Journal of Renewable Energy Science, Technology and Economics
ISSN 2395 – 2644 (print) Vol 1, Issue 1 - May 2015

A Review of the Performance and Viability of Solar Power Technologies with the Optimization of Solar Power Generation

Shiladitya Das, BTech 4th year, Electronics and Communication Engineering

Institute of Engineering & Management, Salt Lake sector V, Kolkata, West Bengal.

Email: shiladityadas19@gmail.com

INTRODUCTION:

Cognizant of the increase in the pressing problems of Green House Gas emissions and Global Warming due to conventional methods of energy generation, emphasis is being laid upon Clean Energy technology to meet the global energy demand. Approximately 3,850,000 exajouls (EJ, 1EJ = 10^{18} J) energy is absorbed by the Earth's atmosphere, land masses and oceans per year.[1] The solar energy that is received by the surface of the Earth in a year is about twice as much as can be obtained from all of Earth's non-renewable resources of coal, oil, natural gas and mined Uranium combined.[2] Coupled with the fact that the sun has another 6.5 billion years of its life left.[3] Solar energy is therefore the most promising source of power. Ground breaking research is being conducted and recent break throughs have taken place in the field of Solar energy which has developed solar power as one of the fastest growing technologies in the market today.

Various technologies like Photovoltaic modules, Thin Films, Concentrated solar power and Concentrated Photovoltaic technology have come to the forefront in harvesting solar energy. It has been observed that once a system has been installed, future upgrades and changes in operation methods can be difficult and expensive. Optimizing the use of solar power, it is imperative to have knowledge and information regarding the various solar technologies so as to be able to identify the correct locations, communities and climate that will be suitable for a particular technology. Therefore the scope of this paper is to bring about a comparative study between the different prominent Solar Power technologies and optimize their usage.

IMPORTANT SOLAR TECHNOLOGIES:

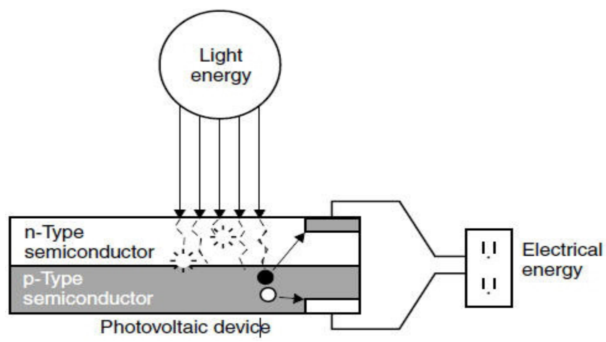
Solar power technology has developed a lot from its inchoate state and presently the two most important Active Solar technologies for the generation of electricity includes Photovoltaic (PV) technology which directly converts the energy of sunlight into electricity while the other is called Concentrating Solar power (CSP) which utilizes the heat energy to run a heat engine.

SOLAR PHOTOVOLTAIC TECHNOLOGY:

Presently PV technology supplies around 0.1% of the total global electricity generation. Cost reductions as well as effective policies have paced up the growth of the solar PV industry. This reliable technology has a potential for long-term growth nearly in every habited region and is supposed to provide 5% of global electricity consumption in 2030, going up to 11% by 2050, according to IEA (International Energy Agency).[4]

A PV cell basically consists of a thin wafer comprising of an ultra-thin layer of phosphorous-doped (N-type) silicon on top and a thicker layer of boron-doped (P-type) silicon below. An electric field gets created across the P-N junction that forms between the layers, having a larger depletion region in the P-type layer since the N-type layer is heavily doped. This is done so as to increase the collection probability of electrons that will be generated when the photon energy will dislodge the electrons from the atoms in the cell. The movement of freed electrons and holes generates electricity in the circuit.

Figure 1: Photovoltaic effect



https://sites.google.com/site/reeetech/home/photovoltaic

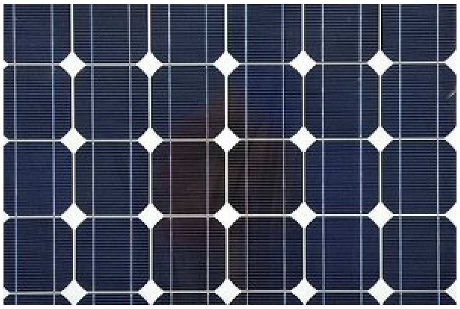
Depending on the material used and the level of commercial maturity, PV cell technology has been classified into three generations-

First generation PV systems- This technology comprises of 85% to 90% of the present global annual market. It consists of crystalline silicon modules which are subdivided into two categories such as Single crystalline (sc-Si) or Mono-crystalline and Multi crystalline (mc-Si) or Poly-crystalline.

- **Mono-crystalline Silicon-** The Czochralski method is used to pull out highly pure silicon ingots which are cut into wafers to produce monocrystalline silicon.
  The efficiency typically ranges from 15%-20% with the highest efficiency achieved by the solar power company Sun Power which is around 24.7% (Lab efficiency). The efficiency is projected to increase to 23% by 2020 and to 25% in the later years.[5]

This technology has the longest life of approximately 25 years and performs better than the lower priced multi-crystalline silicon modules. High cost of this technology is inhibiting its growth. Development in the ingot creation and wafer manufacturing process can help reduce costs.

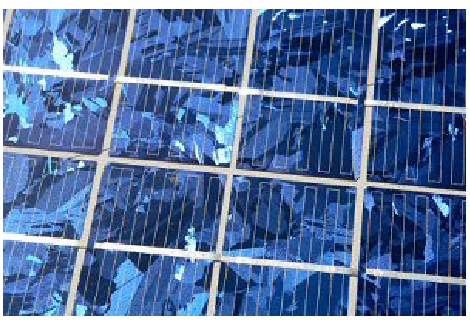
Figure 3: Mono-crystalline Silicon cells



http://www.solarpv.co.uk/siteimages/monocrystalline-cells.jpg

- **Multi-crystalline Silicon-** Raw silicon is melted and purified Solar Grade silicon is cooled and cut into square wafers. The efficiency typically ranges from 13%-16% and this technology, tough it wastes less silicon and being cheaper to mono-crystalline silicon modules suffer from certain drawbacks. Life span is relatively shorter and its performance lacks compared to mono-crystalline modules thus more space is used up to be able to give similar output. They also have a degradation rate of 2% per year.

Figure 4: Multi-crystalline Silicon cells



http://www.solarpv.co.uk/siteimages/polycrystalline-cells.jpg

Crystalline silicon modules tend to be bulky and this induces the problem of portability therefore it leads to a significant increase in transportation cost. The setting up of modules becomes difficult and cumbersome due to their weight thus requiring stronger structures to support them. High temperatures have a strong impact on first generation module performance, higher the temperature, lower is the output of the module. This is a serious problem in countries having high average temperatures. Shading is another serious problem where a small section of the module if shaded can reduce the power output of modules drastically and can also lead to hotspot effect and consequently damage the solar cells.

To combat the problems of weight, cost, shading and high temperature effects on efficiency, technology has developed and the Second generation PV technologies have been introduced into the market.

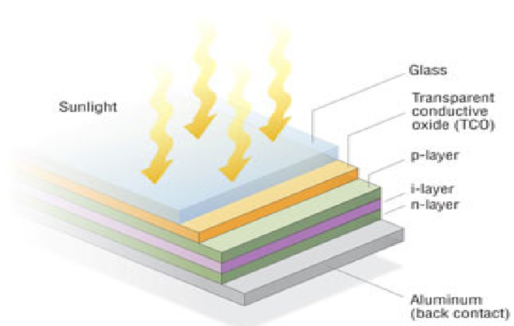
Second generation PV systems- This technology comprises of 10% to 15% of the present global annual market. It consists of Solar Thin Film technology which is subdivided into three categories such as a) amorphous (a-Si) and micromorph silicon (a-Si/uc-Si) b) Cadmium-Telluride (CdTe) c) Copper-Indium-Selenide (CIS) and Copper-Indium-Gallium-Diselenide (CIGS).

Thin Film technology-

Thin films are constructed by the deposition of photosensitive material in very thin layers in the rage of a few microns (um) on a substrate such as glass, plastic, stainless steel or metal foil. The deposition of the layers can be achieved by directly spraying the material onto the glass or metal substrate thus the manufacturing process becomes faster, energy efficient and mass production becomes easier compared to the ingot creation approach of crystalline silicon. Since Thin films can absorb light more efficiently than crystalline materials, the layers can be made very thin (to even less than a micron up to 0.3 micrometers as in case of a single layer of amorphous silicon) the benefit that we can reap is a significant cost reduction but at the expense of reduced efficiency due to a non-single crystal structure.

- **Amorphous silicon (a-Si)-** Amorphous silicon was used to make the first thin film solar cells. Amorphous means shapeless, the silicon material does not have a definite structure or is crystallized on a molecular level. The light absorptive capacity of amorphous silicon is much higher than crystalline silicon thus only thin layers are required of around one micrometer thick as compared to the crystalline silicon wafer thickness of 200 microns.The low conversion efficiency in the range of 5% to 9% impedes its applications in large power plant operations, thus their use lies manly in the realm of pocket calculators and other small hand held devices.[6] They also suffer less from higher temperatures and operate well in diffused light conditions when compared to crystalline silicon.

<u>Figure 5: Amorphous silicon Thin film structure</u>

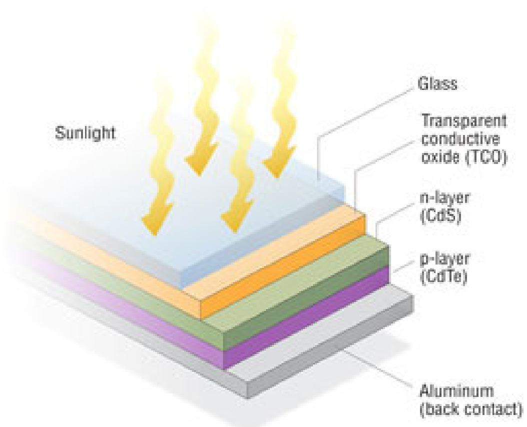


http://energyinformative.org/wp-content/uploads/2013/06/graphic_asi.jpg

- **Cadmium Telluride (CdTe)-** The absorption capability of CdTe is quite high around 90% of the solar spectrum.[7] The band gap is also 1.5eV which is close to the ideal for photovoltaic conversion efficiency (1.45eV). The advantage associated with CdTe is the lower fabrication cost since the manufacturing processes such as high-rate evaporation, spraying or screen printing is cheap. Cadmium Sulfide (CdS) along with CdTe creates the N-type and P-type layers necessary for PV cell functioning.

  The efficiency of this thin film technology is competitive which lies upwards of 15%. Good efficiency coupled with lower cost and better functioning than crystalline silicon at higher temperatures and diffused light conditions makes this technology a promising one. In multi-kilowatt systems at higher temperatures, this technology actually beats crystalline silicon in terms of cost.[8] The biggest drawback of this technology is the material that is being used, Cadmium. Cadmium being a heavy metal is highly toxic to the environment and since it affects the food chain, it can cause ecological imbalance.

  Figure 6: Cadmium Telluride Thin film structure

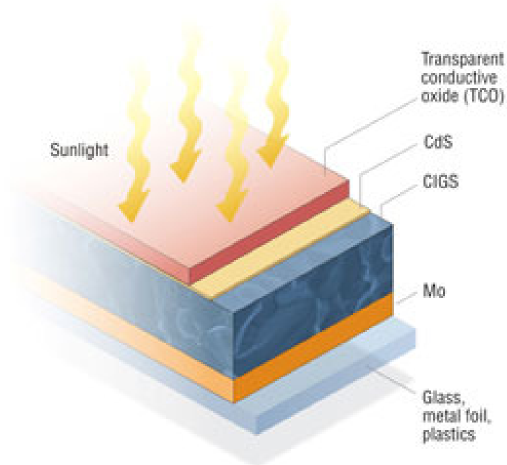


http://energyinformative.org/wp-content/uploads/2013/06/graphic_cdte.jpg

- **Copper Indium Gallium Selenide (CIS/CIGS)-** This new thin film technology is more advanced than CdTe thin films. CIGS reduces the problem of toxicity that was associated with CdTe and also has a higher conversion efficiency. Similar to CdTe technology, here also a layer of CdS is used to build the N-type and P-type structure. The cost becomes a major factor here as fabrication costs are high for this technology. A layer of molybdenum (Mo) is used to create an effective electrode in CIGS-on-glass cells. This layer of Mo is not required in CIGS-on-foil cells as the metal foil itself act as the electrode. The other electrode is made of a layer of Zinc Oxide (ZnO).

  In 2013, scientists at Empa, the Swiss Fedral Laboratories for Material Science and Technology have been successful to create CIGS cells on polymer foils having a record efficiency of 20.4%.[9]

Figure 7: Copper Indium Gallium Selenide Thin film structure



http://energyinformative.org/wp-content/uploads/2013/06/graphic_cigs.jpg

Performance in Real Operating Conditions- A Comparative Study

One of the biggest problems that solar cells face out in the open is the effect of high temperature. First generation crystalline silicon and second generation thin film technology both suffer from reduced performance due to heating. The lower negative temperature coefficient of Thin film PV technologies is one advantage that they enjoy over crystalline silicon technology. Thus in places having a hot climate like Singapore, where the cell temperatures go up to 70 degree Celsius, even having a lower conversion efficiency than crystalline silicon, Thin film technology generates 5%-10% more electricity per year.[10]

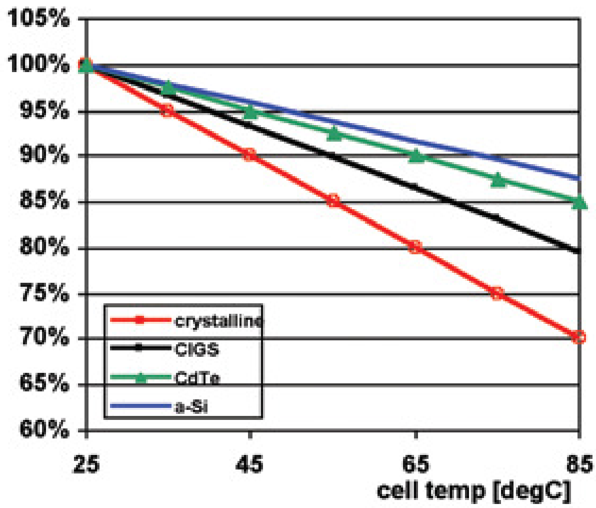
Table 1: Temperature Coefficients of various PV technologies

Technology	Temperature Coefficient [%/C]
Crystalline Silicon	-0.4 to -0.5
CIGS	-0.32 to -0.36
CdTe	-0.25
a-Si	-0.21

Energy Market Authority Handbook for Solar Photovoltaic (PV) Systems

Figure 8: Graph of power output of PV technologies with respect to cell temperature

Y axis- Module output relative to STC   X axis- Cell temperature [deg C]



Energy Market Authority Handbook for Solar Photovoltaic (PV) Systems

Direct and strong sunlight is very important for crystalline silicon cells to provide full output power. The problem lies in the fact that areas that have direct strong solar irradiance that is in the countries in the Sunbelt or Torrid Zone tend to have higher temperatures which again has a depreciative effect on the output power. These panels also suffer from a high degradation rate of 1.5% per annum from the Watts Peak value.

Thin film PV technology on the other hand works much better than crystalline silicon in overcast conditions where there is no direct sunlight. The degradation rate is also less than 1% per annum from the Watts Peak value thus making this technology usable in a more variety of places with different climatic conditions than first generation PV technology.[11]

Table 2: Performance of First and Second generation PV technology- an Overview

	Mono-crystalline	**Poly-crystalline**	**a-Si**	**CdTe**	**CIS/CIGS**
Module efficiency	15%-20%	13%-16%	6%-8%	9%-11%	10%-12%
Best research cell efficiency	25.0%	20.4%	13.4%	18.7%	20.4%
Area required for 1KWp	6-9 sq m	8-9 sq m	13-20 sq m	11-13 sq m	9-11 sq m
Temperature resistance	10%-15% output drop at high temperature	Less temperature resistant than monocrystalline	Tolerates extreme heat	Relatively lower impact on performance	

National Renewable Energy Laboratory (NREL)

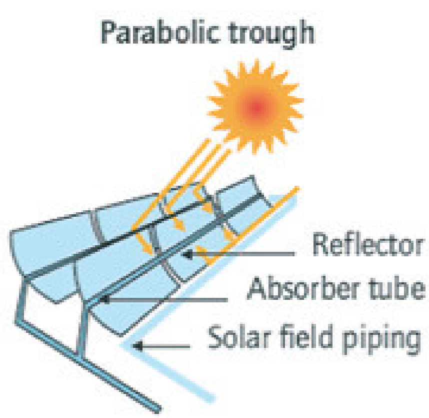
CONCENTRATING SOLAR POWER TECHNOLOGY:

This technology has a very less installed capacity as compared to PV technology at around 2GW worldwide up to the year 2012 with a plan to install 12GW of capacity by 2015. The capital cost for installation of CSP power plant is considerably higher than PV power plants but with a significant drop of component cost (drop by around 15% by 2015) and advancement of technology, CSP will turn out to be a viable source of sustainable power in the longer run.
CSP makes use of mirrors, reflectors and concentrators to focus sunlight onto a smaller area, thus increasing the concentration factor to high levels. This heat is used to heat up a heat transfer fluid which is used to generate steam to run steam turbines. The absence of sunlight during night hours can be countered by using a heat storage system which holds the heated up fluid in properly insulated storage tanks. Since CSP technologies need to constantly direct the sun's rays onto a receiving area, the systems are installed with solar tracking systems.

Various CSP Technologies-

- **Parabolic Trough (PT)-** Comprising of more than 90% of the presently installed CSP capacity, Parabolic Trough system is the most mature technology. Parabolic mirrors are used here which concentrate the sun's rays to heat receiving steel tubes with high heat absorbing coating which run along the focal line of the system. The heat transfer fluid used is synthetic oil with a maximum operating temperature of 390 degree Celsius. Since it is limited by a lower degradation temperature, the resulting solar conversion efficiency is around 14% to 16%. Molten salt having good stability, higher degradation temperature upwards of 550 degree Celsius and high heat capacity works well as a heat transfer and heat storage fluid, increasing the efficiency up to 15% to 17%. The three 50MW Andasol units units by ACS/Cobra Group and Marquesado Solar SL and two 50MW (Valle I and II) plants by Torresol Energy in spain are unique as synthetic oil is used as a heat transfer fluid and molten salt as the thermal storage fluid.[12]

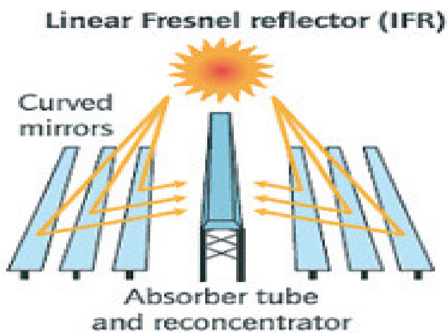
Figure 10: Basic Parabolic Trough design



IRENA-ETSAP Technology Brief E10 Concentrating Solar Power

- **Fresnel Reflectors (FR)-** A series of ground-based flat or slightly curved mirrors at different angles are used to focus sunlight onto a fixed receiver located above the mirror field. The mirrors are equipped with a single axis tracking system that tracks the sun throughout the day. This is a Direct Steam Generation (DSG) technology where the heat is directly used to convert flowing water into saturated steam. The problem faced by FR DSG systems is in storage as it can become difficult and expensive. The advantage is the minimum use of mirror supporting structures as the mirrors are ground-based thus there is a good reduction in cost from this angle. The efficiency of FR systems is lower than PT systems but the lower manufacturing and installation cost helps to balance it.

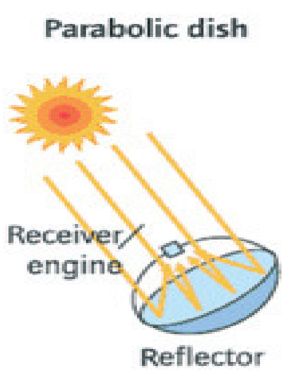
Figure 11: Basics of Fresnel Reflector design



IRENA-ETSAP Technology Brief E10 Concentrating Solar Power

- **Solar Dish (SD)-** This technology basically comprises of a parabolic dish concentrator which concentrates sunlight to its focal point where a heat engine is installed. SD technology is not so widely commercialised or mature like PT but this technology is growing fast and having higher concentration factors and working temperatures, the results are promising. This technology is suitable for distributed generation and since it does not require water for cooling purposes like other CSP technology, its use in arid locations seems reasonable. Stirling engines are generally used as the generation units having efficiency upwards of 30%. Even though SD technology has high manufacturing and installation cost, it has good efficiency and is suited for operations even in arid regions.

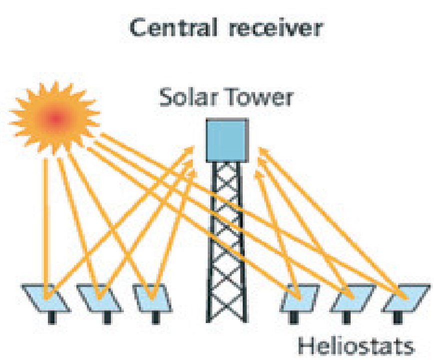
Figure 12: Basics of Solar Dish design



IRENA-ETSAP Technology Brief E10 Concentrating Solar Power

- **Solar Tower (ST)-** Solar Tower CSP plants make use of many heliostats (mirrors) which individually track the sun throughout the day on a dual axis tracking system and concentrate the sunlight onto a receiver mounted on top of a tower placed in the middle of the heliostat field. The higher concentration factors enables ST systems to achieve higher operation temperatures than PT or FR thus leading to better performance. The primary heat transfer fluids that can be used here are water-steam (DSG) at temperatures of 250-300 degree Celsius, synthetic oil at temperatures of 390 degree Celsius and the highest operating temperature is possible while using molten salt at around 565 degree Celsius. Research is being conducted on using gases for temperatures above 800 degree Celsius. The heat transfer fluid is transported to the top of the solar tower where it is heated up at the receiver, and then transported to the heat exchangers. Here the heat is taken up from the heated fluid to convert water into steam which is used to run the steam turbines.

Figure 13- Basics of Solar Tower design



IRENA-ETSAP Technology Brief E10 Concentrating Solar Power

The heat transfer fluid must have a low melting point, high heat capacity, high thermal stability and a high degradation temperature to enable a high operating range and effective thermal storage. The conventional solar salt that is used comprises of 60% $NaNO_3$-40% KNO_3 and HITEC comprising of 7% $NaNO_3$-53% KNO_3-40%$NaNO_2$.[13] Research has shown that a new eutectic mixture with certain amounts of $LiNO_3$ is showing favourable results leading to a reduced melting point and an increase in heat capacity and high degradation temperatures.

Table 3: Comparison of melting point, heat capacity and degradation temperature of various salts

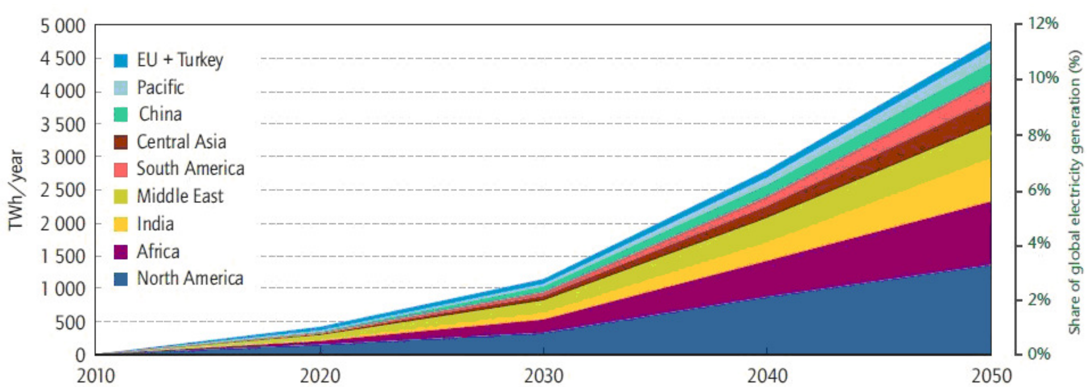
Eutectic mixture	Melting point (degree Celsius)	Heat capacity (j/g.C)	Degradation temperature (degree Celsius)
Conventional solar salt	220	2.15	511.77
HITEC salt	142	2.23	625.38

Mixture with 15% LiNO3	104	2.46	579.72
Mixture with 20% LiNO3	79	2.78	560.93

International Conference on Renewable Energies and Power Quality (ICREPQ'14)
Cordoba (Spain), 8th to 10th April, 2014
Thermal evaluation of molten salts for solar thermal energy storage
C. Villada, F. Bolívar, F. Jaramillo, J.G. Castaño and F. Echeverría

From this table we can see that when the mixture contains 15% of LiNO3, the melting point reduces, the heat capacity increases and we get a higher degradation temperature than conventional solar salt. When the mixture contains 20% LiNO3, the heat capacity further increases, melting point further decreases but the trade off here is that the degradation temperature starts to decrease. HITEC has the highest degradation temperature here at 625 C but if we look at the bigger picture, the overall better performance that can be achieved by taking into account all points, which are lower melting point, higher heat capacity, higher degradation temperature, the eutectic mixture containing 15% LiNO3 will be a better choice.

Figure 15: Growth of CSP production by region (TWh/yr)



Source: International Energy Agency (IEA), Technology Roadmap-Concentrated solar power

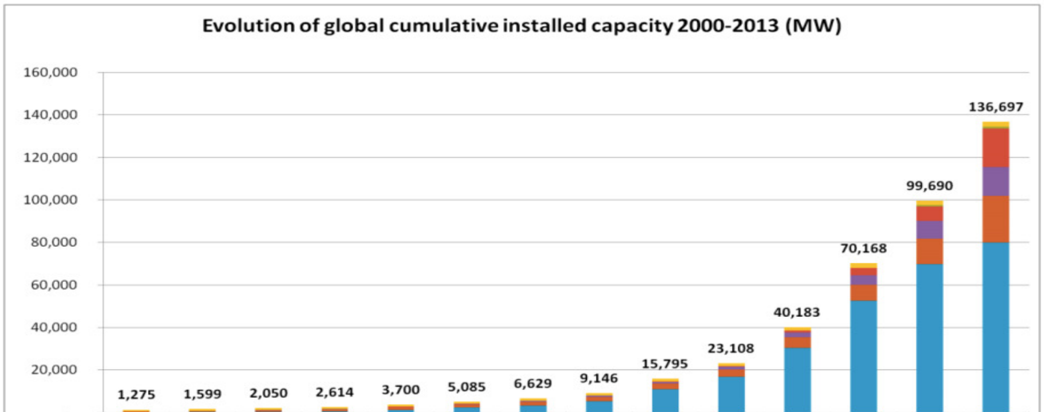
From this chart we can see that the maximum growth in CSP technology has been predicted till 2050 and we can see that North America(South-West USA), Africa(Northern Africa) and India(Western India) can become the largest producers. Their locations, solar insolation and higher temperatures will help to play a major role in the growth of this technology.

PV and CSP technology, a comparative overview-

Since CSP makes use of steam turbines, they generate alternating current (AC) while PV generates direct current (DC). CSP technology is more grid friendly as this AC can be directly fed to the grid whereas an inverter is required to convert this DC to AC in case of PV then only it can be fed to the grid.[14] Low loss High Voltage DC (HVDC) lines can be a good option for PV technologies to transport power over long distances and then an inverter can be used at the consumer end. The use of turbines makes CSP easier to hybridise with other conventional power systems than PV. A big advantage that CSP has over PV is the storage
system. CSP can store heat for over 15 hrs in the insulated storage tanks so as to run the turbines but storage becomes a problem with PV as the batteries become very expensive. The advantage

that PV enjoys is the relative plant simplicity and lower installation and manufacturing cost, usability in domestic places even roof tops and does not use water which is required by CSP for condensation purposes.

Figure 16: Evolution of global cumulative installed Solar Power capacity 2000-2013

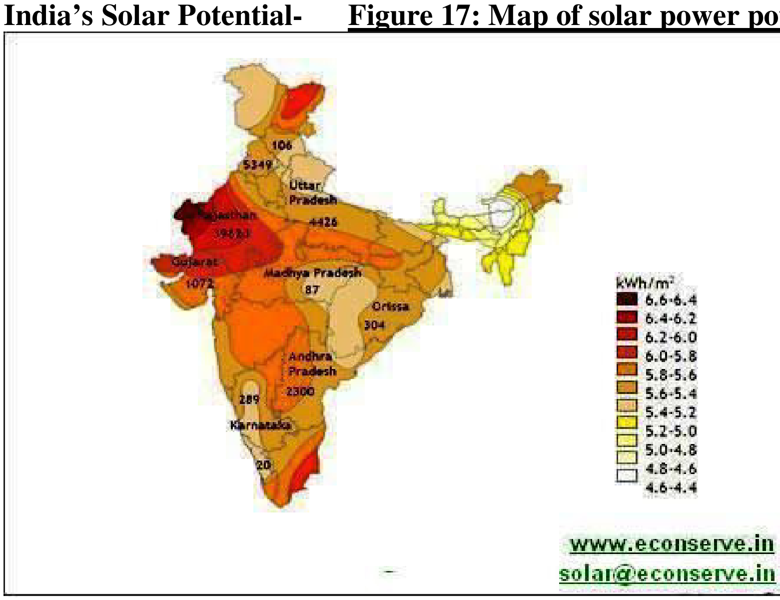


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
ROW	751	807	887	964	993	1,003	1,108	1,150	1,226	1,306	1,590	2,098	2,098	2,183
MEA	-	-	-	-	1	1	1	2	3	25	80	205	570	953
China	19	24	42	52	62	70	80	100	140	300	800	3,300	6,800	18,100
AMERICA	21	24	54	102	163	246	355	522	828	1,328	2,410	4,590	8,365	13,518
APAC	368	496	686	916	1,198	1,502	1,827	2,098	2,628	3,373	4,951	7,513	12,159	21,992
Europe	116	249	381	580	1,283	2,264	3,258	5,274	10,970	16,777	30,352	52,462	69,699	79,952
TOTAL	1,275	1,599	2,050	2,614	3,700	5,085	6,629	9,146	15,795	23,108	40,183	70,168	99,690	136,697

Source: EPIA http://i1.wp.com/cleantechnica.com/files/2014/04/world-solar-power-capacity.png

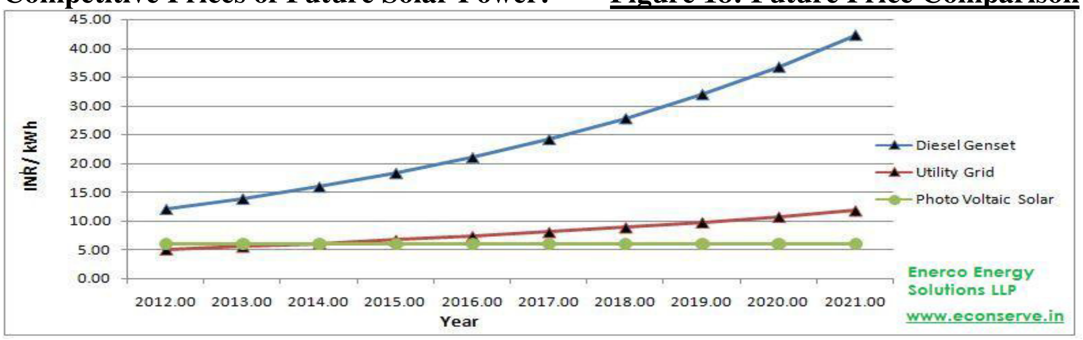
This chart clearly shows that there has been a huge exponential growth of the total cumulative installed solar power capacity from the year 2000 to the year 2013. Europe has been the world leader in this field of unconventional power and the country Germany has the maximum solar PV installations. Reduction in component prices, supporting policies progressive research has helped to make this technology grow at a promising rate.

India's Solar Potential- **Figure 17: Map of solar power potential of India**



When we see this map we find that the western part of India in the states of Rajasthan and Gujrat, the solar power generation potential is the highest in the country. Availability of vast open land in Rajasthan and northern Gujrat close to the Rann of Kachh are suitable places for implementation of Mono and Multi Crystalline Solar modules. Solar Dish systems can be used for daytime power requirement of small scale industries of distributed communities in high insolation regions while roof-top PV can be used to store power for night-time purpose. We also see that the states of Maharashtra, Uttar Pradesh, Madhya Pradesh and Andhra Pradesh have good solar generation capability along with the various important rivers passing through these regions like Narmada, Ganges and Godavari. These rivers can help to supply water for steam generation thus favouring the setting up of CSP plants (PT and ST). Focusing on the North-Eastern region we see that the solar generation capacity is lagging due to low solar insolation and diffused sunlight. The Solar technology that can be implemented here is Thin Film technology as we know they can perform even under diffused light conditions and since they are light weight, we can cut expenses on implementation costs.

Competitive Prices of Future Solar Power: **Figure 18: Future Price Comparison**



With the rapid development of Solar technology, government aid and supporting policies and laws, the prices are reducing at a good and promising rate. From the above graph when we compare the prices of Diesel, Grid and Solar power, we see that solar power tends to be cheaper in the future compared to the other sources of power thus having the capability to become the dominant source of power in future.

Present Indian Scenario: **Table 4: Present Solar Generation Capacity (state-wise)**

State	MWp	%
Gujarat	654.8	66.9
Rajasthan	510.25	20.2
Andhra Pradesh	21.8	2.2
Maharashtra	20.0	2.0
Tamil Nadu	15.0	1.5
Orissa	13.0	1.3
Uttar Pradesh	12.0	1.2
Karnataka	9.0	0.9
Punjab	9.0	0.9
Haryana	7.8	0.8
Uttarakhand	5.0	0.5
Chhattisgarh	4.0	0.4
Jharkhand	4.0	0.4
Delhi	2.5	0.3
Madhya Pradesh	2.0	0.2
West Bengal	2.0	0.2
Total	**1686.44**	**100**

SUN POWER ENERGY FOREVER Construction magazine Construction news Builders magazine Building Construction Magazine.htm

CONCLUSION:

This paper has focused on the various Solar Power technologies that are relevant for Grid Interactive as well as Stand Alone power systems in India. As mentioned earlier, a comparative knowledge on these different technologies is very important before implementing them for real life usage as once implemented, further changes in future can become expensive and difficult. It is thus wise to know about the various factors concerning PV as well as CSP technologies and their requirements before their implementation for optimization of Solar Power Generation.

We saw that the states of Gujrat and Rajasthan have the highest potential for Solar Power generation (preferably PV) because of high Solar insolation. Small distributed communities in Western Rajasthan or other parts of the country having high solar insolation and distributed habitation can use centralised (community-wise) SD systems for day-time purpose because of high efficiency, no water requirements, works better at higher temperatures unlike PV systems and provides AC power directly which can be used for various day time activities like running machines, pumps and small scaled industries. Roof-Top stand-alone PV systems can be used to store power for night-time use.

CSP technology like PT and ST should be set up close to the main rivers of India as they need water for steam generation. The advantage that we get here is that CSP output is in the form of AC power and if seen carefully, most of the industries are located close to the rivers so this power can be supplied to the industries directly for industrial and economic growth.

Thin Film technology being light and has the capability to work under diffused light conditions are a better option for solar power generation in North-Eastern India due to the fact that solar insolation is weak in that region.

With the rate of price rise and resource depletion of diesel, coal and natural gas, conventional power generation is bound to get very costly in the near future. Technological development is constantly bringing down the cost of solar power system components and India being in the Torrid Zone has one of the best potentials for Solar Power Generation both PV and CSP. Thus the coupling of these facts proves to be a strong boost for the Solar Power Industry.

REFERENCES:

1) Solar_energy#cite_note-Smil_2006.2C_p._12-8
2) Solar_energy#cite_note-16
3) (http://energyinformative.org/)
4)]International Energy Agency (IEA*), Technology Roadmap-Solar Photovoltaic Energy*, 2010 www.iea.org/papers/2010/pv_roadmap.pdf
5) Green Energy – Solar Energy, *Photovoltic (PV) Cell*, 2011, https://sites.google.com/site/reeetech/home/photovoltaic
6) Op cit
7) Op cit
8) Best Thin Film Solar Panels – Amorphous, Cadmium Telluride or CIGS - Energy Informative.htm
9) The National Renewable Laboratory(NREL)First Solar
10) Energy Market Authority Handbook for Solar Photovoltaic (PV) Systems
11) Green Energy – Solar Energy, *Photovoltic (PV) Cell*, 2011, https://sites.google.com/site/reeetech/home/photovoltaic
12) Green Peace, Concentrated Solar Thermal Power-Now! 2005
13) International Conference on Renewable Energies and Power Quality (ICREPQ'14),Cordoba (Spain), 8th to 10th April, 2014
Thermal evaluation of molten salts for solar thermal energy storage
C. Villada, F. Bolívar, F. Jaramillo, J.G. Castaño and F. Echeverría
14) Renewable Green Energy Power
http://www.renewablegreenenergypower.com/solar-energy-facts-concentrated-solar-power csp-vs-photovoltaic-pv-panels/