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# A Review of Solar Energy in Pakistan: Current Status and Future Prospects

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**Abstract:** From the past few decades, Pakistan is facing serious energy crisis, owing to heavy dependence on fossil fuels, depletion of local fossil fuel reserves at a faster pace, heavy burden on the national exchequer, due to import of oil, etc. Renewable energy, in general, and solar energy, in particular, has the potential to mitigate our energy problems. Although, Pakistan lies in the Sun-Belt and receives plentiful solar irradiation of over 2 MWh/m$^2$ and 1500-3000 sunshine hours every year, unfortunately, we have not been very successful to harness solar energy to its full potential, due to different factors, such as, initial high cost associated with solar panels, maintenance issues, import duties, lack of supportive policies, lack of awareness and lack of R&D, in this specific area. Solar energy has the advantages of providing off-grid solutions to the un-electrified rural population, decreasing deforestation, energy security as solar energy is locally available, sustainable and need not to be imported, providing green energy, etc. The various applications of solar energy in Pakistan, include; photovoltaic and solar thermal application, such as, solar water heaters, solar cooker, solar dryers and solar desalination. Government has taken a number of initiatives for the development of solar energy in Pakistan. A number of national office buildings have been converted to grid connected solar energy. The first 100 MW solar power plant in the proposed 1000 MW Quaid-i-Azam Solar Power Park, has become functional. Other incentives include tax reduction on solar PVs and introduction of net metering systems, etc. Factors, such as, supportive policies, raising awareness, strengthening R&D activities and private sector participation in the solar energy sector, can contribute significantly to the development of solar energy sector to its full potential..

**Key words:** Energy crisis, Solar energy applications, Quaid-i-Azam solar power park, Solar potential of Pakistan.

## INTRODUCTION

Energy remains the lifeline and the key component for economic and social development, business activities, industrialization and improvement of living standards. The socioeconomic activities of a country are closely linked with the continuous, affordable and sustainable supplies of energy. Increasing industrialization and urbanization have created an increased demand for energy over the past few years (Fatai *et al*., 2004; Muneer *et al.*, 2006). In Pakistan, energy requirements are being met mainly through oil and gas, which make about 70% of our energy requirements. The demand of electricity is higher than the supply, due to which, load shedding is being observed both in rural and urban areas of the country.

Overdependence on fossil fuels, such as, oil and gas has led to a number of environmental challenges on one hand and placing a huge burden on the national exchequer on the other hand. Harnessing renewable energy resources is not only important in terms of offsetting the climatic challenges associated with the fossil fuels but it also reduces the oil import bill and provides energy security to the country.

Many countries have taken initiatives to use renewable energy resources for producing electricity. South Asian countries, including India and Bangladesh, have made major advancements in increasing the share of renewable energy in the total energy mix. Various efforts have been made from the past several years to increase the share of renewable in the country, however, their current contribution remains very low.

Due to electricity shortages and long power outages, the industries were forced to shut down resulting in huge economic loss. Agriculture and domestic sectors also suffered immensely. Currently, Pakistan faces about 5-6,000 MW of power shortages**.** This gap between demand and supply is highly pronounced during the summer season. The per capita electricity consumption of Pakistan is lower than even some of the South Asian countries. Table 1 provides a comparison of per capita electricity consumption in various South Asian countries.

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**Table 1: Comparison of per capita electricity consumption in various South Asian countries.**

| No. | Country | Per capita consumption of electricity in kWh |
|---|---|---|
| 1 | India | 644 |
| 2 | Sri Lanka | 637 |
| 3 | Pakistan | 457 |
| 4 | Bangladesh | 278.1 |

**Source:** Ahmed *et al*., 2016.

With the ever increasing population, energy demand in Pakistan is expected to increase eight-fold by 2030 and about 20 fold by 2050. The annual demand for electricity in Pakistan is growing over 9%(IPRI, 2015). The main energy sources of Pakistan are oil and gas, hydropower, nuclear and a minor contribution of renewable, including solar, wind and biomass, etc.

During 2013, the total energy supply was 64.5 million tons of oil equivalents (MTOE). The primary energy sources were Oil approx. 21 MTOE, Gas 31 MTOE, LPG about 0.3 MTOE, Coal around 4.0 MTOE, Hydroelectricity about 7.0 MTOE, Nuclear electricity approx. 1 MTOE and imported energy about 0.08 MTOE with different levels of share (**HDIP**, 2013).

Amongst the various renewable energy resources, solar energy has full potential to answer the energy challenges of the country. Pakistan is blessed with extensive sunlight throughout the year as it lies in the Sun Belt. Therefore, we need to harness existing solar potential in addressing and overcoming our energy challenges. Suitable and timely exploitation of the solar energy resources of the country is the need of the hour. Public and private sector investment in solar energy is important for harnessing its true potential.

The total installed capacity of electricity generation in Pakistan in the year 2015 was 23,759 MW. The installed capacity of electricity generation in Pakistan by type (source) is given in Table 2 (**HDIP**, 2015).

**Table 2: Installed capacity of electricity by type.**

| Type | Electricity installed capacity (MW) |
|---|---|
| Thermal (Oil, Gas, Coal) | 15,541 |
| Hydel | 7,030 |
| Nuclear | 750 |
| Renewable | 438 |
| **Total** | **23,759** |

**Source:** Pakistan Energy Year Book 2015, HDIP, M/o Petroleum and Natural Resources.

Of the total electricity generated in Pakistan in 2015, 63.5% share was from thermal (including 36.8% from oil, 26.6% was from Gas and 0.1 % from Coal), 30.4% was from Hydel, 5.4% was from Nuclear and only 0.7% was from Renewable Energy Resources (**HDIP**, 2015) as depicted in Fig. 1 below:

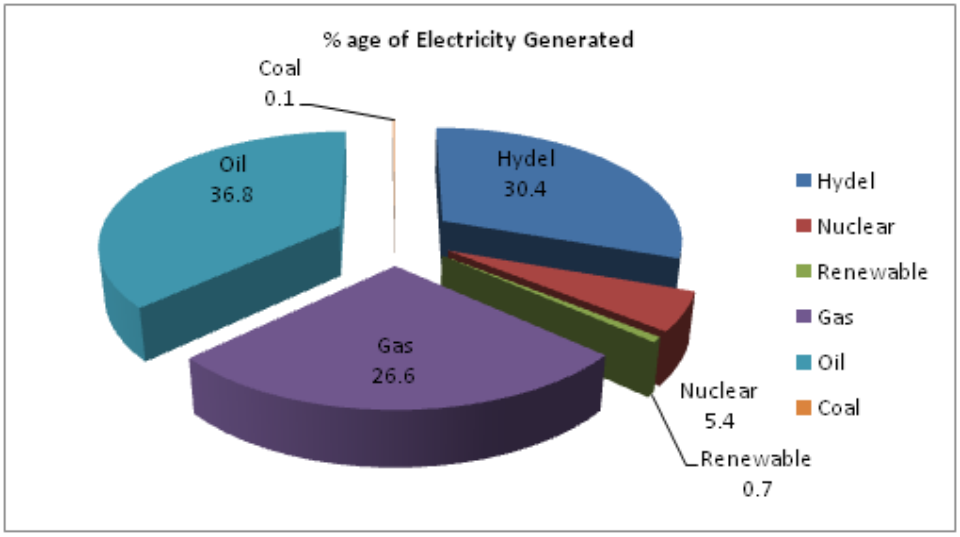


**Fig. 1: Percentage of electricity generated from source of energy.**

**Source:** Pakistan Energy Year Book 2015, HDIP, M/o Petroleum and Natural Resources.

## PREVALENT ENERGY CRISIS

From the past few years, Pakistan is experiencing extreme energy shortage, which is not only adversely affecting the life of the common man but also creates impediments in the socio economic development of the country. The industry has suffered badly due to the prevailing energy crisis, resulting in its decline (Javed *et al*., 2016).

Besides the industry, other sectors, including the transport sector, domestic sector and power generation sectors, have also suffered due to this energy crisis. There is a huge gap between the demand and supply in the power generation sector. Furthermore, the costs of electricity have also increased a lot during the past few years, making its

affordability difficult for consumers both domestic and commercial (Malik, 2012).

One of the reasons for the energy crisis and power shortages in Pakistan is that major portion of its overall energy mix is based on thermal, for which it is dependent on costly oil imports. The share of hydro electricity has also decreased considerably as compared to the past. The contribution of renewable energy in the overall energy mix is almost negligible. Globally, the share of renewable energy is increasing due to various reasons, including its renewable nature, continuous availability and being environment friendly.

## GEOGRAPHIC SKETCH OF PAKISTAN AND ITS CLIMATE

The Islamic Republic of Pakistan is located between latitude 24.50 and 36.75 degree north and longitude 61 to 75.50 degree east. Pakistan is the world's 36$^{th}$ largest country, having a total area of 796,096 sq km and shares its border with India to the east, Iran to the west, China to the north, Afghanistan to the north-west and the Arabian Sea to the south. Pakistan is separated from Tajikistan by a thin Corridor, namely Wakhan in Afghanistan. The famous Khyber Pass and Bolan Pass on the western borders of Pakistan have been used historically as migration routes between Central Eurasia and South Asia. The Coastline of Pakistan is about 1,046 km (650 miles) long (Mirza *et al*., 2003). Pakistan has four provinces, namely Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan, one capital territory, the Islamabad Capital Territory and several federally administered tribal areas.

The topography of Pakistan is varied and consists of the flat plains of Indus in the East and the Balochistan plateau in the West. In Gilgit Baltistan and highlands of Khyber Pakhtunkhwa provinces lie the greatest and highest mountain ranges of the Himalayas, the Hindukush and the Karakoram. K2 the world's second highest mountain peak, having a height of 8,611m (28,251 feet), is also located in Pakistan.

Pakistan's climate changes with its topography. Pakistan lies above the tropic of cancer in the temperate zone. The climate ranges from tropical to temperate. Although most of the climate is hot, dry desert, however, conditions in the coastal south are arid and the northwest is temperate. The country has suitable rainfall in the monsoon season and lesser rainfall in the dry season. The climate is considered arctic and severe in the mountainous north.

## SOLAR ENERGY POTENTIAL IN PAKISTAN

**Current status and resource assessment:** To overcome the existing energy problems of Pakistan, solar energy can play a significant role. Therefore, harnessing solar potential can play a vital role in addressing and overcoming our energy challenges. Evaluating the potential of solar PV in Pakistan, Sheikh (2009) concluded that if only 100 km$^2$ area of the country is covered with PV panels, having 14% efficiency, than it will have the potential to produce energy equivalent to 30 million tons of oil equivalent (MTOE) in Pakistan (Sheikh, 2009). Moreover, Gondal and Sahir (2008) have estimated that if 0.45% of the total land area of urban regions is considered for solar PV installations, then it is considered sufficient to meet electrical power requirements of the country.

According to the Policy for Development of Renewable Energy for Power Generation (2006), the share of Renewable Energy Technologies is to be increased up to 10, 000 MW by 2030 in the overall energy mix of the country. Suitable and timely exploitation of the solar energy resources of the country can help to achieve these targets a great deal (Jatoi, 2006).

Pakistan is blessed with extensive sunlight throughout the year. This makes Pakistan as an ideal place to invest in solar energy for harnessing its true potential. The estimated solar energy potential of Pakistan is 2,900,000 MW (NREL, 2012). The geographical location of Pakistan provides it with an average temperature of 26-28°C and 1900-2200 kWh/m$^3$ annual global irradiance (The Association of Science Education, 2015). The recently developed solar maps provide a detailed insight into the true potential for solar energy in Pakistan. Solar energy has a number of applications, including solar PV, solar thermal, solar desalination, further, there is a great potential for solar water heating and solar thermal power generation. In current circumstances, the prevailing shortfall of energy and over reliance on fossils to meet energy requirements can be dealt effectively by utilizing the solar energy as an indigenous resource. This will further ensure sustainable energy security.

The need of the hour is to adopt an effective policy, followed by coherent strategy and models to implement it in the country. Public-private partnership can prove to be productive in this regard. Globally, solar systems are gaining popularity and evolving at a fast pace. Innovations are being made in the types of cells and the storage capacity. A large number of areas in Pakistan lack access to the national grid and in such situation, solar energy can be beneficial for these areas. This will also help in relieving burden from the transmission and distribution network of the country, which is already weak (Asif, 2017).

The potential for solar energy in Pakistan is massive, however, till a few years back, most of the utilization of Solar PV was limited to distributed or off-grid scale. It was only in 2012 that Pakistan got its first solar electricity project with the help of JICA, having a total generating capacity of around 356 kW. On solar thermal side, the applications are still limited to solar water heaters, solar geysers, solar cookers, etc. The use of solar thermal technology for

converting solar energy into heat for power generation is yet to explored and tapped.

The Renewable Energy made its first vital appearance in the primary commercial energy supply during 2015-16 (HDIP, 2015). Based on data, provided by AEDB, the yearly cumulative capacity of Grid connected solar electricity projects developed and under various stages of development are provided in Table 3.

**Table 3: Grid connected solar electricity development in Pakistan.**

| Year | Yearly cumulative capacity (MW) |
|---|---|
| 2015 | 100 |
| 2016 | 400 |
| 2017 | 730 |
| 2018 | 1556 |

**Source:** http://www.aedb.org/index.php/ae-technologies/solar-power/solar-current-status.

**Radiation potential in Pakistan:** The location of Pakistan is very good for the exploitation of solar energy as it lies in the sun-belt. Most parts of the country receive about 8 to 10 hours of high solar radiation per day. The average number of sunshine days in a year is more than 300 (Raheem *et al.*, 2016).

In Pakistan, the mean global irradiation falling on horizontal surface per day is about 200–250 watt per $m^2$. There are about 1500-3000 sunshine hours in a year. Balochistan province has an annual mean sunshine duration of more than eight hours and receives an average daily global **i**nsolation of 19–20 $MJ/m^2$ a day. These conditions are very good for harnessing of solar energy (Mirza *et al.*, 2003).

According to estimates, given by AEDB, the solar power potential of Pakistan is about 2,990 GW or 2,900, 000 MW (Alauddin, 2012). Moreover, Adnan *et al.* (2012) explored the solar energy potential of the country, collecting climatic data from 58 meteorological stations and using Angstrom equation and Hargreaves formula. It was found that solar radiation intensity was more than $200W/m^2$ during the period: March to October, in most of the regions of Balochistan province; April to September in Khyber Pukhtunkhwa province, including Gilgit Baltistan and Kashmir regions; March to October in Punjab province and February to October in Sindh province. In southern Punjab, Sindh and Balochistan, the average solar radiation intensity was in the range of $1500W/m^2$/day to $2750W/m^2$/day for 10 hours a day.

In Gilgit Baltistan, the highest incoming solar radiation intensity was 339.25 $W/m^2$ at Gilgit in June. The highest incoming solar radiation intensity observed in Khyber Pakhtunkhwa was $319.33W/m^2$ at Risalpur in June. In Punjab, maximum solar radiation intensity of $315.14W/m^2$ was observed in May in lower southern parts of the province, like Bahawalpur, Bahawalnagar and Khanpur. The highest solar radiation intensity observed in Balochistan, 329.05 W/ $m^2$ at Quetta during June. In Sindh province, the maximum solar radiation ($331.27W/m^2$) was observed in the central regions of Sindh during June (Adnan *et al.*, 2012).

## APPLICATIONS OF SOLAR ENERGY IN PAKISTAN

**Solar thermal applications:** Solar thermal applications utilize the heat properties of solar energy are relatively less costly, which can be easily adopted and are relatively simple. Some common examples of solar thermal applications in Pakistan include:

**Solar water heaters (SWH):** In spite of being a mature technology, the application of solar water heaters in Pakistan is not very common due to various reasons, such as, high capital cost than the conventional geysers running on natural gas or electricity. However, with the help of some public sector organizations, low cost solar water heaters are being developed and increasingly used in the Gilgit Baltistan mostly mountains where supply of natural gas is limited. Increase in the prices of natural gas and heaters have also encouraged the private sector to develop solar water heaters (Mirza *et al.*, 2003). Although, the capital cost of SWH is on the higher side but the payback period is less than four years. Awareness, in this regard, may help to fast track adaptation of SWH. Solar thermal appliances, including solar water heaters and solar cookers for fuel conservation, are also in use in the Gilgit Baltistan and KPK, with the support of organizations, such as, the Aga Khan Foundation.

**Solar cookers:** Both concentrator and box type solar cookers are being used in the country. Public sector organizations have developed cheaper and efficient designs of these cookers. NGOs, in the past, have also supplied solar cookers to refugee camps. The Pakistan Council for Renewable Energy Technologies (PCRET) has also worked for the promotion of solar cookers (Mirza *et al.*, 2003).

In the mountainous areas, particularly Hindukush and Himalayas, solar cookers are mostly used, however, comparing to mountainous areas of China and India, the number of solar cookers is still very low. Popularization of solar cookers in the mountain regions of Pakistan will help a lot to reduce the use of forest wood as a fuel (Mirza *et al.*, 2003).

**Solar dryers:** Drying agriculture products using solar dryer is another application of solar energy, resulting in quality products on one hand and saving of electricity/fuel costs on the other hand. In the northern mountainous areas of Pakistan, solar dryers are used, particularly to dry fruits, such as apricot, which otherwise would have been wasted due to poor logistics and lack of basic infrastructure. Non Governmental Organizations are also involved in the popularization of solar dryers. The agriculture sector in Sindh and Punjab provinces, also has the potential for the application of solar dryers (Mirza *et al.*, 2003).

**Solar desalination:** One of the issues in most parts of Balochistan, Sindh and southern Punjab is the non

availability of sweet drinking water. The underground water in these areas contains sodium chloride and is mostly saline, which is not suitable for drinking, washing and cleaning besides causing diseases.

Solar desalination technologies can be used to desalinate and purify this saline water. These technologies are cheap, low tech and can be easily adopted in these areas. In Gwadar two solar desalination plants, having capacity to clean 6000 gallons of sea water, have been successfully installed (Mirza *et al.,* 2003).

**Solar PV:** Solar PV or Photovoltaic changes solar energy directly into electricity and this is one of the most useful forms of energy. For rural and remote areas, which are not connected to the grid, the PV technologies are quite handy and the demand is small in these localities.

In Pakistan, Thar Desert and remote rural areas of Sindh and Balochistan provinces are well suited for standalone Photovoltaic (Mirza *et al.,* 2003). Some of the reasons for suitability of solar PV in these areas are very low population density, large distances between different villages, absence of approach roads, small power demand of the clay and straw made hut type houses, where connection to grid is not feasible economically (Mirza *et al.,* 2003).

Around 18 Photovoltaic stations installed by the government in the 1980s for rural electrification, having a total installed capacity of about 450 kW, did not perform due to lack of technical knowhow and maintenance problems. Afterwards, solar technologies were used for highway emergency telephones, rural standalone telephone exchanges, medicines and vaccines refrigeration, solar water pumping (World Energy Council, 2000).

Solar PV initiatives are being encouraged and popularized both in the private and public sectors in the country. PV products are being traded by different companies and also various related components are manufactured in Pakistan. These products include PV modules, invertors, batteries, battery charges, garden lights, solar lamps, solar fans, etc. (Mirza *et al.,* 2003). Solar powered emergency call boxes have also been installed on selected motorways.

## GRID CONNECTED SOLAR ELECTRICITY GENERATION IN PAKISTAN

**Pakistan's first on-grid solar power station at the premises of Planning Commission and Pakistan Engineering Council:** With the help of Japan International Cooperation Agency (JICA), Pakistan was able to get its first on-grid solar power station in 2012 under a project titled, "Introduction of Clean Energy by Solar Electricity Generation System". Under this project, 178.08 kW Photovoltaic (PV) Solar Systems were installed both at the premises of Planning Commission (P Block), Pak Secretariat and Pakistan Engineering Council's building. The total generating capacity of both projects is 356.16 kW. One of the main features of this project was that for the first time arrangements were made for net metering in a solar electricity project in Pakistan, allowing selling the additional electricity to the Distribution Company.

**Quaid-i-Azam Solar Park:** The Quaid-i-Azam Solar Park is Pakistan's first solar power plant at Bahawalpur district of Punjab province. Once completed, it will have the capacity to generate 1,000 MW. In May 2015, the first 100 MW were commissioned and the major portion of the remaining 900 MW will be installed under the CPEC initiative.

## INSTITUTIONAL ARRANGEMENTS

**Historical perspective:** Some of the historical efforts made by the government of Pakistan to introduce renewable energy in Pakistan include the establishment of Solar Energy Research Center under Pakistan Council for Scientific and Industrial Research, Ministry of Science and Technology, similarly, various projects were initiated by Pakistan Atomic Energy Commission, afterwards, Pakistan Council for Appropriate Technology and National Institute of Silicon Technology were established in 1980's under Ministry of Science and Technology. Similarly, a Directorate of Renewable Energy was established under Ministry of Water and Power.

**Alternate Energy Development Board:** Alternative Energy Development Board (AEDB) is the premier agency of the Federal Government, established earlier in 2003, with the mandate to promote renewable energy in the country at a fast pace. AEDB has been set a target to ensure that 5% of electricity generation is through alternate and renewable sources by 2030. Furthermore, it has been assigned a task to electrify more than 8,000 villages of remote areas through alternate and renewable technologies (GoP, 2006).

**Pakistan Council for Renewable Energy Technologies:** In 2001, Pakistan Council for Appropriate Technologies (PCAT) and National Institute of Silicon Technology (NIST) were merged to establish Pakistan Council of Renewable Energy Technologies (PCRET).

It is mandated to coordinate R&D and promotional activities in different renewable energy technologies. With its head office located at Islamabad, PCRET has offices at provincial capitals, including Lahore, Karachi, Quetta and Peshawar, and many field offices at Abbottabad, Bahawalpur, Muzaffarabad, and Ghokti.

**Renewable and Alternative Energy Association of Pakistan:** Renewable and Alternative Energy Association of Pakistan (REAP) is a registered association, working in the areas of alternative and renewable energy. It has an objective to promote renewable and alternative energy in the country, so as to reduce the ever increasing dependence of the country on fossil fuels.

**U.S.-Pakistan Center for Advanced Studies in Energy (USPCAS-E):** NUST, in cooperation with

USAID, established "U.S. Pakistan Center for Advanced Studies in Energy (USPCAS-E)" for addressing the energy challenges and promoting strong cooperation between Pakistan and US in the areas of "research and policy development" in renewable energy and emerging technologies, thermal engineering leading to energy security utilizing indigenous resources, promotion of technologies and practices that increase energy efficiency in all sectors

## CONCLUSION

Energy is of utmost importance for the socioeconomic development of any country. In the wake of depleting fossil fuel energy resources, high fossil fuel prices; many under developed and developing countries, including Pakistan, are facing severe energy short-falls. This acute energy shortage has adversely affected all sectors of life, including industries, agriculture, transport, services sector and domestic sectors.

To address problems of energy scarcity, alternative means of energy resources are being explored all over the world. In Pakistan, different options of renewable energy are being explored. Solar Energy, in particular, has a lot of potential in Pakistan to address the energy challenges of the country. Solar energy besides offsetting the expensive imported fossil fuel energy and reducing the oil import bills also has the advantage of being green energy that has no adverse environmental impact.

Although, solar energy has been introduced in Pakistan from more than three decades, and it has achieved some initial and isolated success at small scale; for instance, the Quaid-i-Azam Solar Power Park at Bahawalpur, turning several government buildings on solar energy, introduction of solar geysers, heaters and electrifying a number of villages through solar stand alone PV systems are some of the success stories, however, its role in the overall energy mix of the country is still negligible. On the basis of its geographic location and climatic conditions, Pakistan is ideally placed to use solar energy as a major source of electricity in the country. In order to harness and realize maximum solar energy potential, a more holistic approach is needed to enhance the share of solar energy in the overall energy mix of the country. The government needs to address issues (social, technical, economical) of solar energy and attract private sector investment both local and foreign in this sector. Promoting and supporting the solar energy in Pakistan, through a strong political will, can go a long way in addressing the problems of energy in Pakistan. To end with, solar energy may not be the panacea for our entire energy crisis but it has all the potential to reduce our energy crisis to a greater extent in short span of time.

The need of the hour is to invest heavily in this field as it holds a tremendous potential to address the energy challenges of Pakistan. Government needs to introduce supportive policies and commercialize the production of solar panels in the country in order to make it affordable for the consumers. R&D in solar energy will have to be further strengthened. Priority needs to be given to renewable energy in policy making and implementation. The technical capacity will have to be enhanced and awareness on benefits of solar energy will need to be propagated to masses. Cooperation and collaboration at regional level will have to be strengthened. The private sector needs to be provided with incentives to invest in this field. The environmental regulations need to be strictly followed and deforestation needs to be completely banned to avoid serious challenges of climate change. Solar energy can be a major step forward to reduce the green house gas emissions.

As already indicated above, Pakistan has a huge theoretical potential to provide most of its electricity needs from solar, the need is to come up with a comprehensive and holistic program, backed by political support and consistent investor friendly policies. Time is an important factor in this regard, and the sooner, we realize the full potential of the solar resource the better, it will be not only to address the energy problems of the country but also to increase the per capita energy consumption in Pakistan; resulting in improved quality of life.

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