more familiar with solar energy and it is quite likely that in the current scenario of extreme load shedding and power cut off, this subsidy will be much welcome by Pakistani people as it is the top most priority for the people now a days to get the desired level of electricity and do their usual daily work. It can be even helpful for small scale business services.

6.0 Conclusion:

It is quite clear from the above mentioned results that solar energy have more potential in Pakistan as compared to Czech Republic due to high solar irradiation available for photovoltaic system. Energy output of photovoltaic system in Pakistan is twice as compared to Czech Republic and energy payback time is also half as compared to Czech Republic. This clearly shows its feasibility for adoption of PV technology in Pakistan in contrast to Czech Republic. But there is a little difference in price payback time as it is showing not much difference in terms of economy due to the electricity price per kWh is higher in Czech Republic as compared to Pakistan and panel prices are also higher in Pakistan. And hence it shows a little difference of 2-3 years in between them to payback the price of a given system. This should be keep in mind that during above calculations inflation did not considered as it is also the major factor in predicting the feasibility of any given system. Electricity prices in Pakistan has been raised to 3-4 times within 5-6 years which is due to their dependency on electricity generation by conventional fossil fuels which is very expensive and so by the time when there will be more price increase in electricity, the feasibility of PV system will be higher and prices of the PV system will also decrease as there will be more and more people will find their solution towards more abundantly available cheap renewable resources which ultimately increase its adoption and decrease the cost.

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Abbreviations:

AC………………………… Alternating Current

ASP………………………. Average selling price

BOS……………………….. Balance of System

BIPV…………………......... Building integrated photovoltaics

BAPV……………………... Building applied photovoltaics

CDM……………………… Clean development mechanism

DC………………………… Direct Current

EHCS……………………… English house condition survey

EPBT……………………… Energy payback time

EROI……………………… Energy return on investment

ERF……………………….. Energy return factor

EU………………………… European Union

FiT………………………... Feed in tariff

GDP………………………. Gross domestic product

GER………………………. Gross energy requirement

GHG……………………… Greenhouse gases

GIS……………………….. Geographical information systems

GW……………………….. Gigawatt

GWP……………………... Global warming potential

hp………………………… Horse power

kWh……………………… Kilowatt hour

LCA……………………… Life cycle analysis

mW………………………..... milli watt

NEPA……………………… National electric power authority

NREL……………………… National renewable energy laboratory

OECD……………………... Organization of economic co-operation and development

LED……………………….. Light emitting diode

PV…………………………. Photovoltaics

PVP………………………... Photovoltaic powered

SHS………………………... Solar home systems

UNFCCC………………….. United Nations framework conventions on climate change