

## Different Solar Potential Co-Ordinates of Pakistan

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### Abstract

MIT, Stanford University and University of California have recently made a research on atmosphere/energy program. The research group has made a plan and concluded that a renewable energy powered world indeed a possibility by 2050. They have analysed the future energy demand of 139 countries and compared the solar, wind and hydroelectric potential of the countries. The research team made an interactive global map which shows the projected energy mix on each of the analysed countries. The report of the map study shows that Pakistan has potential of producing 92% of its electricity requirements from solar energy, at a rate that's amongst the highest in the world. Solar PV plants can produce 58.1% and concentrated solar plants (CSP) can produce 15% of electricity production. Study of the different solar potential co-ordinates of Pakistan is worth for forth coming planning to utilize solar potential properly and meet power demand of the country. This research is aimed to study the irradiation net power density (in MJ/m<sup>2</sup>/day and MWh/m<sup>2</sup>/year) of different co-ordinate of Pakistan. In parallel to study the install capacity of solar thermal and solar PV on district and provincial levels, study solar maps of Pakistan and different seasons on annual basis.

**Keywords:** Concentrated solar power (CSP); Global energy potential; Normal solar radiations; On grid installation capacity; Photovoltaic (PV) systems; Solar thermal; Solar map of Pakistan

### Introduction

Fossil and nuclear sources are depleting gradually, renewable energy sources are ideal candidate for a global energy transition that must occur over this century [1-4]. Many problems such as environmental and social are also associated with fossil fuel and nuclear resources. Renewable energy has impact and restriction as the other energy sources has. The knowledge of these restriction is of the great importance to plan and formulate policies for sustainable energy. Wind and solar energy stands out for larger and possibly grids scale potential. Wind energy potential at contemporary charted out by state energy a sharp drop has seen in the installation costs, this helps to attract private sector toward investment in this realm. The wind potential is likely to remain significant only to coastal areas which are at far a distance from national grid only to tune of a couple of gigawatts. Solar energy is in abundance across all the coordinates of the country is justifiably seen as ultimate sources to tap. Solar energy also addresses the atmospheric pollution and climate issues. Over the years a number of states run organization in Pakistan initiated a number of solar energy projects at different mode of utilization but still failed to achieve remarkable contribution [4-6]. Efforts have been made to enhance the fabrication capability exists by state run National Institutes of Silicon Technology (NIST) remains at pilot scale. Water

and Power Development Authority (WAPDA) of Pakistan ventured to install small scale power generation but remained fail to sustain it. The imported solar panels are available at exorbitant prices in open markets of Pakistan.

### Literature Review

#### Solar power

It is the conversion of incident Sun energy into electricity directly using photovoltaic or indirectly using concentrated solar power. Concentrated solar power (CSP) systems utilize mirrors, lenses and maximum power tracking system to focus the incident Sun light of large area into a small beam photovoltaic system using photovoltaic effect to convert Sun light energy into direct electric current using semi conducting materials. Solar power is clean sustainable and environmental friendly [7].

#### Solar thermal

Concentrating solar power plant (CSPP) is one of the best solar technologies to convert Sun incident light into thermal potential to run turbines and generate power in an affordable way (Figures 1-12). Solar thermal technology helps to mitigate climate change as a well pass reduce the consumption of fossil fuels. Solar thermal technologies are being installed in many developed places such as Spain, Israel, USA and Greece and developing countries like India, Mexico, Egypt and Morocco (Tables 1-8). These technologies are as follows [6,7]:

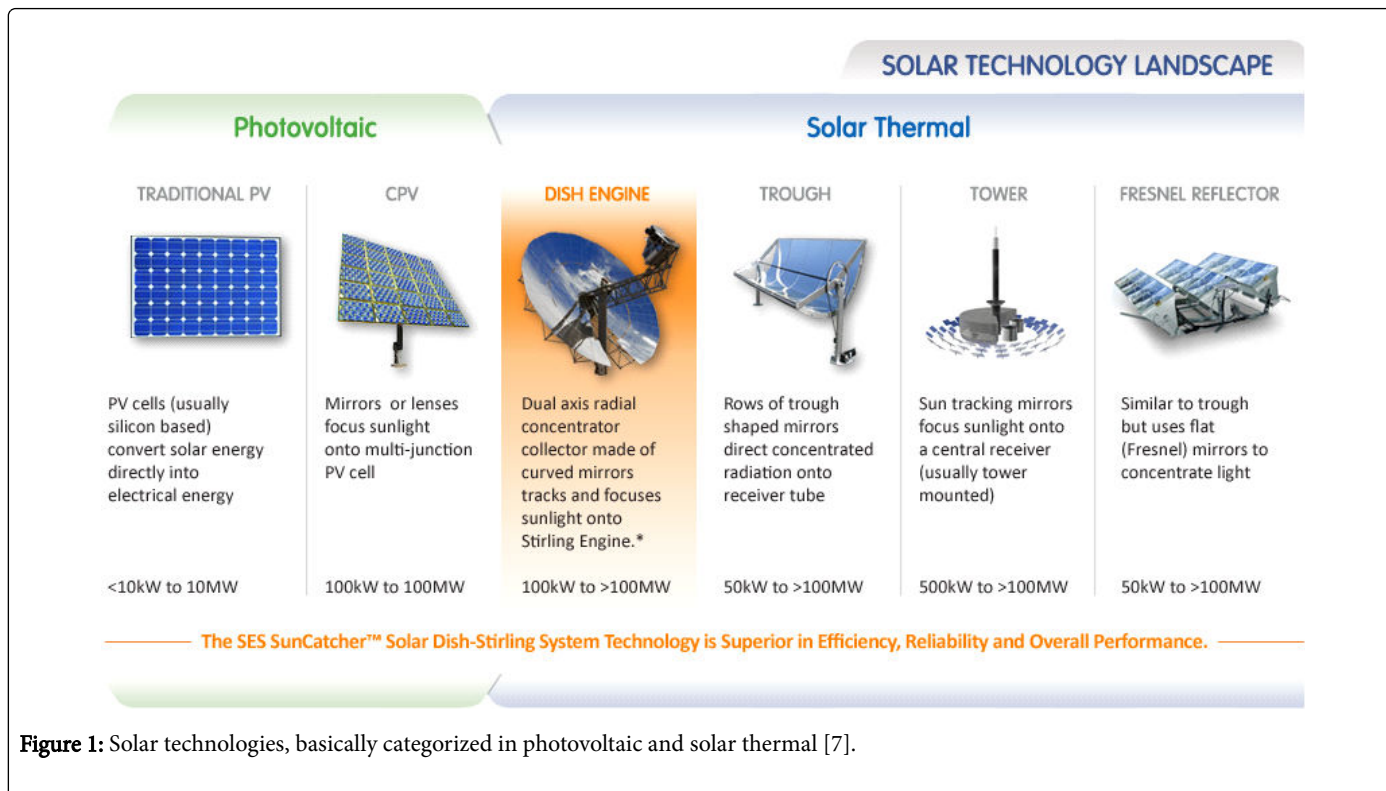


Figure 1: Solar technologies, basically categorized in photovoltaic and solar thermal [7].

Year	Energy consumption of World <sup>TM</sup>	% of Wind and solar
2005	15674	0.0097
2006	16336	0.0108
2007	17126	0.0124
2008	17454	0.015
2009	17339	0.0183
2010	13543	0.021
2011	19122	0.026
2012	19582	0.031
2013	20195	0.0374
2014	20552	4.21
2015	20776	4.95
2016	21190	0.0566

Table 1: Global energy statistical year book 2017 [8].

## Methodology

We review in this section the solar potential of different Pakistan's co-ordinates and contemporary development to harness the solar potential to meet the prevailing power crises in the country.

## Global energy potential

The total Sun light energy absorbed by the land masses and oceans is approximately 3, 850, 000 exa joules/year [9]. The conventional sources reserves are in terawatt/year (TWyear) and renewable energy reserves are in terawatts TW. The average power of solar irradiation on earth is 174, 000 TW. 86,000 TW cover land masses given that global ice free land is approximately 13, 000 MH, so theoretically attained power would be about 23, 000 TW [10]. 23, 000 TW refers to earth global solar power of total land masses. With atmospheric losses taken into account and energy 200 million TWh/year. For year 2016 worldwide energy consumption is, wind power 25 to 70 TW, hydro power 3 to 4 TW, solar power 23,000 TW, wave power 0.2 to 2 TW, Geo thermal power 0.3 to 2 TW, Bio mass 2 to 6 TW, OTEC 3 to 11 TW and fossil fuel are: Natural gas 215 TW, coals 90 TW, oil 240 TW and nuclear power 90 to 300 TW [11].

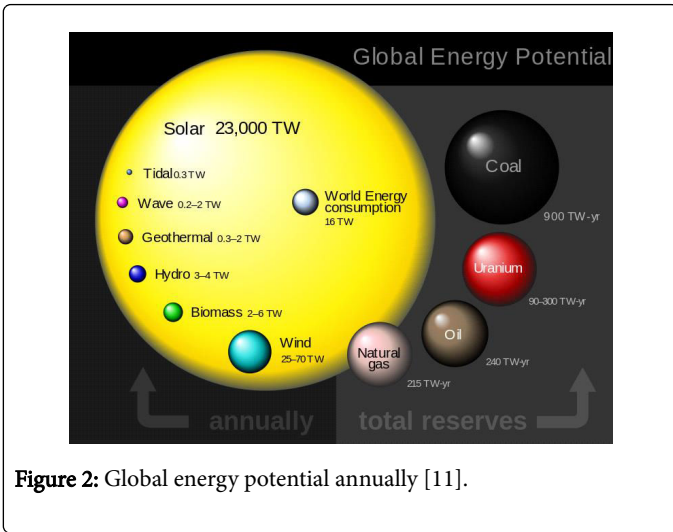


Figure 2: Global energy potential annually [11].

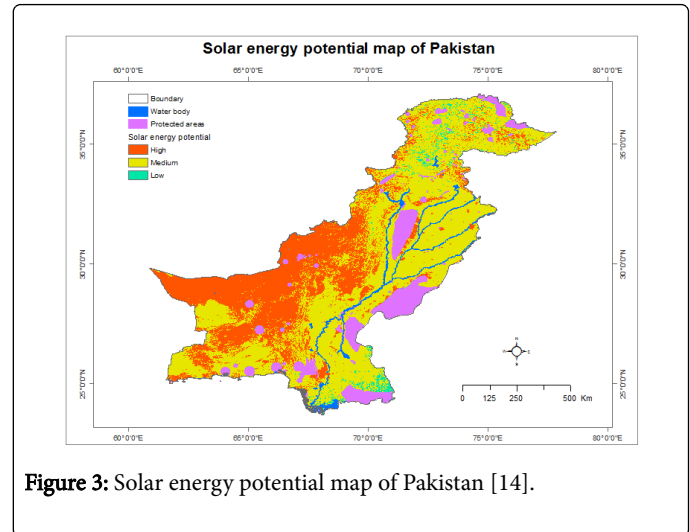


Figure 3: Solar energy potential map of Pakistan [14].

### Pakistan solar energy potential

Pakistan has a potential of 2.334 million MW of electricity per year through photovoltaic and solar thermal system. To overcome the prevailing energy crises in the country, the industrialists should venture in this sector. At contemporary in Pakistan with the help of International Renewable Energy Agency (IREA) China and private sector are building solar power plant in Baluchistan, Kashmir, Punjab and Sindh.

### On grid installed capacity

Pakistan has inaugurated first ever on grid solar power plant on 29th May 2012 in Islamabad. It was a project that was specially granted by Japan International Cooperation Agency (JICA) under cool earth project, the project was titled "Introduction of cool energy by solar electricity generation system". The project included the installation of 178.08 KW PV systems for Pakistan Engineering Council (PEC) and Planning Commission of Pakistan (P block). The planning commission and PEC combined generating capacity is 356.16 KW. This was the first on grade project in Pakistan. This project allows the recipients to sell the extra electricity by net-metering to the distribution company of Islamabad division Islamabad Electricity Supply Company (IESCO). The grant assistance of the project was 480 million Yuan, 553.63 million Pakistani Rupees. It took 3 years of time commencing from 2010 [12]. In Lahore, Beacon house canal side campus, first-ever installed solar PV system standard integrated capable of grid tie-in with the capacity of 10 KW. It was a pilot project designed by US consultants for BSS based upon feasibility by trade and development agency (USTAD) [13].

### Results and Discussion

#### Solar irradiance in Pakistan

Pakistan receives significant level of solar irradiations across the board. Irradiations changes from north to south. The map given below divides Pakistan in to four bands of irradiance-dark orange, ochre, yellow and fail orange: the irradiations intensity gets increases with depth of color. Highest levels of solar irradiance are found in Balochistan, Southern Punjab and Sindh. ICT, KPK, PATA and Azad Kashmir receive low level of irradiance [15].

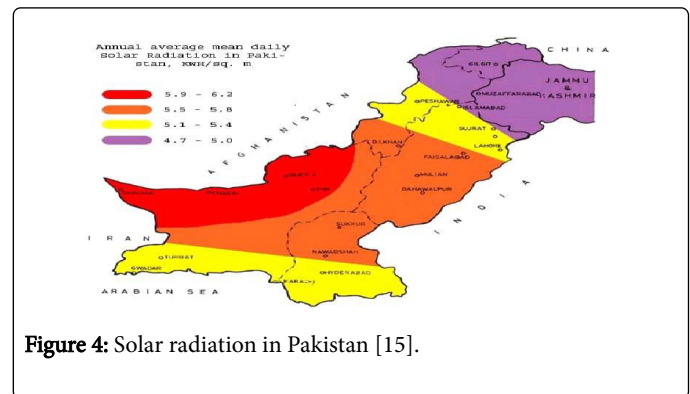


Figure 4: Solar radiation in Pakistan [15].

Pakistan's co-ordinates lie in seasonal climatic regions especially in monsoon climatic region. This climatic region has cloudy months June, July and august that affects the solar irradiations to reach to earth surface. Pakistan's co-ordinates having more than 300 clear days in a year.

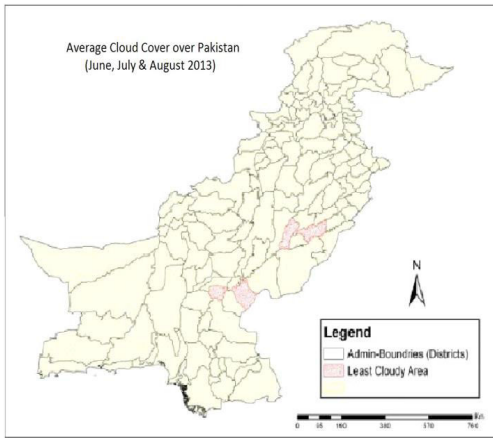


Figure 5: Average clouds over Pakistan [15].

South western co-ordinates of Balochistan and Northern co-ordinates of Sindh are most favourable for harnessing solar incident energy. Pakistan has location in such an area where the solar irradiations are highest in its co-ordinates that is suitable for concentrated solar power (CSP) applications and photovoltaic (PV) systems. South Quetta valley and many parts of the central Punjab receive maximum solar energy (Figure 6).

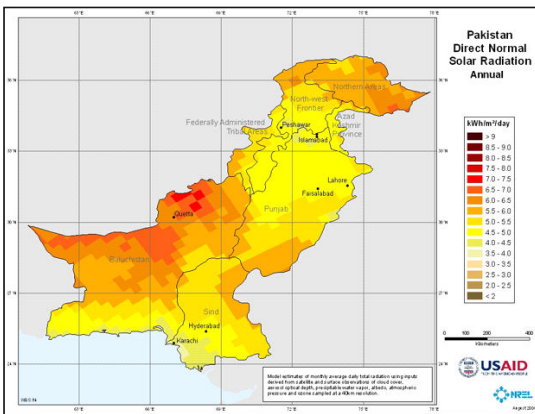


Figure 6: Pakistan direct normal solar radiation (Annual) [15].

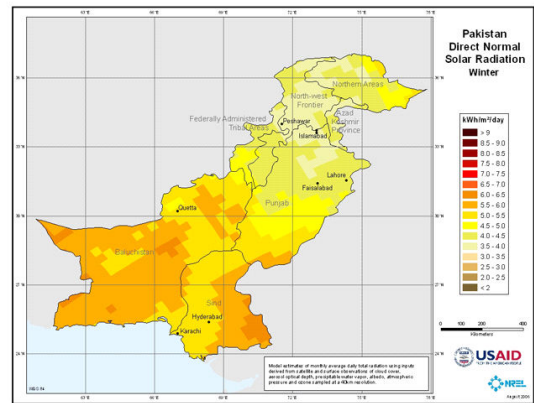


Figure 8: Direct normal solar radiation for winter [15].

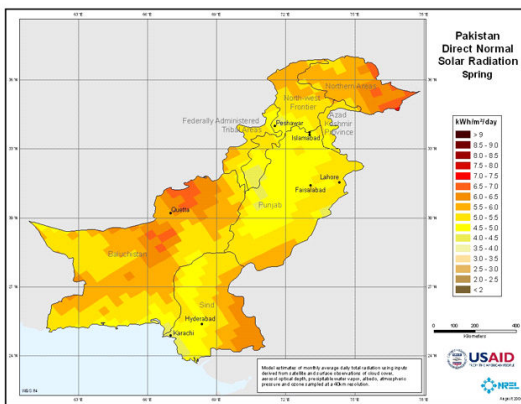


Figure 7: Direct normal solar radiation for spring [15].

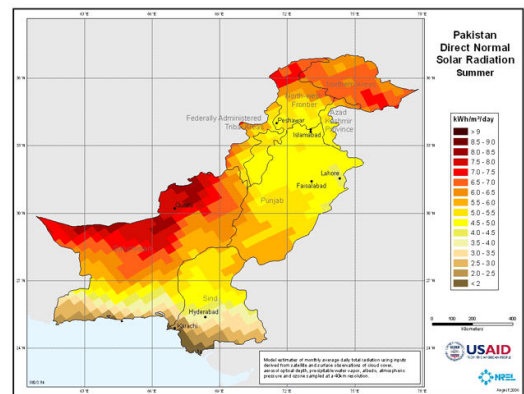


Figure 9: Direct normal solar radiation for summer [15].

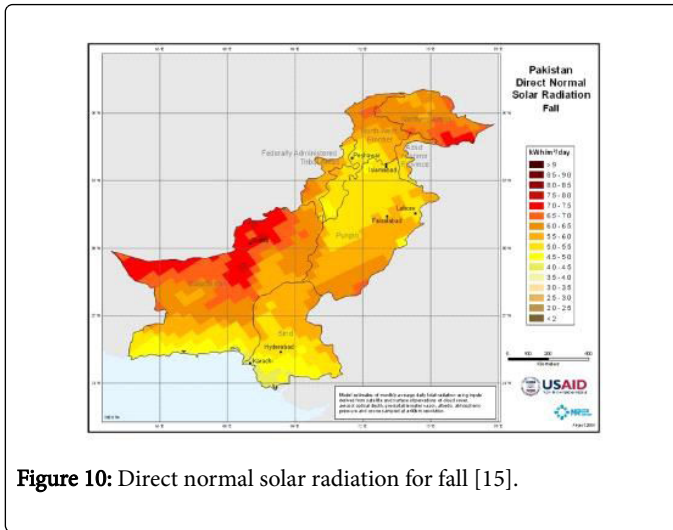


Figure 10: Direct normal solar radiation for fall [15].

would be suitable to encounter the contemporary requirement of the country using devices having efficiency 20%.

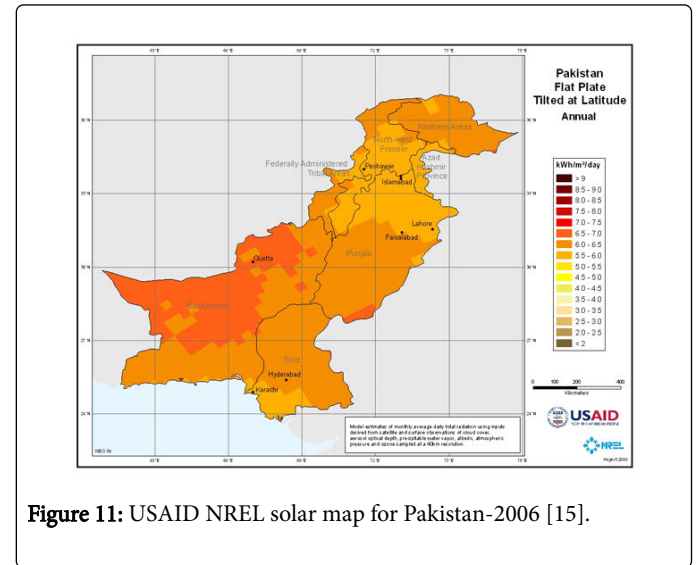


Figure 11: USAID NREL solar map for Pakistan-2006 [15].

The annual direct normal solar radiation for CSP of four provinces of Pakistan is as follow in Table 2 [16].

Province	Irradiation (Mm) KWh/m <sup>2</sup> /day	Irradiation (Max) KWh/m <sup>2</sup> /day
Balochistan	7	7.5
Southern Punjab	6.5	7
Northern Sindh	5	5.5
KPK	4.5	5

Table 2: Irradiation of four provinces of Pakistan.

### Annual insolation

- The average daily global insulations of Balochistan is 19 to 20 MJ/m<sup>2</sup>/day
- The average annual global insolation of Balochistan is 1.93 to 2.03 MWh/m<sup>2</sup>/year.
- The average insolation of Pakistan is 5.5 kWh/m<sup>2</sup>/day.

Monthly average solar irradiation of capitals cities of four provinces of Pakistan are as follows in Table 3 [16].

Capital Province	of	Irradiation (Am) KWh/m <sup>2</sup>	Irradiation (Max) KWh/m <sup>2</sup>
Lahore		2.8	6.27
Peshawar		2.4	6.35
Karachi		3.39	6.31
Quetta		3.6	7.65

Table 3: Irradiation of capital cities of four provinces of Pakistan.

Most areas of Balochistan have its annual flat plate tilted at latitude solar radiation in range from 7 to 7.5 KWh/m<sup>2</sup>/day. Gilgit-Baltistan, Sindh and Southern Punjab have its annual flat plate tilted at latitude solar radiation in range of 6 to 6.5 KWh/m<sup>2</sup>/day. Rest of the country's coordinates have its ranges from 5.5 to 6 KWh/m<sup>2</sup>/day. This indicates that Pakistan is in the Sun Belt [17].

If the vast solar potential is properly utilized, it would be worth to produce electric power and supply electricity especially for the off grid communities of the southern and northern hilly areas of the country. As per report of Pakistan Energy Book for the year of 2004-2005, only 0.25% area of Balochistan province if use to generate solar power

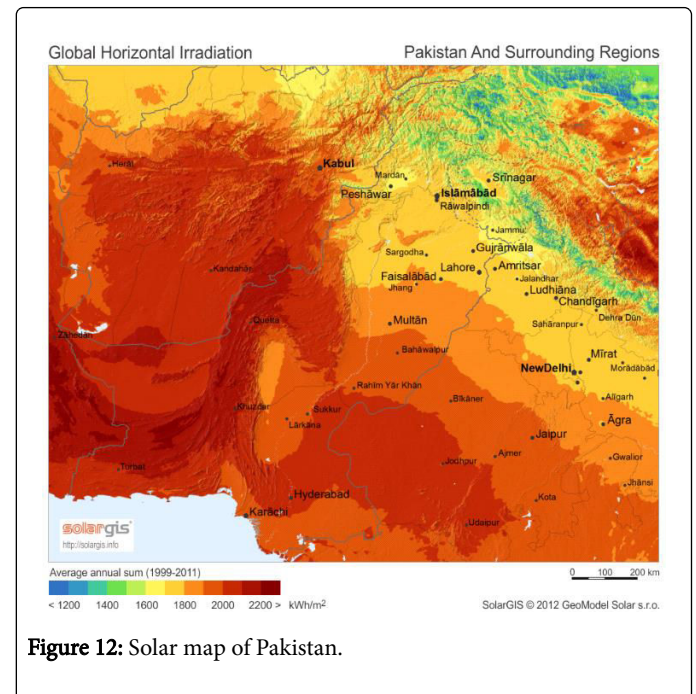


Figure 12: Solar map of Pakistan.

To offer a simple, strong and assured tier structure, the amount of tiers must be kept checked. The specialists believe that, according to the solar irradiance profile of Pakistan, the ideal two tiered structure is following:

South Region=high Sun regions (dark orange and ochre bands on the insolation map)	North Region=lower Sun regions (yellow and light orange bands on the insolation map)
Balochistan	Northern Punjab
Sindh	Federally Administered Tribal Areas
Southern Punjab (including Cholistan)	Khyber Pakhtunkhwa
	Islamabad Capital Territory
	Azad Kashmir
	Gilgit-Baltistan

**Table 4:** Comparison between lower Sun radiation regions and high Sun radiation regions.

### Upfront tariff for solar PV power projects

**Existing tariff petitions:** The only project company, Access Solar (Pvt) Limited, has filed a tariff petition for determination of solar tariff for its proposed power plant at Pind Dadan Khan, Punjab having capacity of 11.52 MW. The company will provide upfront solar tariff [16].

Solar PV	Tariff
Installed capacity (WTI)	10.000
Minimum annual energy (GM)	14.699
CPI (General) November 2013	191.210
US CPI (AI urban consumers) November 2013	233.069
Exchange rate (Rs./US)	105.000

**Table 5:** Upfront tariff for solar PV for north region.

Solar PV	Tariff
Installed capacity (WTI)	10.000
Minimum annual energy (GM)	15.330
CPI (General) November 2013	191.210
US CPI (AI Urban Consumers) November 2013	233.069
Exchange rate (Rs./US)	105.000

**Table 6:** Upfront tariff for solar PV for south region.

### Solar on-grid development

**Pakistan largest solar park:** Pakistan has inaugurated its first large-scale solar power park (Qaid-e-Azam Solar Park) in Bahawalpur. Here are some particulars of it:

General capacity: 1, 000 MW

Capacity of Phase 1st: 100 MW

Phase 1st completion date: December 2014

Capacity of Phase II: 300 MW

Capacity of the project of Phase III: 600 MW

S. No	Company	Capacity (MW)	Province
1	First Solar	2	Punjab
2	DACC Associates	50	Punjab
3	Access Solar (Pvt) Ltd	10	Punjab
4	Associated Technologies Pvt Ltd	30	Punjab
5	Bulchsh Energy Pvt Ltd	10	Punjab
6	Avatar Energy Group	50	Punjab
7	Wah Industries Ltd	5	Punjab
8	Solargert Pvt Ltd	50	Punjab
9	Hecate Energy	50	Punjab
10	Hecate Energy	150	Punjab
11	Trans Tech Palcistart	50	Punjab
12	Sunlux Energy Innovations	5	Punjab
13	Sapphire Solar Pvt Ltd	10	Sindh
14	Realforce Ruba Palcistart Power Pvt Ltd	20	Punjab
15	Global Strategies (Pvt) Ltd	10	Punjab
16	Forte Palcistart	0.99	Punjab
17	Integrated Power Solution (Pvt) Ltd	50	Sindh
18	Jafri & Associates	50	Sindh
19	Solar Blue Pvt Ltd	10	Sindh
20	Zaheer Khan & Brothers	10	Punjab
21	Dawood Group Ltd	10	Sindh
22	Table Rock Associate	100	Punjab
23	Safe Solar Power Pvt Ltd	10	Punjab
24	Techaccess FZ LLC II	10	Punjab
	Total	792.99	

**Table 7:** List of LOIS issued for a consolidated capacity for 792.99 mw [18].

Final capacity: 1, 000 MW

Solar energy of final phase per year: 2, 000 kWh/m<sup>2</sup>.

Accomplishment of final phase of the project date: Dec 2016

Quaid-i-Azam Solar Park estimated cost is US 1.5 billion dollars and its power generation capacity is 1000 MW. The life span of the plant is 25 years.

Area for project dedicated: 6500 Acres.

Boundary wall of the project: 9 KM

Projects	Capacity	Status	Province
Grid connected PV-PEC	178 kW	completed	Islamabad capital territory
Grid connected PV-PC	178 kW	completed	Islamabad capital territory
Quaid-e-Azam Solar Park	300 NRV	In process	Punjab
Industrials zones projects	N/A	MoU signed	Punjab
Faisalabad Motorway Project	1501,14	MoU signed	Punjab
Tehsil Zahri, Dist. Khuzdar	10 kW	completed	Balochistan
Tehsil Jaffar abad	7.9 kW	completed	Balochistan
Rural Electrification, Tehsil Surab	59.5 kW	In process	Balochistan
Rural Electrification, Tehsil Khuzdar	34.3 kW	In process	Balochistan
Rural Electrification, Tehsil Kalat	41.1 kW	In process	Balochistan
Hospital Electrification Dist. Mustung	14.5 kW	In process	Balochistan
Solar power project, Khuchlak Dist. Quetta	300 MW	MoU signed	Balochistan

**Table 8:** List of PV projects in Pakistan.

Pakistan power production capacity is 19, 000 MW, but at contemporary much more power is needed to meet demand. Power projects are being set up at Thar to meet the power demand. After completion of the power projects and sufficient use of the solar potential Pakistan will stand in the list of top ten countries to produce more than 1, 000 MW of solar energy.

## Conclusion

- Pakistan has location East 62°-75° on Longitude and North 24°-37° on latitude.
- Pakistan lies in an area of “The world having greatest insulation”.
- Pakistan receives 5.5 kW/m<sup>2</sup> per day on an average.
- World global solar potential is 30,00,000 TWh/year. Pakistan’s estimated solar potential is 1, 00, 000 MW.
- The electricity generation rate is 2 cents/kWh in Japan.
- Pakistan is required to generate 2000 MW and put in national grid every year which is only possible through solar and wind. The population of UK is less than half the population of Pakistan. It was generating 70, 000 MW in 1970 while Pakistan is generating 22, 000 MW now.
- The provincial government of Sindh should be allowed by Government of Pakistan to research the feasibility of solar power. To make the seawater drinkable through solar energy the Government is planning to install a water filtration plant.

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