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A comprehensive study of solar power in India and World

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ABSTRACT

Energy is considered a prime agent in the generation of wealth and a significant factor in economic development. Energy is also essential for improving the quality of life. Development of conventional forms of energy for meeting the growing energy needs of society at a reasonable cost is the responsibility of the Government. Limited fossil resources and environmental problems associated with them have emphasized the need for new sustainable energy supply options that use renewable energies. Development and promotion of non-conventional/alternate/new and renewable sources of energy such as solar, wind and bio-energy, etc., are also getting sustained attention. Alternative energy news source has long asserted that there are fortunes to be made from smart investments in renewable energy. Solar power is one of the hottest areas in energy investment right now, but there is much debate about the future of solar technology and solar energy markets. This report examines various ways in which solar power is precisely such an opportunity.

Contents

1. Introduction

Solar power is the generation of electricity from sunlight. This can be direct as with photovoltaic's (PV), or indirect as with concentrating solar power (CSP), where the sun's energy is focused to boil water which is then used to provide power. The largest solar power plants, like the 354 MW solar energy generating systems (SEGS), are concentrating solar thermal plants, but recently multi-megawatt photovoltaic plants have been built. Completed in 2008, the 46 MW Moura photovoltaic power station in Portugal and the 40 MW Waldpolenz Solar Park in Germany are characteristic of the trend toward larger photovoltaic power stations. Much larger ones are proposed, such as the 100 MW Fort Peck Solar Farm,

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the 550 MW Topaz Solar Farm, and the 600 MW Rancho Cielo Solar Farm.

Solar power plants can face high installation costs, although this has been decreasing due to the learning curve. A new study on the installed costs of solar PV power systems in the U.S. shows that the average cost of these systems declined significantly from 1998 to 2007, but remained relatively flat during the last two years of this period [1]. Developing countries have started to build solar power plants, replacing other sources of energy generation [2]. Solar power has great potential, but in 2008 supplied only 0.02% of the world's total energy supply. However, use has been doubling every two, or less, years, and at that rate solar power, which has the potential to supply over 1000 times the total consumption of energy, would become the dominant energy source within a few decades [3].

Since solar radiation is intermittent, solar power generation is combined either with storage or other energy sources to provide continuous power, although for small distributed producer/consumers, net metering makes this transparent to the consumer. On a larger scale, in Germany, a combined power plant has been demonstrated, using a mix of wind, biomass, hydro-, and solar power generation, resulting in 100% renewable energy [4].

2. Concentrating solar power (CSP)

Concentrating solar power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The concentrated heat is then used as a heat source for a conventional power plant. A wide range of concentrating technologies exists; the most developed are the parabolic trough, the concentrating linear fresnel reflector, the Sterling dish and the solar power tower. Various techniques are used to track the Sun and focus light. In all of these systems a working fluid is heated by the concentrated sunlight, and is then used for power generation or energy storage [5].

2.1. Parabolic through system

Parabolic trough systems use mirrored troughs which focus energy on a fluid-carrying receiver tube at the parabola's focal line. The receiver is a tube positioned right above the middle of the parabolic mirror and is filled with a working fluid. The reflector is made to follow the Sun during the daylight hours by tracking along a single axis (Fig. 1a). Either the troughs or the tubes track the sun to heat the fluid, which is then pumped through heat exchangers to generate superheated steam to run a turbine generator. Parabolic trough systems provide the best land-use factor of any solar technology [6]. The SEGS plants in California and Acciona's Nevada Solar One near Boulder City, Nevada are representatives of this technology [7,8]. The Suntrof-Mulk parabolic trough, developed by Melvin Prueitt, uses a technique inspired by Archimedes' principle to rotate the mirrors [9].

Concentrating linear fresnel reflectors are CSP-plants which use many thin mirror strips instead of parabolic mirrors to concentrate sunlight onto two tubes with working fluid. This has the advantage that flat mirrors can be used which is much cheaper than parabolic mirrors, and that more reflectors can be placed in the same amount of space, allowing more of the available sunlight to be used. Concentrating linear fresnel reflectors can be used in either large or more compact plants.

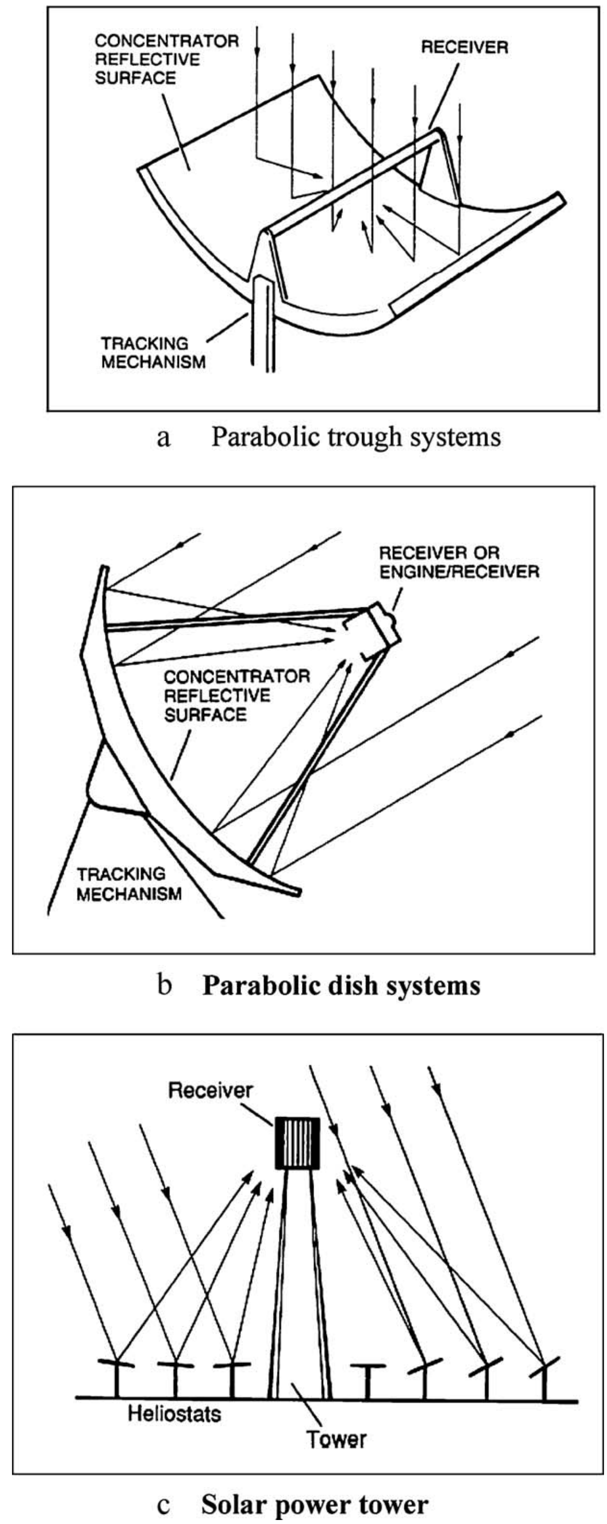

Fig. 1. Concentrating solar power systems.

2.2. Parabolic dish system

Parabolic dish systems use a parabolic mirror that focuses incoming solar radiation on a receiver mounted above the dish at its focal point. A dish system can be used either to operate an individual Rankine-cycle or Stirling engine located at its focus, or linked together with other dishes to heat a transfer fluid which is then used to drive a turbine (Fig. 1b). The reflector tracks the Sun along two axes. Parabolic coordinates ("parabolic") dish systems give the highest efficiency among CSP technologies [10]. The 500 m^2 ANU "Big Dish" in Canberra, Australia is an example of this technology

Table 1
World's largest concentrating solar thermal power stations.

Capacity (MW)	Technology type	Name	Country	Location	Notes
354	Parabolic trough	Solar energy generating systems	USA	Mojave desert California	Collection of 9 units
75	Parabolic trough	Martin next generation solar energy center	USA	Near Indiantown, Florida	Expected Late 2010
64	Parabolic trough	Nevada Solar One	USA	Las Vegas, Nevada	
50	Parabolic trough	Andasol 1	Spain	Granada	Completed November 2008
20	Solar power tower	PS20 solar power tower	Spain	Seville	Completed April 2009
11	Solar power tower	PS10 solar power tower	Spain	Seville	Europe's first commercial solar tower

[11]. The Stirling solar dish combines a parabolic concentrating dish with a Stirling heat engine which normally drives an electric generator. The advantages of Stirling solar over photovoltaic cells are higher efficiency of converting sunlight into electricity and longer lifetime.

2.3. Solar power tower

The Solar power tower consists of a field of thousands of mirrors (heliostats) surrounding a tower which holds a heat transfer fluid to concentrate light on a central receiver atop a tower (Fig. 1c). Each heliostat has its own tracking mechanism to keep it focused on the tower to heat the transfer fluid, which is then used to run a turbine. Power towers are more cost effective, offer higher efficiency and better energy storage capability among CSP technologies. The Solar Two in Barstow, California and the Planta Solar 10 in Sanlucar la Mayor, Spain are representatives of this technology [7]. Table 1 shows the world largest concentrating solar thermal power stations. Although the applications mentioned here are concerned with the generation of electricity, the essential product of each system is heat, which could potentially be used to provide process heat for industrial applications. A solar updraft tower (also known as a solar chimney or solar tower) consists of a large greenhouse that funnels into a central tower. As sunlight shines on the greenhouse, the air inside is heated, and expands. The expanding air flows toward the central tower, where a turbine converts the air flow into electricity. A 50 kW prototype was constructed in Ciudad Real, Spain and operated for eight years before decommissioning in 1989 [12].

2.4. Concentrated solar power system applications

Concentrated solar power systems can be used for a range of applications depending upon the energy conversion utilized, electricity or heat. However, at present, most systems focus on electricity generation. The different types of CSP system, discussed above, are suitable for different applications, as shown in Fig. 2. The parabolic trough collector is the best solution for applications in the low temperature ranges such as detoxification, liquid waste recycling and heating water. All three systems are suitable for the mid temperature range applications, and the central tower is the most suitable system because temperatures of more than 1000 °C can be easily sustained.

3. Photovoltaic solar power

A solar cell, or photovoltaic cell (PV), is a device that converts light into electric current using the photoelectric effect. The photovoltaic cell is a solid-state device composed of thin layers of semiconductor materials which produce an electric current when exposed to light. Photovoltaic power generation employs solar panels comprising a number of cells containing a photovoltaic material. Materials presently used for photovoltaic include mono-crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium selenide/sulfide. Due to the growing demand for renewable energy sources, the manufacture of solar cells and photovoltaic arrays has advanced considerably in recent years.

Concentrating photovoltaic's (CPV) is another new method of electricity generation from the sun. CPV systems employ sunlight concentrated onto photovoltaic surfaces for the purpose of electrical power production. Solar concentrators of all varieties may be used, which are often mounted on a solar tracker in order to keep the focal point upon the cell as the sun moves across the sky. Tracking can increase flat panel photovoltaic output by 20% in winter, and by 50% in summer [13]. There are many competing technologies, including at least fourteen types of photovoltaic cells, such

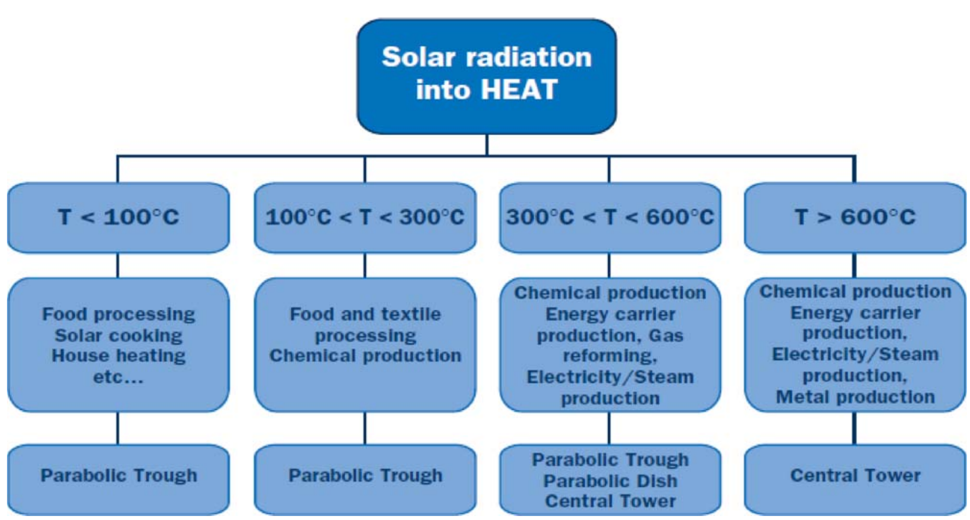

Fig. 2. Applications for concentrated solar power system.

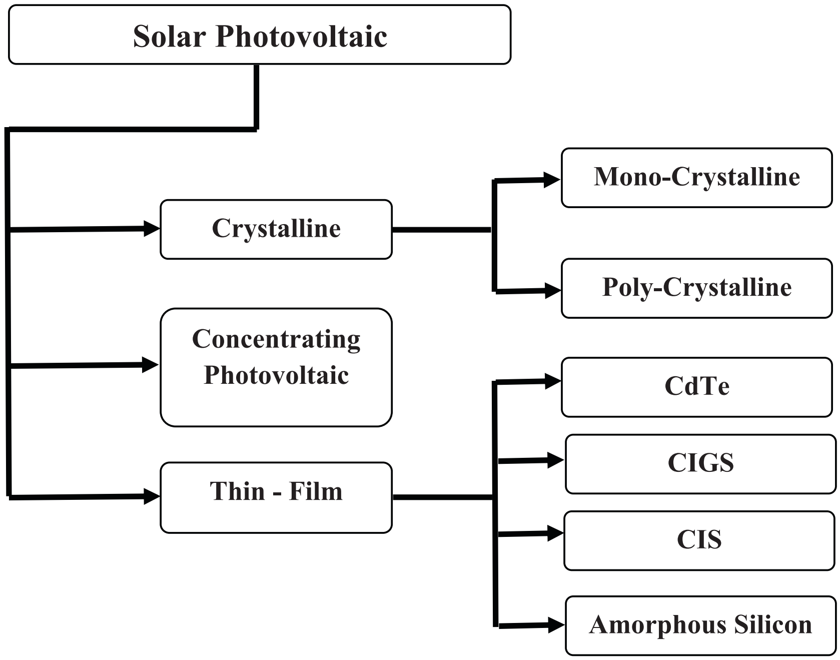

Fig. 3. Solar energy technology.

as thin film, mono-crystalline silicon, polycrystalline silicon, and amorphous cells, as well as multiple types of concentrating solar power [14]. Single cells are connected in groups to form a module, and modules are grouped to form an array. The voltage and the current output from the array depend upon how the system is configured. The solar PV energy technology can be broadly classified as follows in Fig. 3.

4. Solar power: a review

4.1. Concentrating solar thermal power plants

Commercial concentrating solar thermal power (CSP) plants were first developed in the 1980s. CSP plants such as solar electric generation systems (SEGS) project in the United States have a levelized energy cost (LEC) of 12–14 ¢/kWh [15]. The 11 MW PS10 power tower in Spain, completed in late 2005, is Europe's first commercial CSP system, and a total capacity of 300 MW is expected to be installed in the same area by 2013 [16]. SEGS is the largest solar energy generating facility in the world. It consists of nine solar power plants in California's Mojave Desert, where insolation is among the best available in the United States. NextEra Energy Resources operates and partially owns the plants. SEGS III–VII (150 MW) are located at Kramer Junction, SEGS VIII–IX (160 MW) at Harper Lake, and SEGS I–II (44 MW) at Daggett respectively (Table 2). The SEGS plants have a 354 MW installed capacity, making it the largest installation of solar plants of any kind in the world. The average gross solar output for all nine plants at SEGS is around 75 MWe – a capacity factor of 21%. In addition, the turbines can be utilized at night by burning natural gas. NextEra claims that the solar plants power 232,500 homes and displace 3800 tons of pollution per year that would have been produced if the electricity had been provided by fossil fuels, such as oil [17]. The facilities have a total of 936,384 mirrors and cover more than 1600 acres (6.5 km^2). The SEGS power plants were built by Luz Industries [18], and commissioned between 1984 and 1991.

4.2. Photovoltaic power plants

Solar photovoltaic cells convert sunlight into electricity and many solar photovoltaic power stations have been built, mainly in Europe. As of October 2009, the largest photovoltaic (PV) power plants in the world are the Sarnia Photovoltaic Power Plant (Canada, 80 MW), Olmedilla Photovoltaic Park (Spain, 60 MW), the Strasskirchen Solar Park (Germany, 54 MW), the Lieberose Photovoltaic Park (Germany, 53 MW), the Puertollano Photovoltaic Park (Spain, 50 MW), the Moura Photovoltaic Power Station

Table 2
SEGS plant history and operational data {Solargenix Energy [19], KJC Operating Company [20], IEEE [21], NREL [22]}.

Plant	Year built	Location	Net turbine capacity (MW)	Field area (m^2)	Oil temperature (°C)	Gross solar production of electricity (MWh)	
						1996	Average 1998–2002
SEGS I	1984	Daggett	14	82,960	307	19,900	16,500
SEGS II	1985	Daggett	30	165,376	316	36,000	32,500
SEGS III	1986	Kramer Jct.	30	230,300	349	64,170	68,555
SEGS IV	1986	Kramer Jct.	30	230,300	349	61,970	68,278
SEGS V	1987	Kramer Jct.	30	233,120	349	71,439	72,879
SEGS VI	1988	Kramer Jct.	30	188,000	391	71,409	67,758
SEGS VII	1988	Kramer Jct.	30	194,280	391	70,138	65,048
SEGS VIII	1989	Harper Lake	80	464,340	391	139,174	137,990
SEGS IX	1990	Harper Lake	80	483,960		141,916	125,036

Table 3
World's largest photovoltaic power stations (14 MW or larger) [23].

Power station	Country	Nominal Power (MW_p)	Production (Annual GWh)	Capacity factor	Notes
Sarnia PV power plant	Canada	80			Completion 2010
Olmedilla Photovoltaic Park	Spain	60	85	0.16	Completed September 2008
Strasskirchen Solar Park	Germany	54	57		
Lieberose Photovoltaic Park	Germany	53	53	0.11	2009
Puertollano Photovoltaic Park	Spain	47.6			231,653 crystalline silicon modules, Suntech and Solaria, opened 2008
Moura photovoltaic power station	Portugal	46	93	0.23	Completed December 2008
Kothen Solar Park	Germany	45			2009
Finsterwalde Solar Park	Germany	42			2009
Waldpolenz Solar Park	Germany	40	40	0.11	550,000 First Solar thin-film CdTe modules. Completed December 2008
Planta Solar La Magascona and La Magasquila	Spain	34.5			
Arnedo Solar Plant	Spain	34			Completed October 2008
Planta Solar Dulcinea	Spain	31.8			Completed 2009
Merida/Don Alvaro Solar Park	Spain	30			Completed September 2008
Planta Solar Ose de la Vega	Spain	30			
Planta Fotovoltaico Casas de Los Pinos	Spain	28			
Planta Solar Fuente Alamo	Spain	26	44		
DeSoto Next Generation Solar Energy Center	USA	25	42	0.19	Completed October 2009
SinAn power plant	Korea	24	33	0.16	Completed October 2008
Monalto di Castro PV power plant	Italy	24	40		Completed 2009
Arnprior Solar Generating Station	Canada	23.4			
Planta fotovoltaica de Lucainena de las Torres	Spain	23.2			Completed August 2008
Parque Fotovoltaico Abertura Solar	Spain	23.1	47	0.23	
Parque Solar Hoya de Los Vincentes	Spain	23	41	0.20	
Huerta Solar Almaraz	Spain	22.1			Completed September 2008
Mengkofen Solar Park	Germany	21.7			
Parque Solar El Coronil 1	Spain	21.4			
Solarpark Calveron	Spain	21.2	40	0.22	
Rothenburg Solar Park	Germany	20			
Seoul Solar Power Plant	Korea	20			
Huerta Solar Almaraz	Spain	20			Completed September 2008
Planta solar fotovoltaico Calasparra	Spain	20			Completed September 2008
Beneixama photovoltaic power plant	Spain	20	30	0.17	Tenesol, Aleo and Solon solar modules with Q-Cells cells
El Bonillo Solar Park	Spain	20			Completed October 2008
Kunming Shilin Solar Power Plant	China	20			Capacity 166 MW. Production started on May 2010 at 20 MW.
Parque Solar Olivenza	Spain	18			
Parque Solar Bonillo	Spain	18			Completed October 2008
Solaranlage Allmanshoffen	Germany	15			
Planta Solar Calzada de Oropesa	Spain	15			
Gochang power plant	Korea	15	23	0.17	Completed October 2008
Planta de energía solar Mahora	Spain	15			Completed September 2008
Koethen	Germany	14.75	13		200,000 First Solar thin-film CdTe modules. Completed December 2008
Nellis Solar Power Plant	USA	14.02	30	0.24	70,000 solar panels
Planta Solar Lorca	Spain	14			

(Portugal, 46 MW), and the Waldpolenz Solar Park (Germany, 40 MW) [23]. Some photovoltaic power stations which are presently proposed will have a capacity of 150 MW or more [24].

Between 1970 and 1983 photovoltaic installations grew rapidly, but falling oil prices in the early 1980s moderated the growth of PV from 1984 to 1996. Since 2006 it has been economical for investors to install photovoltaics for free in return for a long term power purchase agreement. 50% of commercial systems were installed in this manner in 2007 and it is expected that 90% will by 2009. Nellis Air Force Base is receiving photoelectric power for about 2.2 ¢/kWh and grid power for 9 ¢/kWh [25]. Many of these plants are integrated with agriculture and some use innovative tracking systems that follow the sun's daily path across the sky to generate more electricity than conventional fixed-mounted systems. There are no fuel costs or emissions during operation of the power stations. Tables 3–5

Table 4
Selected smaller plants.

Name of PV power plant	Country	DC peak power (MW)	GWh/year	Capacity factor	Notes
Planta Solar de Salamanca	Spain	13.8			70,000 Kyocera panels
Lobosillo Solar Park	Spain	12.7			Chaori and YingLi modules
Erlasee Solar Park	Germany	12	14	0.13	1408 Solon mover
Serpa solar power plant	Portugal	11	20	0.21	52,000 solar modules
Pocking Solar Park	Germany	10	11.5	0.13	57,912 solar modules
Monte Alto photovoltaic power plant	Spain	9.5	14	0.17	
Gottelborn Solar Park	Germany	8.4	8.4	0.11	
Alamosa photovoltaic power plant	USA	8.2	17	0.24	Completed December 2007
Bavaria Solar Park in Muhlhausen	Germany	6.3	6.7	0.12	57,600 solar modules
Rote Jahne Solar Park	Germany	6	5.7	0.11	90,000 First Solar thin-film modules
Darro Solar Park	Spain	5.8	11.6	0.23	Conergy and SunPower modules
Kameyama	Japan	5.2			47,000 square meters on Sharp LCD factory roof

Table 5
Large systems in planning or under construction.

Name of plant	Country	DC peak power (MW)	GWh/year	Capacity factor	Notes
Rancho Cielo Solar Farm	USA	600			Thin film silicon from Signet Solar**
Topaz Solar Farm	USA	550	1100	0.23	Thin film CdTe from First Solar**
High Plains Ranch	USA	250	550	0.25	Monocrystaline silicon from SunPower with tracking **
AV Solar Ranch One	USA	230	600	0.30	**
Mildura Solar concentrator power station	Australia	154	270	0.20	Heliostat concentrator using GaAs cells from Spectrolab**
KCRD Solar Farm	USA	80			Scheduled to be completed in 2012 **
Sarnia, Ontario	Canada	80	N.A	N.A	Phase I complete (20MW) 2009. First Solar CdTe modules
Nová Ves Solar Park	Czech Republic	35			186,960 modules*
Sevetin Solar Farm	Czech Republic	30			*
Davidson County Solar Farm	USA	21.5			36 individual structures**
Cádiz solar power plant	Spain	20.1	36	0.20	*
Kennedy Space Center, Florida	USA	10			To be constructed by SunPower for FPL Energy, completion date 2010.**

* Under construction.
** Proposed.

show the world largest concentrating solar thermal power stations [23].

World solar photovoltaic (PV) market installations reached a record high of 7.3 GW in 2009, representing growth of 20% over the previous year. This was revealed in the latest edition of Marketbuzz 2010 Report from Solarbuzz [26], a part of The NPD Group. The PV industry generated $38.5 billion in global revenues in 2009, while successfully rising over $13.5 billion in equity and debt, up 8% on the prior year. European countries accounted for 5.60 GW, or 77% of world demand in 2009. The top three countries in Europe were Germany, Italy and Czech Republic, which collectively accounted for 4.07 GW. All three countries experienced soaring demand, with Italy becoming the second largest market in the world. In contrast, Spanish demand in 2009 collapsed to just 4% of its prior year level. Of total European demand, net solar cell imports accounted for 74% of the total. The third largest market in the world was the United States, which grew 36% to 485 MW. Following closely behind was a rejuvenated Japan, which took fourth spot, growing 109%. In August 2009, First solar also announced plans to build a 2000 MW photovoltaic system in Ordos City, Inner Mongolia, China in four phases consisting of 30 MW in 2010, 970 MW in 2014, and another 1000 MW by 2019.

The analysis in the new Marketbuzz 2010 report references 112 countries across the world in 2009. World solar cell production reached a consolidated figure of 9.34 GW in 2009, up from 6.85 GW a year earlier, with thin film production accounting for 18% of that total. China and Taiwanese production continued to build share and now account for 49% of global cell production. The top seven polysilicon manufacturers had 114,500 tons per annum of capacity in 2009, up 92% on their 2008 level, while the top eight wafer manufacturers accounted for 32.9% of global wafer capacity in 2009. The excess of solar cell production over market demand caused weighted crystalline silicon module price average for 2009 to crash 38% over the prior year level. This reduction in crystalline silicon prices also had the effect of eroding their percentage premium to thin film factory gate pricing. Looking forward, the industry will return to high growth in 2010 and also over the next 5 years. Even in the slowest growth scenario, the global market will be 2.5 times its current size by 2014. Under the Production Led scenario, the fastest growing forecast, annual industry revenues approach $100 billion by 2014. After providing a comprehensive look back at 2009 industry results, the new Marketbuzz™ 2010 report devotes one third of its content to 2010–2014 forecast outcomes, including a thorough preview of market developments, policies, prices and production requirements, which will be essential to help shape corporate strategies over this period. Manufacturing costs, gross margins and capital expenditure profiles are also addressed.

5. Solar energy potential in India

India lies in the sunny belt of the world. The scope for generating power and thermal applications using solar energy is huge. Most parts of India get 300 days of sunshine a year, which makes the country a very promising place for solar energy utilization [27]. The daily average solar energy incident over India varies from 4 to 7 kWh/m^2 with the sunshine hours ranging between 2300 and 3200 per year, depending upon location [28]. The technical potential of solar energy in India is huge. The country receives enough solar energy to generate more than 500,000 TWh per year of electricity, assuming 10% conversion efficiency for PV modules.

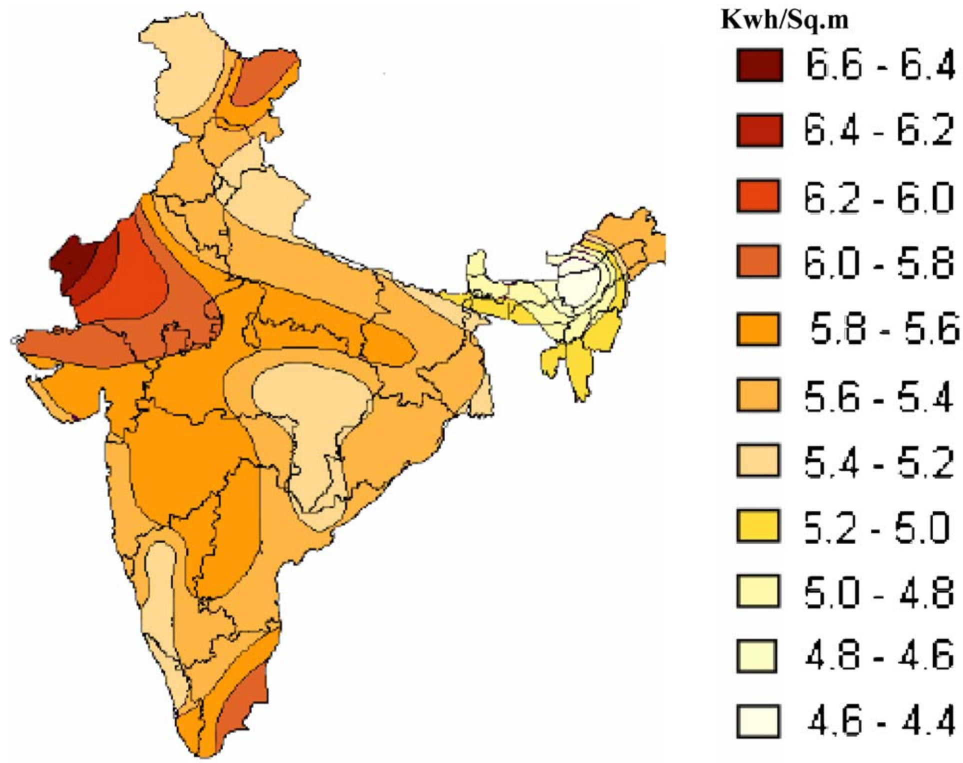

Fig. 4. Solar radiation on India [30].

It is three orders of magnitude greater than the likely electricity demand for India by the year 2015 [29]. Fig. 4 shows map of India with solar radiation levels in different parts of the country. It can be observed that although the highest annual global radiation is received in Rajasthan, northern Gujarat and parts of Ladakh region, the parts of Andhra Pradesh, Maharashtra, Madhya Pradesh also receive fairly large amount of radiation as compared to many parts of the world especially Japan, Europe and the US where development and deployment of solar technologies is maximum [30].

6. Current solar PV energy scenario in India

The Indian government is reported to have finalized the draft for the National Solar Mission, outlining ambitious long-term plans to attain an installed solar power generation capacity of 20,000 MW by the year 2020, which would be increased to 100,000 MW by the year 2030 and further to 200,000 MW by the year 2050. To unfold in three phases, it aims to achieve parity with coal-based thermal power generation by 2030. In the first phase of implementation (2009–2012), a sum of Rs. 10,130 crore would be required. The monetary requirement would be Rs. 22,515 crore and Rs. 11,921 crore in the second (2012–2017) and third (2017–2020) phases of implementation, respectively. The Mission envisages an investment of Rs. 91,684 crore over the next 30 years. This will include an interest subsidy to the tune of Rs. 7300 crore. The plan also aims to reduce the cost of solar power generation by 2017–2020 in order to make solar power competitive with power generated from fossil fuels [31].

Solar PV has one of the highest capital costs of all renewable energy sources, but it has the lowest operational cost, owing to the very low maintenance and repair needs. For solar energy to become a widely used renewable source of energy, it is imperative that the capital costs are reduced significantly for Solar PV. 12.28 MW solar PV power generation capacity with grid connected has been installed since 30th June, 2010 [32]. For a solar PV power plant, the approximate capital cost per MW is Rs. 17 crores. This includes the cost of panels, the balance of systems, and the cost of land and other support infrastructures (Table 6).

Table 6
Break-up for the capital expenses [33].

Component	Amount (Rs. crore*)	% of Total
Solar panel arrays	7.7	45
Inverter	2.5	15
Balance of system	3.4	12
Installation	1.7	10
Others (Infrastructure)	3.0	18

**One USD = 45.15 INR [http://finance.yahoo.com/currency-converter/#from=USD; to=INR;amt=1].

* One Crore = 10 Million INR.

Solar PV is fast changing industry, given the pace of technological and policy changes. In India, where most regions enjoy nearly 300 sunny days a year, is an ideal market for solar power companies. However, the high cost of light-to-electricity conversion at Rs. 12 to Rs. 20 per kWh has acted as a deterrent so far. Currently, India has around 60 companies assembling and supplying solar photovoltaic systems, nine companies manufacturing solar cells and 19 companies manufacturing photovoltaic modules or panels, according to an Indian Semiconductor Association study. However, spurred by factors like an increased demand for clean power, an energy-starved industry and the falling cost of solar-power generation, companies in this space are coming up with a noteworthy number of domestic projects. It has also helped that the government is lending support to such projects through state electricity boards with subsidies.

PV installations in India today almost entirely comprise small capacity applications. They are most visibly seen in lighting applications (street lighting, and home lightning systems) in the cities and towns, and in small electrification systems and solar lanterns in rural areas. PV has also begun to be deployed to a small degree

Table 7
Current status of the renewable energy in India [32].

No.	Sources/Systems	Achievements during 2010–2011 (upto 30.06.2010)	Cumulative achievements (upto 30.06.2010)
I. Power from renewables			
A. Grid-interactive renewable power			
1.	Biomass power (Agro residues)	45.50 MW	901.10 MW
2.	Wind power	202.73 MW	12009.48 MW
3.	Small hydro power (up to 25 MW)	31.64 MW	2767.05 MW
4.	Cogeneration-bagasse	67.50 MW	1411.53 MW
5.	Waste to energy	7.50 MW	72.46 MW
6.	Solar power	2.00 MW	12.28 MW
	Sub Total (in MW) (A)	356.87 MW	17173.90 MW
B. Off-grid/distributed renewable power (including captive/CHP plants)			
7	Biomass power/Cogen.(non-bagasse)	6.00 MW	238.17 MW
8.	Biomass gasifier	4.00 MWeq.	125.44 MWeq
9.	Waste-to-energy	6.00 MWeq.	52.72 MWeq
10.	Solar PV power plants and street lights	0.00 MWp	2.92 MWp
11.	Aero-generators/hybrid systems	0.00 MW	1.07 MW
	Sub total (B)	16.00 MWeq	420.32 MWeq
	Total (A + B)	2410.76 MW	17221.86 MW
II. Remote village electrification		208 Villages and hamlets	6867 Villages and hamlets
III. Decentralized energy systems			
12.	Family type biogas plants	7000	42,60,000
13.	SPV home lighting system	Nos	6,03,307 nos.
14.	Solar lantern	Nos	7,97,344 nos.
15.	SPV street lighting system	Nos	1,19,634 nos.
16.	SPV pumps	Nos	7,334 nos.
17.	Solar water heating – collector area	Nos	3.53 Mln. sq.m.
18.	Solar cookers	nos	6,72,000

MWeq. = Megawatt equivalent; MW = Megawatt; kW = kilowatt; kWp = kilowatt peak; sq. m. = square meter.

in powering water pump sets. Table 7 shows the latest information of the renewable energy installation in India [32].

The Central Indian Govt. has recently approved 12 proposals under the Special Incentives Package Scheme (SIPS). Put together, these proposals could bring in about Rs. 76,573 crore of investment to the domestic solar power sector. Under SIPS, the government provides an incentive of 20 per cent of the capital expenditure during the first 10 years to a unit located in a special economic zone (SEZ). Units based outside get a 25% incentive. Incentives could be in the form of capital subsidy or equity participation.

7. Future solar power projects in India

Proposals in this space have been submitted by Solar Semiconductor (Rs. 11,821 crore), Reliance Industries (Rs. 11,631 crore), Moser Baer PV Technologies (Rs. 6000 crore), Signet Solar (Rs. 9672 crore), Titan Energy Systems (Rs. 5880 crore), KSK Energy Ventures (Rs. 3211 crore) and Tata BP Solar India (Rs. 1693 crore). Besides this, the government has received similar applications from companies such as EPV Solar, Vavasi Telegence and Lanco Solar, according to industry sources. Clearly, the solar power sector is seeing heightened activity.

Tata BP Solar, which has been designing, manufacturing and installing solar solutions for the past 15 years is "investing significantly in infrastructure to expand its manufacturing capacity to 300 MW". Revenues for Tata BP Solar exceeded Rs. 1100 crore in 2008–2009. The company a 51:49 joint venture between BP Solar and Tata Power Company is looking to expand into rural areas by partnering with banking and telecom companies. The company is also catering to the requirements of the railways and defense sectors; two of the largest consumers of solar power in India. For instance, it has installed India's largest Building Integrated Photovoltaic's (BIPV) at the Samudra Institute of Maritime Studies in Lonavla, Pune. The 90 kWp (kilowatt-peak) BIPV can meet the entire power requirement of the institute.

Moser Baer Photo Voltaic Limited (MBPV) and PV Technologies India Limited (PVTIL) are subsidiaries of Moser Baer India Limited and were launched between 2005 and 2007. The primary objective of the entities is to manufacture world-class solar modules and design an EPC for effective deployment of PV Systems. The current production capacity of MBPV stands at 90 MW crystalline cells, 90 MW crystalline modules, and 50 MW thin films. Moser Baer's company also has an initial capacity of a few megawatts in concentration PV, which is being rapidly developed for the market and has great cost reduction potential [34]. Moser Baer's strategy is to manufacture small appliances, ranging from one to 10 kW in capacity. These include solar lanterns which have found use in villages, solar lights that illuminate Jaipur's highways and Gurgaon's DLF malls, and solar energy appliances that would power ATM machines in rural areas in the near future. At present, Moser Baer is focusing on two grid-connected solar farms – one in Rajasthan and the other in Punjab – each with 5 MW capacity.

Bharat Heavy Electricals Limited (BHEL) recently commissioned two grid-interactive solar power plants of 100 kW each in Lakshadweep. This is the largest solar power project of its kind in the country which aims to use solar energy to power an entire region. So far, BHEL has commissioned a total of 11 solar power plants in the Lakshadweep islands, adding over 1 MW of solar power to the power-generating capacity of the coral islands. The plants have been set up at Chetlat and Amini islands of Lakshadweep. BHEL's solar power plants cater to about 15% of the Union Territory's energy demand. With the installation of solar power plants, Lakshwadeep will save 300,000 l of diesel a year, huge savings given that diesel is transported by sea from Kochi, which is a costly affair. The solar power plants, as opposed to environmentally hazardous diesel generators, will be conducive to the fragile ecology of the coral islands.

Public sector major Oil and Natural Gas Commission (ONGC), too, is foraying into solar energy. Railways, telecom, military agencies and space organizations remain the largest consumers of photovoltaic systems in India. But there's much catching up to do with developed countries where grid connectivity accounts for about 75% of the installed capacity and off-grid lighting and consumer applications for the rest of solar power production.

Indian first megawatt size grid connected solar power plant has been inaugurated at Jamuria, in Asansol district of West Bengal [34]. The plant has already generated more than 300,000 units of electricity in about three month's time. Two more plants of 2 MW capacity each have been set up in Karnataka at Kolar and Belgaum districts. They will add one more megawatt to both plants very soon. One more plant of one megawatt will be set up in Raichur district in Karnataka. Renewable energy Ministry has recently cleared proposals to set up another 28 MW capacity solar plant in the country. Many private companies are preparing projects to set up more plants.

Gujarat, a state of India, is quite eager to opt for alternative sources of energy. It started out as a small dream. The Gujarat government visualized only 500 MW of solar power generation by 2014. But this humble goal may now be increased to 3000 MW. The Gujarat Government is undertaking a $10 billion project and it will hold the distinction of the world's largest solar power facility in India. This project will be backed by former U.S. President Bill Clinton. The 3000 MW project will get aid with logistics and financial support from the William J Clinton Foundation. This foundation is a charitable organization founded by the former President. The foundation and the Gujarat government signed a preliminary agreement on 8th September, 2009. Recently a memorandum of understanding (MoU) was signed between Gujrat Sate Energy Department, and Chairman of the Clinton Climate Initiative (CCI). The Clinton Foundation will help us in bringing manufacturers and power generators and also in providing access to international funding at cost-effective interest rates. They are facilitators. We will invest in the infrastructure. The project would be allotted a 10,000 ha of land spread across three locations within an area of 150 km^2 (58 square miles) in Gujarat.

If things move in the right direction, Rajasthan is set to bask in the sunshine. The desert state is likely to attract an investment of Rs. 45,000 crore in the solar energy sector. The M.D. of Rajasthan Renewable Energy Corporation (REEC) informed that 72 power companies have registered with the corporation for the generation of 2500 MW in the solar energy sector. REEC have received proposals from companies like RIL (Reliance Industries Ltd), Par Solar, Jindal Power, GVK Power and Infrastructure Ltd., Moser Baer Photovoltaic Ltd., and Zoom Developers for setting up solar plants in the state. REEC will take up these projects as per the guidelines of the recently announced Jawaharlal Nehru Solar Mission. The state government has already sanctioned projects of 66 MW distributed between 11 companies. After the fixing of tariff by the RERC (Rajasthan Energy Regulatory Commission), the companies will start setting up their respective plants across the districts of Barmer, Jaisalmer, Bikaner, and Jodhpur. These plants will be based on different technologies like solar photovoltaic, solar thermal, thin film, and so on. In addition, RIL and Par Solar are setting up solar plants of 5 MW each in Nagaur and Jodhpur, respectively. RIL has already signed up power purchase agreement with three power companies of Rajasthan–Jaipur Discom, Ajmer Discom, and Jodhpur Discom. However, power generation from solar energy is prohibitively expensive. The cost per megawatt of solar power comes to around Rs. 18 crore, while that of wind power is Rs. 5 crore [35].

The HAREDA (Haryana Renewable Energy Development Agency) has decided to set up three solar power projects; a cost of over Rs. 5.9 crore of 225 kW capacities in Gurgaon district under a new scheme launched to motivate commercial/industrial establishments to use solar energy. The HAREDA had received sanction from the Ministry of New and Renewable Energy for setting up these projects. Out of these, two solar power projects of 100 kW each would be set up at M/s Omax Autos Ltd., Manesar, and M/s Automax, Village Binola, at a cost of Rs. 2.6 crore each. The third project of 25 kW capacity would be set up at M/s Serco BPO (business process outsourcing) Pvt. Ltd., Gurgaon, at a cost of Rs. 0.9 crore [36].

8. Indian government incentives and support

Since solar power is at the introductory stage of its life cycle, Government initiatives are expected to drive it until 2012. The Government of India realizing the need for alternate sources of energy other than coal and oil has introduced many schemes and incentives to support the growth of the Solar Energy Sector. Government of India has recently launched the ambitious Jawaharlal Nehru National Solar Mission (JNNSM) which aims to promote the development and use of solar energy for power generation and other uses in the country [32]. India's National Action Plan on Climate Change (2008) articulates a Central Role for Solar Power. The Government of India's National Action Plan on Climate Change released in mid-2008, by the Prime Minister's Council on Climate Change identifies eight critical missions, one of which is the National Solar Mission. The mission has a twin objective – to contribute to India's long term energy security as well as its ecological security. The Solar Mission would be implemented in 3 stages leading up to an installed capacity of 20,000 MW by the end of the 13th five year plan in 2022. It is envisaged that as a result of rapid scale up as well as technological developments, the price of solar power will attain parity with grid power at the end of the Mission, enabling accelerated and large-scale expansion thereafter.

The focal point for the grid connected utility scale power plants, for the Phase 1 of the Mission, will be the NTPC Vidyut Vyapar Nigam (NVVN), which is the power trading arm of the NTPC. Government has designated it for the purchase of solar power generated by independent solar power producers, at rates fixed by the Central Regulatory Electricity Commission (CERC) and for a period specified by the latter. The mission includes a major initiative for promoting rooftop solar photovoltaic (PV) applications. The solar tariff announced by the regulators will be applicable for such installations. The power distribution companies will be involved in purchase of this power. The mission would have a 'much focused R&D programme' which seeks to address the India-specific challenges in promoting solar energy.

8.1. Solar mission targets are

- To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.
- To ramp up capacity of grid-connected solar power generation to 1000 MW within three years – by 2013; an additional 3000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000 MW installed power by 2017 or more, based on the enhanced and enabled international finance and technology transfer. The ambitious target for 2022 of 20,000 MW or more, will be dependent on the 'learning' of the first two phases, which if successful, could lead to conditions of grid-competitive solar power. The transition could be appropriately up scaled, based on availability of international finance and technology.
- To create favorable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership.
- To promote programs for off grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022.

• To achieve 15 million square meters solar thermal collector area by 2017 and 20 million square meters solar thermal collector area by 2022.
• To deploy 20 million solar lighting systems for rural areas by 2022.

The Mission underlines the Government's intention to give a boost to solar energy and is a purposeful step by India towards climate change mitigation. An analysis done by Greenpeace shows that the Jawaharlal Nehru National Solar Mission plan could ensure an annual reduction of 434 million tons of CO_2 emissions every year by 2050 based on the assumption that solar will replace fossil fuels.

8.2. Incentives offered

• Central Electricity Regulatory Commission (CERC) has announced preferential tariff of Rs. 18.44 per unit for solar PV power and Rs. 13.45 per unit for solar thermal power for 25 years;
• Zero or concessional duty applicable on import of certain specific items;
• Zero excise duty on domestic manufacture of many solar energy devices and systems;
• NTPC Vidyut Vyapar Nigam will purchase solar power for a period of 25 years at a fixed tariff announced by CERC;
• CERC will review the costs every year and fix tariff accordingly for new projects.

9. Conclusions

The global energy consumption is rising rapidly. It is likely that environmental considerations will constrain the access to fossil fuels in the future. As a result, a part of the increasing energy demand is likely to be met by renewable energy sources i.e. solar power. Solar thermal and photovoltaic electricity generation are two promising technologies for climate compatible power with such enormous potential that, theoretically, they could cover much more than just the present worldwide demand for electricity consumption. Together both technologies can provide an important contribution to climate protection. Photovoltaic systems have advantages for low-power demand, stand-alone systems and building-integrated grid-connected systems. The solar energy based power generating systems can play a major role towards the fulfillment of energy requirements of industry. In USA and European countries such energy production facilities are already in operation or are under construction. In India, The Ministry of Non-conventional Energy Sources, Government of India is attempting to electrify as many villages as possible with the solar photovoltaic system. The economically exploitable potential of the solar power technology of India is quite high. In India there are many areas where solar power plants can be erected for the production of electricity. Since this solar thermal technology has been successfully implemented in developed countries, with high solar potential, the development of this technology is imperative. The rapid growth in solar power has been driven internationally; USA, European, Chinese, Indian and Australian market for solar power has also responded strongly to policy support. This short review is an attempt to show how improvements in technology and competitiveness among players in the fields of manufacture, supply, and installation leading to reduction in costs, but not at the sharp rate that is competitive with conventional power.

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