



Solar Power: A Green Future

Sandeep Kaur

Guru Kashi University, Talwandi Sabo, Bathinda, Punjab

Abstract-With rising energy demands and alarming rate of global warming, many energy sources which were thought to be reliable few decades ago now need to be excluded from the picture. Solar Power which just comprises only 1% of world's energy demand is seen to be a reliable source now for the future. And it is expected to fulfil 16% of world's energy demand by 2050 and considerably cutting down carbon emission and decreasing global warming effect for a green future.

Keywords: CSP, Concentrated Solar Power, PV, Photovoltaic, Linear Fresnel Reflectors, Parabolic,Trough, Enclosed Trough, Dish Stirling, Solar Power Tower.

1. Introduction

Solar Power is the conversion of the heat and light energy emitted by sun directly or indirectly into electricity. In direct conversion photovoltaic cells convert the directly falling sunlight on them into electricity, while in indirect conversion large system of lenses/mirrors focuses large area's sunlight to a small beam and thus called Concentrated Solar Power (CSP). Being a renewable source of energy, it won't add to the already rising carbon emissions around the globe and thus helping in reduction of global warming effect in one way. As the source of energy is sun in this case, so there won't be a need to look for another source of energy in near future. Solar Power by the end of 2014 reached capacity of 178 GW around the world which is roughly 1% of the total energy consumption of the world [9]. Meanwhile, Europe and China are leading rest of the world in power generation by this means [25]. The very moment man opened his eyes; first thing he saw in the open sky was the Sun. From that day he knew it is a huge source of energy. In 2012, world energy consumption was 1,55,505 TWh out of which consumption by electricity was 18,608 TWh [26] and what solar energy can produce is 4,37,500-1,37,18,611 TWh [8]. This makes it nearly 90 times the world's consumption per year [7]. It shows the amount of potential in this form of power production. Increasing electricity bills with the increase in energy demand is making it difficult for a common man to rely on conventional power sources, i.e. fossils, hydro-power, etc. while on the contrary solar power is cheaper, eco-friendly, renewable and can remote areas without the need of erecting electricity poles/towers and spreading wires, etc.

2. What is Solar Power?

The word "Solar" means relating to sun and the word "Power" means rate of doing work. Therefore Solar Power is generated by the rays of sun being converted into electric energy. It can be directly converted into electricity or indirectly by thermal energy through steam turbines to electricity. Direct conversion through Photovoltaic cells is also known as PV, while indirect conversion by concentrated solar power by lenses and mirrors is known as Concentrating Solar Power, Concentrated Solar Thermal or simply CSP [1,17].

2.1 Photovoltaic Solar Power (PV)

The term "photovoltaic" has been derived from Greek word (phōs) meaning light, and "volt" from the unit of electromotive force "volt". In this form of solar power generation solar panels installed convert sun's light energy into electricity directly [3]. A Solar panel is made up of semiconducting material, i.e. Silicon usually, which forms a thin wafer treated so as to form opposite electric fields on both sides and sandwiched between two electrical contacts. It has to be covered with a sheet of glass and an anti-reflective coating in order to protect it from harsh conditions and

to absorb sunlight without scattering it away respectively. Now when sunlight strikes the solar panel it gets absorbed electrons get knocked loose from the atoms in whatever semiconducting material is used (silicon in this case). Thus charging the silicon wafer positively on one side and negatively on the other, hence pushing all the loose electrons in the same direction, giving rise to electric current. Now the two electrical contacts capture this current and pass it to whatever circuit is attached to it. In this process the current generated is DC or Direct Current, which can be used to charge batteries or can be inverted into AC or Alternating Current for household usage using an inverter. In large combinations (like in Solar Parks, Solar Complexes or Solar Power Generation Plants), number of cells are connected electrically in a frame or structure known as photovoltaic module. These are designed to give output of desired volts. The efficiency of a module is dependent upon the amount of light that strikes the module. Further these modules can be connected to form arrays and thus covering more area. Therefore more the area of an array, greater will be the production of electricity.

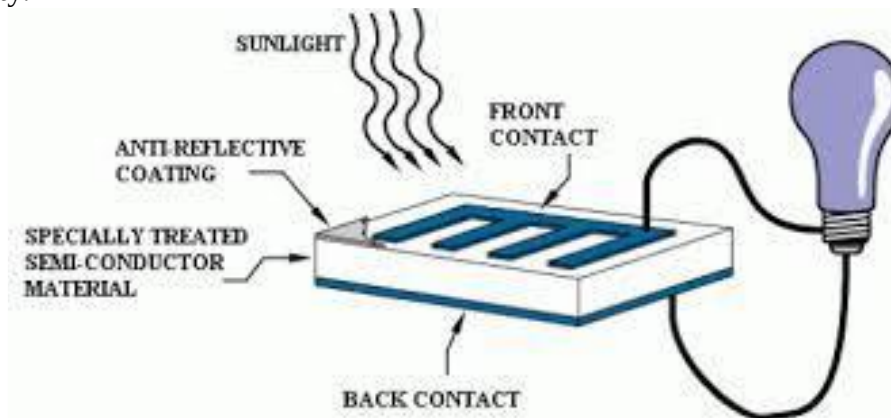


Fig. 1: Various Parts of a Photovoltaic.

2.1(a) Present Scenario

PV comprises of more than 90% of electric generation by means of Solar Power. By the end of 2014 power generation capacity by PV touched 177 GW mark and is rapidly moving towards the 200 GW mark. All the major developing nations like China, India, etc. and developed nations like Germany, US, Japan are rapidly installing this technology to counter the effect of Carbon emissions and green house gases by discouraging use of other conventional energy sources. Up-till now Germany is leading other nations in generation of electricity by means of PV, as this source of electricity feeds 7% of its annual electricity consumption and total production 35.5 GW. More than 100 nations have adopted Solar PV and the number is still counting and this has made Solar PV third largest renewable energy source after Hydro and Wind energy. More and more PV Solar parks are coming up, the largest Solar Park: Solar Star (I & II) in US with capacity of 579 MW_p is expected to be left behind by many coming up with capacities reaching 10000 MW_p for example: Project Helios in Greece and Adani Renewable Energy Park Rajasthan, India are planned to come up in late 2020s [24,27]. Not only this power production by PV is expected to touch 450-900 TW in 2030 and 3.3 to 6.6 PW by 2060. After adoption of Paris Climate Pact 2015 by 196 nations around the world for cutting of carbon emissions and to move towards renewable energy resources, these figures may even rise higher than predicted.



Fig. 2: Solar Park with Photovoltaics.

2.1(b) Scenario in India

India has long been dependent upon Oil, Natural Gas, Coal Thermal Power and Hydro-Electric power to fulfil the energy needs of its population. As of June 2015 India is the 3rd largest importer of Crude Oil after US and China. India is 4th largest consumer of energy in the world (without doubt as it has 2nd largest population in the world) after China, US and Russia. Total energy supply in India comprises of: Crude Oil (1%), Natural Gas (9%), Coal (59%), Nuclear (2%), Hydro electricity (17%) and just 12% by other renewable sources of energy[22]. India has installed capacity of 282 GW as of November 2015. The Solar Power comprises 4097 MW as of July 2015[23]. With state of Rajasthan leading the production at 1199.70 MW followed by Gujarat at 1000.05 MW[21].

But plans are up to reach target PV to 100 GW till 2022. Not only this, many Solar Parks are coming up in India in coming decade, for example: Adani Renewable Energy Park Rajasthan with 10000 MW, Ladakh Power Project with 7500 MW, Sambhar Lake Ultra Mega Solar Power Project Rajasthan with 4000 MW, Pavagada Saura Ghataka with 2000 MW, Mahabubnagar Solar Park with 1000 MW are some of the projects above 1000 MW capacity to be completed by next decade. Many states in India have their own Power Boards hence, competition rising for the adoption of Solar PV in various states.

Some latest announcements by states for installation of Solar PV in India include: Punjab's 1000 MW canal top Solar PV project covering up 5000 Kms of canals with the help of Lockheed Martin, which will fulfil 15% of the state's power demand. Punjab also has the world's largest roof top PV project with the capacity of 7.52 MW[19]. States of Madhya Pradesh, Karnataka, Tamil Nadu are also coming up with such Solar Parks as India houses to a rich part of solar radiations of about 5000 trillion KWh over the entire land mass[11,20].

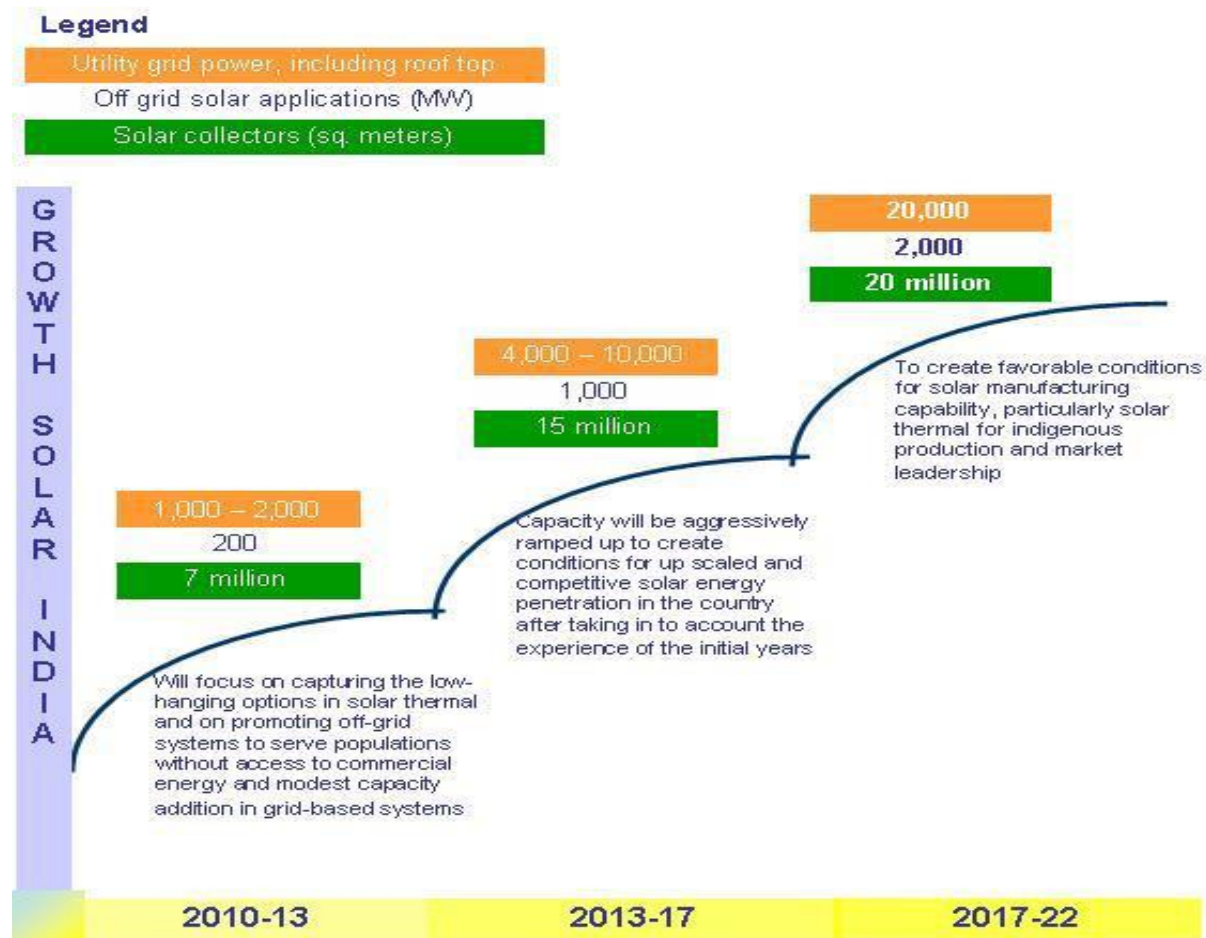


Fig.3: Growth of Solar Power in India.

2.2 Concentrated Solar Power (CSP)

As the name suggests, in this form of lenses/mirrors are used to focus sunlight over larger area to a small area/point. Electricity gets generated when this concentrated light gets converted to heat energy to drive steam turbine connected to a power generator. It is also sometimes called as Solar Thermo Electricity, or in other sense it is alternative to Thermal Power Plants which conventionally use coal as source of heat energy. By March 2015, total CSP capacity of the world crossed 4.5 GW mark, with Spain leading rest of the world at around 2.3 GW of CSP capacity, followed by US at 1.6 GW. India has CSP capacity of 225 MW.

2.2(a) Types of CSP

Depending upon type of concentrator CSP can be divided into following 5 types[4]:

2.2(a)(i) Parabolic Trough

It consists of linear reflector in shape of a parabola which concentrates sunlight onto a tube like receiver positioned along its focal line. It is placed directly above the middle of mirror and contains a working fluid (usually molten salt), the reflectors follow the sun throughout the day and heats the working fluid upto 150-350°C which is then used for power generation. This is the most developed form of CSP and is most widely used form of CSP at about 90% of all the CSP plants around the world. World's largest Parabolic Trough CSP plant is (SEGS) Solar Energy Generating Systems in California, US at capacity of 354 MW.

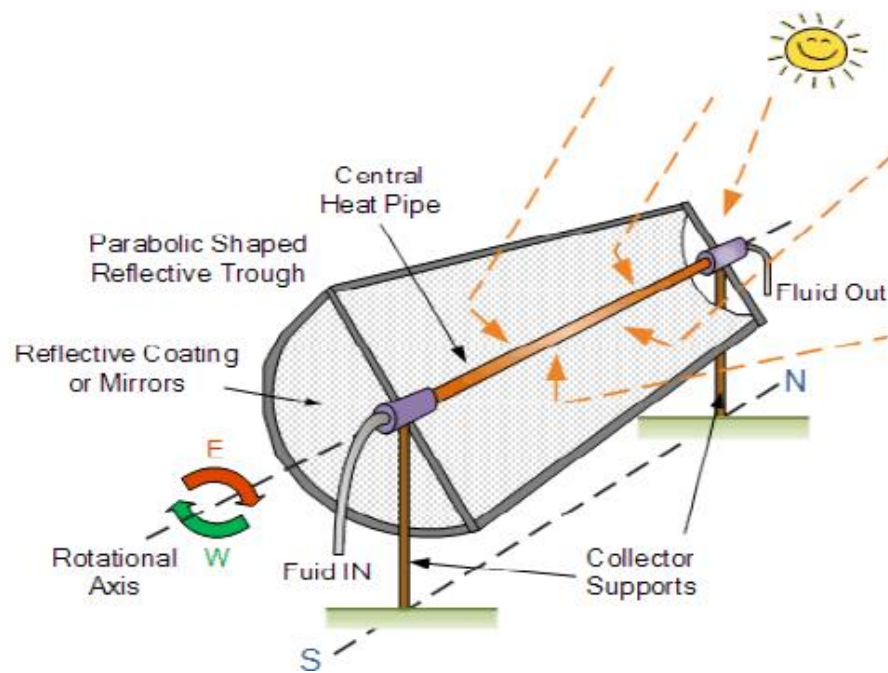


Fig. 4: Various Components of Parabolic Trough.

2.2(a)(ii) Enclosed Trough

In this type of system mirrors/lenses are hanged inside a greenhouse type of glasshouse with single solar tracker to keep the mirrors/lenses facing towards sun, in same structure steel pipes are hanged which contain water, when sunlight is focused on these pipes, the water inside gets boiled turning into steam, for now the largest enclosed trough plant is in southern Oman with capacity of 7MW, but soon another 1021 MW enclosed trough Miraah project is coming up in Oman. The glasshouse protects mirrors from sand and is washed away by automated washing system.



Fig. 5: Solar Power Production using Enclosed Trough.

2.2(a)(iii) Linear Fresnel Reflectors

In this type long, narrow and flat mirror strips are used to reflect sunlight to a fixed absorber tube that contains water and is at common focal line of all mirrors, in some cases secondary half tube shaped reflector is mounted above the absorber tube so as to channelize all the reflected sunlight to the absorber tube and not letting anything escape, the steam is superheated to a temperature of 300- 500°C, this steam rotates the turbine coupled with alternator to produce electricity. The steam is then condensed and the cycle goes on. This is cheapest form of CSP. It doesn't need any heat transfer fluid, which may be toxic and directly converts water to steam. It has CSP's best land to electricity ratio as the land below reflectors can be used for various purposes and its compact design [14,15]. This is comparatively new technology so the world capacity of CSP by Linear Fresnel Reflectors has just reached 250 MW, with largest Linear Fresnel Reflector plant being Dhursar in Rajasthan, India having capacity of 125 MW.



Fig. 6: Solar Park with Linear Fresnel Reflectors.

2.2(a)(iv) Dish Stirling

It consists of a dish shaped parabolic reflector with receiver at its focal point. It can track sun along two axes. The working fluid here is placed in receiver is heated to 250-700°C which is then used by sterling engine to generate power. It has high solar to electricity efficiency at around 31-32% (in recent experiments it is said to have reached 34%). It is one of the least used technologies till now. The largest sterling dish installation was in Maricopa, Phoenix US, having capacity of 1.5 MW before being sold and moved to China[12].



Fig. 7: Dish Sterling being used for Solar Power Production.

2.2(a)(v) Solar Power Tower

It consists of an array of heliostats (dual axis tracking reflectors) which directs sunlight to a receiver at the top of a tower in centre of the heliostats. The receiver tank consists of working fluid (sea water usually) which is heated to temperatures as high as 500-1000°C which in turn rotates the steam turbine to produce electricity. This system is less developed than conventional trough system, but offers more energy storage capacity and better efficiency. The Largest Solar Power Tower facility is Ivanpah Solar Power Facility in Mojave Desert, in California, US. It consists of 1,73,500 dual mirror heliostats focussing sunlight on 3 centralised towers. Its total capacity is 392 MW which makes it the largest CSP facility in the world too[13,18]. India has only one such station, i.e. ACME Solar Tower in Bikaner, Rajasthan with the capacity of 2.5 MW.

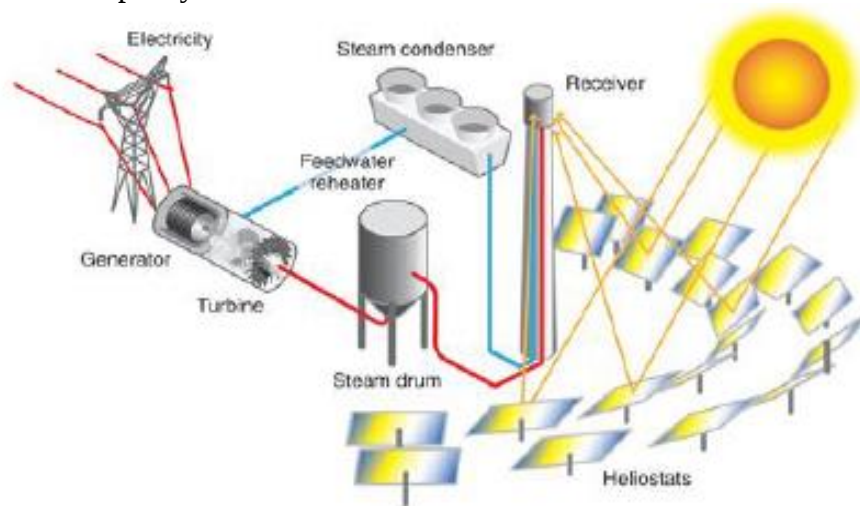


Fig. 8: Components of Production by Solar Power Towers.

2.2(b) Scenario in India

India at present has 9 CSP facilities. The oldest being ACME Solar Tower in Bikaner, Rajasthan in production since April, 2011 and has capacity of 2.5 MW. Second one is National Solar Thermal Power Facility in Gurgaon owned by IIT Bombay, it uses Parabolic Trough technology and has capacity of 1 MW, and it is in production since October, 2012. Godavari Solar Project is third oldest CSP project in India. It uses Parabolic Trough technology to reach capacity of 50 MW. It is situated in Nokh, Rajasthan and is operational since June, 2013. Megha Solar Project is situated in

Anantapur, Andhra Pradesh. It uses Parabolic Trough technology and has capacity of 50 MW and is in production since November, 2014. Dhursar CSP is world's largest Linear Fresnel Reflector facility, having capacity of 125 MW. It is situated in Dhursar, Rajasthan, owned by Reliance Power and is in production since November, 2014. The KVK Energy Solar Project in Askandra, Rajasthan uses Parabolic Trough technology and has capacity of 100 MW. Diwakar CSP Project at Askandra,

Rajasthan uses Parabolic Trough technology and has capacity of 100 MW. Gujarat Solar One in Kutch, Gujarat has capacity of 28 MW and uses Parabolic Trough technique [21]. Abhijeet Solar Project in Phalodi, Rajasthan also uses Parabolic Trough technique and has capacity of 50 MW. As the advancements are made the future scope of CSP in India is increasing day by day. Forecasts are that by the end of 2024 India will have 1.3 GW of operational CSP plants [5,20].

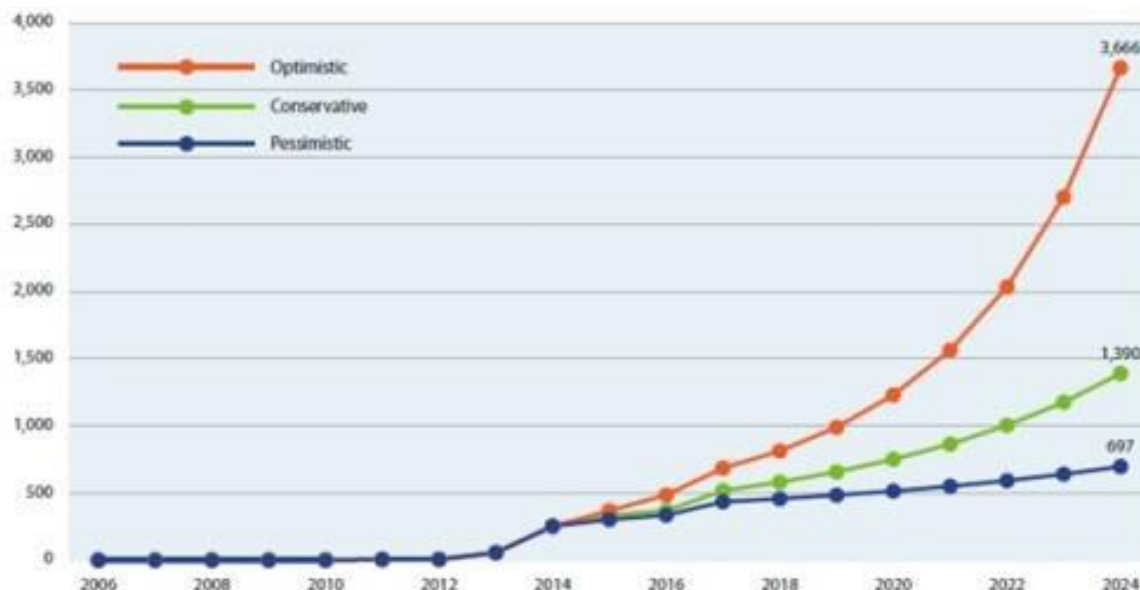


Fig. 9: Various Forecasts for CSP in India.

2.2(c) Future of CSP around the world

With advancements in technology, increasing energy demand and need for green sources of energy, the future of CSP seems bright. Proposals are being made to build very large CSPs of capacities reaching GW. Some of these proposals include 2 GW Ordos in China, 10 GW Project Helios in Greece and Euro-Mediterranean Desertec proposal. A study in 2003 stated that world could produce 23,57,840 TWh of power each year by very large Solar Projects by just using 1-2% of each of the deserts in the world. In similar move Bureau of Land Management (BLM) made available 9,79,21,069 acres of land in SW US for solar project back in 2012 and it had potential to contain 10000-20000 GW Solar Plant[10,18]. IEA (International Energy Agency) projects that by 2050 CSP could provide 11.3% of world's electricity, with 9.6% from true solar power and 1.7% from other backup fuels[4,6]. Some predictions regarding investment and capacity of CSP in 2050 are:

Year	Annual Investment	Cumulative Capacity
2015	€ 21 Billion	420 [MW]
2050	€ 174 Billion	1500 [GW]

3. Conclusion

From all the statistics regarding harness of Solar Energy in past, present and future, one thing is clear that it is the high time for the adoption of solar power over other conventional method, and every penny spent today will definitely be profitable tomorrow, not only for the coming generations but for nature the most. The cut on carbon emissions, control on global warming and greenhouse effect can only be controlled if we put our efforts from this very day. Solar Energy has great potential, as stated earlier it can alone fulfil all the world's energy demands by using minimal area.

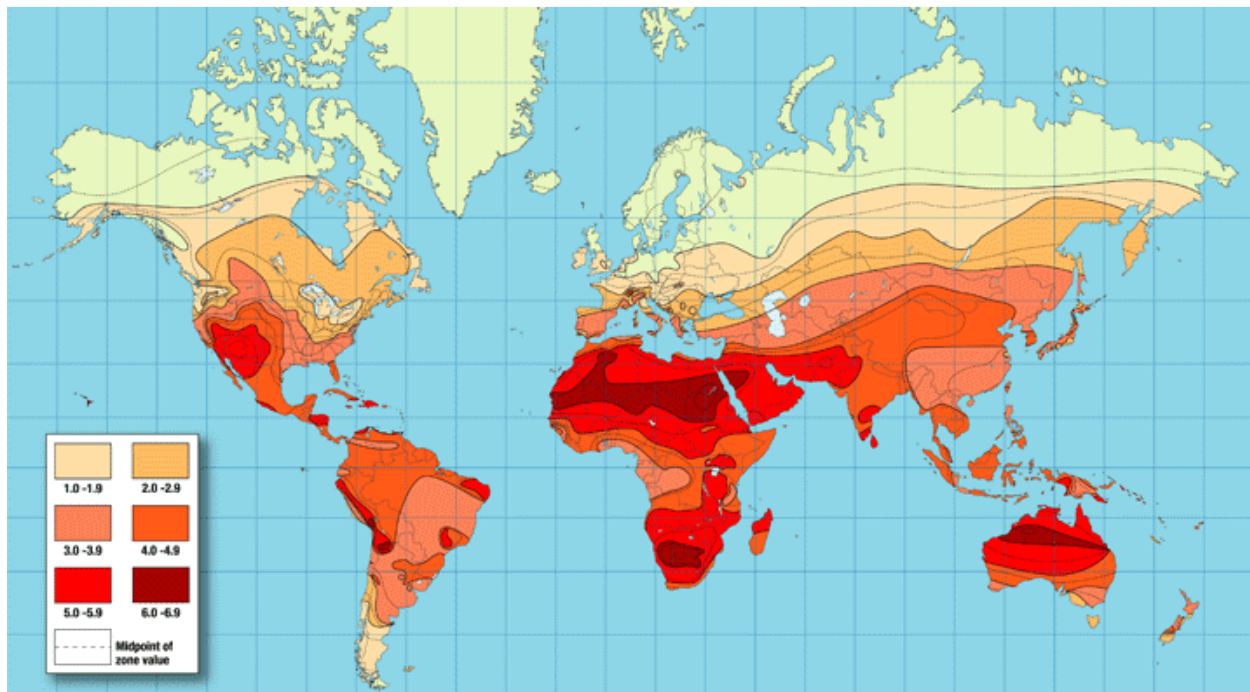


Fig. 10: Solar insolation around the world.

This map of the world shows the solar insolation data around the world, all figures are in KWh/m²/day.

- Areas in cream colour have insolation value less than 1.0 KWh/m²/day mainly in Polar Regions.
- Areas in skin colour have insolation value between 1.0-1.9 KWh/m²/day mainly in sub Polar Regions.
- Areas in light orange colour have insolation value between 2.0-2.9 KWh/m²/day mainly in Temperate Regions.
- Areas in pinkish orange colour have insolation value between 3.0-3.9 KWh/m²/day mainly in sub Tropical and Mediterranean Regions.
- Areas in orange colour have insolation value between 4.0-4.9 KWh/m²/day mainly in Tropical Regions.
- Areas in red colour have insolation value between 5.0-5.9 KWh/m²/day mainly in Semi, Moderately Arid Regions.
- Areas in brown colour have insolation value between 6.0-6.9 KWh/m²/day mainly in Arid Regions.

This shows the amount of potential Solar Insolation has around the World. If we talk about India most of its area has insolation value of 4.0 and above, which indicates a need to shift from conventional power sources to Solar Power[2,16]. Whether PV or CSP, both techniques are equally effective and it is sure, the targets set if met will turn the shape of future in totally different way.

4. E-References

1. https://en.wikipedia.org/wiki/Solar_power
2. <http://solarinsolation.org/>
3. <https://en.wikipedia.org/wiki/Photovoltaics>
4. https://en.wikipedia.org/wiki/Concentrated_solar_power
5. <http://www.nrel.gov/csp/solarpaces/>
6. <http://www.iea-pvps.org/>
7. https://en.wikipedia.org/wiki/Solar_power_by_country
8. <http://www.renewableenergyworld.com/solar-energy.html>
9. <http://www.powerengineeringint.com/renewables/solar.html>
10. <http://social.csptoday.com/technology/large-scale-plants-future-csp>
11. <http://www.mnre.gov.in/schemes/grid-connected/solar/>
12. <http://www.solarthermalpowerplant.com/stirlingdishesolarthermal.html>
13. https://en.wikipedia.org/wiki/Ivanpah_Solar_Power_Facility
14. https://en.wikipedia.org/wiki/Compact_linear_Fresnel_reflector
15. <http://www.solareuromed.com/en/miroirs-de-fresnel>

16. <http://www.greentechmedia.com/channel/solar>
17. https://en.wikipedia.org/wiki/Solar_Energy_Generating_Systems
18. https://en.wikipedia.org/wiki/Solana_Generating_Station
19. <http://thegreenenergyblog.com/uncategorized/lockheed-martin-to-provide-nanotech-basedstructures-for-canal-top-solar-power-projects-in-india>
20. https://en.wikipedia.org/wiki/Solar_power_in_India
21. https://en.wikipedia.org/wiki/Gujarat_Solar_Park
22. https://en.wikipedia.org/wiki/Electricity_sector_in_India
23. http://www.pv-magazine.com/news/details/beitrag/indian-solar-2015--a-breakthroughyear_100017819/#axzz3uIDHz6pR
24. https://en.wikipedia.org/wiki/List_of_photovoltaic_power_stations
25. <http://pureenergies.com/us/blog/top-10-countries-using-solar-power/>
26. https://en.wikipedia.org/wiki/World_energy_consumption
27. https://en.wikipedia.org/wiki/Growth_of_photovoltaics

