

Solar Energy – Status, Trends & Opportunities

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Objective

The objective of this report is to provide insights and data on the status and emerging opportunities in the solar energy industry

Target Audience

This report is primarily meant for entrepreneurs, investors or stakeholders in solar energy opportunities.

Key Take-aways

- (1) An understanding of the current status and growth of the solar industry, and of its various market and products segments
- (2) Current trends in investment and entrepreneurial activities in the industry, and
- (3) New and emerging opportunities.

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- USA
- Canada
- Japan
- China
- Germany
- UK
- France
- India

With a clear objective of providing the most benefits to the target segment for this report, we have provided our summary, analysis and recommendations at the end of relevant chapters. We hope that these analyses will assist entrepreneurs and others exploring opportunities in solar energy.

Introduction to the Solar Energy Industry

Solar is one of the fastest growing alternative energy resources today. This introduction provides a brief overview of the industry's classification.

The solar energy industry can be broadly classified as follows:

- Solar Photovoltaic
 - Crystalline
 - Monocrystalline
 - Polycrystalline
 - Thin-layer
 - CdTe (Cadmium Telluride)
 - CIGS (Copper Indium Gallium Selenium)/CIS (Copper Indium Selenium)
 - CIS (Copper Indium Diselenide)
 - Amorphous Silicon (a-Si)
 - Concentrated Photovoltaic
- Solar Thermal
 - Flat-plate Collectors
 - Evacuated Heat-pipe Tubes
 - Concentrating Solar Thermal
 - Parabolic Trough Collectors
 - Dish/Engine Systems
 - Power Towers
 - Hybrid Systems / Integrated Solar Combined Cycle
 - Linear Fresnel

Solar Photovoltaic

Using solar photovoltaic, sunlight is converted into electricity. Solar photovoltaic uses photovoltaic (PV) cells usually in the form of panels, also called solar panels.

Crystalline Silicon PV Cells

The majority of PV cells produced today use crystalline silicon (c-Si) as its light-absorbing semiconductor. The c-Si technology originally was developed for the semiconductor industry to produce PV cells for integrated circuits and microchips. These PV

cells have energy conversion efficiency between 11 percent and 16 percent. The energy conversion efficiency of a solar cell is the percentage of sunlight converted by the cell into electricity. While the efficiency of c-Si is high, it absorbs light poorly and requires many layers to perform efficiently in solar applications.

The two types of crystalline silicon technology used to produce PV cells are mono and multi-crystalline (also called poly-crystalline). Mono-crystalline technology uses thin wafers sliced from a single, pure crystal silicon ingot. With multi-crystalline or polycrystalline technology, silicon crystals are cast into a block and then sliced into wafers. Multi-crystalline silicon is not as pure as mono-crystalline and therefore produces lower-quality wafers. However, it is significantly less expensive.

Thin-Film PV Cells

The high demand for crystalline silicon PV cells has outstripped production causing the prices to rise. As a result, a number of PV cell manufacturers have begun using less-expensive semiconductor materials including amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium diselenide (CIS) or copper indium gallium selenide (CIGS). These materials are good light absorbers and are fairly thin.

They are known as thin-film because they are deposited in very thin layers on stainless steel, glass or a flexible substrate. The thickness of the film is less than 1 micron. Like c-Si, thin-film PV cells are combined into modules and laminated to protect them from the elements. They are less expensive than c-Si, but only have a demonstrated efficiency of approximately 8 percent. The advantage of thin-film technology is that it can be applied over large areas, providing more opportunity to generate electricity in cloudy conditions.

The shortage of crystalline silicon has led to an increased use of thin-film PV cells. Just a few years ago, they were virtually unheard of. Today, they make up approximately 30 percent of the market. (Aug 2008 data)

Thin-film solar panels are made differently to silicon panels. The most common process used to make them is chemical vapor deposition. Gases react inside a chamber to form a condensate that settles uniformly onto a substrate.

Concentrating Photovoltaic

Concentrating photovoltaic systems use lenses or mirrors to concentrate sunlight onto high-efficiency solar cells. These solar cells are typically more expensive than conventional cells used for flat-plate photovoltaic systems. The concentration of sunlight decreases the required cell area while increasing the cell efficiency. This technology has potential for solar cell efficiencies greater than 40 percent. The high cost of advanced, high-efficiency solar cells requires concentrated sunlight for the system to achieve a cost-effective comparison with other solar alternatives. Therefore tracking systems are usually installed to take advantage of every hour of available sunlight.

Solar Thermal

Solar thermal is a rather straightforward application of solar energy. In this, solar heat is used to either directly provide heat energy (as in the case of solar water heaters), or the heat is used to heat liquids into steam, which is then used to drive turbines to produce electricity.

Solar Thermal Collectors

Solar thermal collectors can be of the concentrated or non-concentrated types. Non-concentrated solar thermal panels can be classified as Flat-plate solar collectors or Evacuated tube solar collectors.

Flat-Plate Solar Collectors

These are durable, weatherproof boxes which contain a dark absorber plate located under a transparent cover. They are still the most common type of collector used for water heating in many countries despite being inferior to evacuated tube collectors in many ways.

Evacuated Heat Pipe Tubes

These are designed such that convection and heat loss are eliminated, where as Flat-plate solar panels contain an air gap between absorber and cover plate which allows heat loss to occur. Further, thermal heat pipe systems are capable of limiting the maximum working temperature, where as Flat-plate systems have no internal method of limiting heat buildup which can cause system failure. Finally, evacuated heat pipe systems are lightweight, easy to install and require minimal maintenance. Flat-plate systems, on the other hand, are difficult to install and maintain, and must be completely replaced should one part of the system stop working.

Concentrated Solar Thermal

Concentrated solar is a technology that concentrates solar energy to heat liquids into steam, which is then used to drive turbines to produce electricity. Since concentrated solar uses existing generators, piping and mirrors, the production costs are much lower than PV solar and don't require special production facilities.

Concentrated Solar Collectors

Concentrated solar collectors use mirrored surfaces to concentrate solar energy on an absorber tube that contains a fluid – are able to produce yet more high temperatures (300° C/570°F). As a result of their size and expense, they are scarcely used on residential

applications, and are used in large projects and electrical generation. The following are the types of collectors used for concentrated solar thermal:

- Parabolic Trough Collectors - These collectors combine a curved mirror, shaped like a parabola to maximize the amount of sunlight collected, with an absorber tube embedded along the center of the mirror. The absorber tube is filled with oil or another fluid that can easily be heated. When sunlight hits these collectors, the mirrors focus it on the tube, heating the fluid inside. This hot fluid is then used to boil water and produce steam in a connected device and the steam is transferred to a generator that can produce electricity. A large array of connected parabolic trough collectors is needed to provide enough power for a generator.
- Dish/Engine Systems - These systems use an array of mirrors, arranged in the shape of a dish, to concentrate sunlight onto a receiver placed at the focal point of the dish. The heat produced by these systems is transferred to a heat engine which converts the heat into mechanical energy. This energy then drives a generator to produce electricity.
- Power Towers - Power Tower systems use a circular array of mirrors that track the sunlight and concentrate it on a receiver, placed at the top of a central tower at the focal point of the array. In much the same way as parabolic trough collectors, heat produced by the receiver is used to create steam which then powers a generator.
- Hybrid Systems / ISCC - Hybrid systems combine power towers with natural gas generators, creating a system that can continuously generate electricity, even when the sun isn't shining.
- Linear Fresnel - Linear Fresnel reflectors differ from other CSPs in that their long, low mirrors reflect sunlight onto a single, horizontal tubular receiver, where as other CSPs require multiple receivers. Linear Fresnel reflectors also require fewer acres because more mirrors can be squeezed onto a smaller parcel of land. And significantly, they can produce high temperatures, which lead to a more efficient conversion of sunlight into electricity.

1. The Solar Energy Market

This chapter provides data for the current and future trends in solar energy worldwide-contribution of total energy consumption and growth rates in various market and product segments. This chapter will provide insights to entrepreneurs on the segments that have the most attractive potential – now and in future.

This chapter comprises the following sections

1.1 Solar Market Predictions

1.2 Solar PV vs. Solar Thermal

1.3 Solar PV

1.4 Solar Thermal

1.5 Key Observations & Analysis of the Solar Energy Market

1.1 Solar Market Predictions

Solar is one of the high growth industries within the alternative energy industries.

The solar electricity market is booming. Installations of PV cells and modules around the world have been growing at an average annual rate of more than 35% since 1998.

The global solar energy market (which includes all aspects of the solar energy industry, including modules, system components, and installations) is expected to reach \$100 billion in 2012, up from \$30 billion in 2007.

The total energy will reach about 20 GW by 2012. While volumes will grow by 48% annually, up from 4.9 GW in 2008, revenue will grow at a compound annual rate of 33% from \$33 billion in 2008, as a few key trends emerge:

Consider the following:

- The global solar industry has grown 849% over the past 8 years, from an installed capacity of 877 MW in 2000 to 8,325 MW at the end of 2007, which breaks down to a CAGR of 37.9% for the same period.
- HSBC predicts that the solar industry will grow by 45% a year until 2012.
- EPIA predicts solar will contribute 26% of total global energy needs by 2040.

1.2 Solar PV vs. Solar Thermal

Percentage Share of Various Types of Solar Energy

Solar Thermal Vs Solar PV – 2007

Type of solar energy	% share of total solar energy market
Solar PV	95%
Solar Thermal (CSP)	5%

Note: This is based on estimates and data provided by diverse sources, for 2007

As you can see from the above table, solar thermal of the concentrated solar power (CSP) variety has so far been a minor contributor within the solar energy mix. But things are changing fast for solar thermal. As of June 2008, at least 10 solar-thermal power plants are being developed for installation in the United States, and another 17 are under construction or being planned in Algeria, China, Egypt, Israel, Mexico, Morocco, South Africa, and Spain. With a typical plant generating somewhere between 50 and 500 megawatts, that's a lot of clean power due to come online. (Just for comparison, new photovoltaic installations worldwide totaled a record 2826 MW in 2007 – *Source:* Solarbuzz)

The following sections provide detailed data and statistics for solar PV and solar thermal industries.

1.3 Solar PV

Data for Solar Energy (PV) Worldwide

Solar Global PV Power Capacity by Year

Year	MW
2007	8325
2008	9797
2009	11574
2010	13729
2011	16366
2012	19624

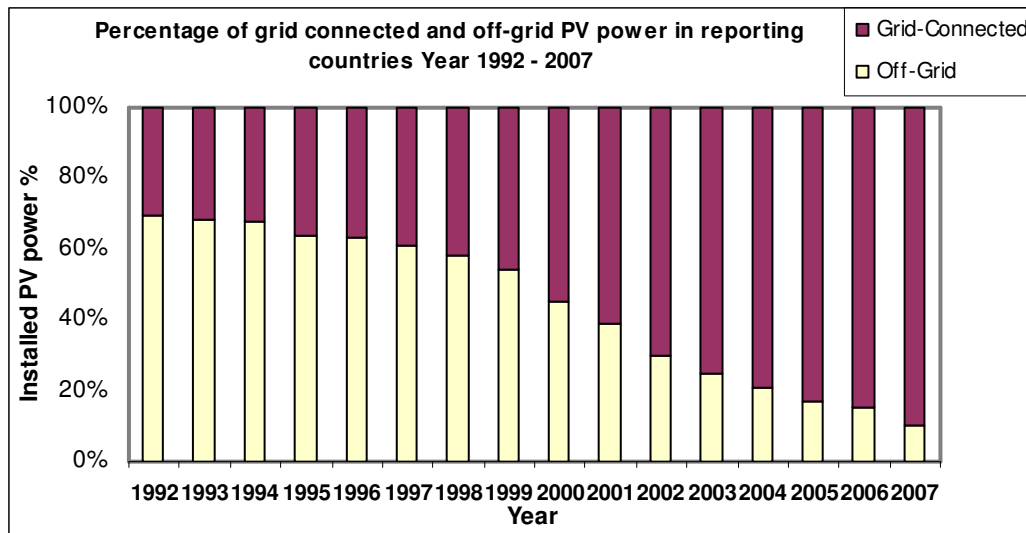
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Global Installed Capacity and Annual Percentage Increase of Solar PV Power

Year	Off-grid		Grid-Connected		Total	
	MW	%	MW	%	MW	%
1992	78		27		105	
1993	94	21	37	37	131	25
1994	112	19	45	22	157	20
1995	132	18	59	31	191	22
1996	158	19	78	32	236	24
1997	187	19	118	51	305	29
1998	216	15	169	43	385	26
1999	244	13	265	68	509	32
2000	277	14	438	65	715	40
2001	319	15	655	50	974	36
2002	354	11	964	47	1318	35
2003	410	16	1399	45	1809	37
2004	450	10	2382	70	2832	57
2005	485	8	3669	54	4154	47
2006	535	10	5049	38	5584	34
2007	663	24	7178	42	7841	40

Source: IEA, PV Trends 2008

Percentage of Grid Connected and Off-grid PV Power in Selected Countries-1992 - 2007



Source IEA 2008: The above data was collected from 20 countries, mostly developed countries

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Solar PV Current and Future Energy Contribution in Global Electricity Supply

Current Contribution of Solar Energy to Global Electricity Demand

- The approximate contribution of solar energy to total electricity consumption is about 0.25% (2007)

Future Contribution of Solar Energy to Global Electricity Demand

Some key future trends in the context of solar energy contribution to electricity demand can be obtained from an analysis done by EPIA/Greenpeace.

The key results of the EPIA/Greenpeace scenario show that, even from a relatively low baseline, solar electricity has the potential to make a major contribution to both future global electricity supply and the mitigation of climate change.

This analysis was done for two different scenarios: a) Advanced, b) Moderate

EPIA/Greenpeace Analysis - Advanced Scenario

This scenario is based on the assumption that continuing and additional market support mechanisms will lead to a dynamic expansion of worldwide solar PV installed capacity.

Market Growth Rates	
Average growth rate 2007-2010	40%
Average growth rate 2011- 2020	28%
Average growth rate 2021- 2030	18%

Source: Greenpeace / EPIA Report, 2008

Global Solar Electricity Output in 2030
8.9 % of global electricity demand from PV – demand forecast from IEA Reference Scenario (based on 2007 IEA data)
13.8 % of global electricity demand from PV – demand forecast from the Green Peace energy evolution scenario

Source: Greenpeace / EPIA Report, 2008

EPIA/Greenpeace Analysis - Moderate Scenario

This scenario envisages the development of PV against the background of a lower level of political commitment.

Market Growth Rates	
Average growth rate 2007-2010	30%
Average growth rate 2011- 2020	21%
Average growth rate 2021- 2030	12%

Source: Greenpeace / EPIA Report, 2008

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- The EPIA/Greenpeace Advanced Scenario shows that by the year 2030, PV systems could be generating approximately 2,600 TWh of electricity around the world. This means that by 2030 solar energy will contribute about 15% of the world's energy consumption.
- The capacity of annually installed solar power systems would reach 281 GW by 2030. About 60% of this would be in the grid-connected market, mainly in industrialised countries.
- Although the key markets are currently located mainly in the industrialised world, a global shift will result in a significant share – about 20% or an annual market of 56 GW – being taken by the developing world for rural electrification in 2030. Since system sizes are much smaller, and the population density greater, this means that up to 3.2 billion people in developing countries would by then be using solar electricity. This would represent a major breakthrough for the technology from its present emerging status

Regional PV Solar Energy Scenario

PV Power Capacity in Participating Countries as of the End of 2007

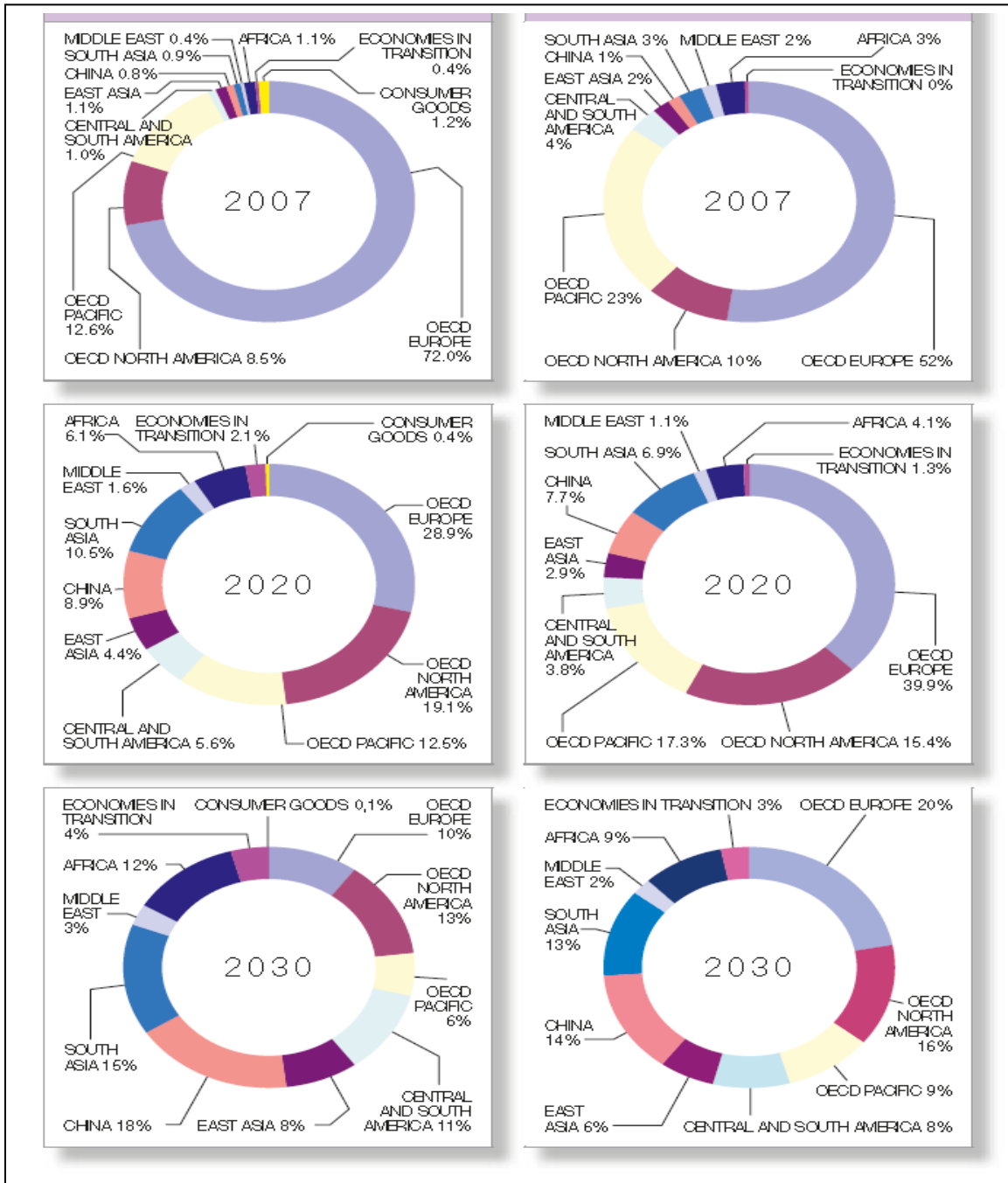
Country	Cumulative off-grid PV capacity (kW)		Cumulative grid connected PV capacity (kW)		Cumulative installed PV power (kW)	Cumulative installed per capita (W/Capita)	PV power installed in 2007 (kW)	Grid connected PV power installed in 2007 (kW)
	Domestic	Non-domestic	Distributed	Centralized				
AUS	27713	38733	15035	1010	82491	4.1	12190	6280
AUT	3224		22721	1756	27701	3.4	2116	2061
CAN	8088	14776	2846	65	25775	0.8	5291	1403
CHE	3200	400	30040	2560	36200	4.9	6500	6300
DEU	35000		3827000		3862000	46.8	1135000	1131000
DNK	100	285	2600	0	3075	0.6	175	125
ESP	29800		625200		655000	15.1	612000	490000
FRA	15881	6666	52685	0	75232	1.2	31299	30306
GBR	420	1050	16620	0	18090	0.3	3810	3650
ISR	1584	210	11	14	1819	0.3	500	0
ITA	6400	7700	83900	23200	120200	2.1	70200	69900
JPN	1884	88266	1823244	5500	1918894	15.0	210395	206833
KOR	983	4960	32559	39099	77601	1.6	42868	42868
MEX	15487	4963	300	0	20750	0.2	1019	150
NLD	5300		44500	3500	53300	3.3	1605	1023
NOR	7450	410	132	0	7992	1.7	324	4
PRT	2841		676	14353	17870	1.7	14454	14254
SWE	3878	688	1676	0	6242	0.7	1392	1121
USA	134000	191000	45000	40500	830500	2.8	206500	151500
Estimated Total	265368	396972	6019835	1158557	7840732		2257638	2160778

Source: IEA, PV Trends 2008

Regional Share of PV Installations – Current & Future
 (Source: Greenpeace / EPIA Report, 2008)

Annual PV installation by regional share

Cumulative PV installation by regional share



World Photovoltaic Installations in 2007 – by Installed Capacity
(Total installation in 2007 = 2826 MW)

Country	% of total
Germany	47
Spain	23
Japan	8
USA	8
Rest of World	14

Source: SolarBuzz (www.solarbuzz.com)

Share of Various Solar PV Technologies (Global)

Type	Share of total solar PV market	Growth rate % (2007-2010)
Crystalline	87.4	14.7
Crystalline – Mono	42.2	
Crystalline – Poly	45.2	
Thin film	12.6	37.8
Thin film – a-Si	5.2	
Thin film – CdTe	4.7	
Thin film – CIS/CIGS	0.5	
Other thin film	2.2	
Concentrated PV	<i>Negligible (estimated to be about 0.1%)</i>	

Source: PhotonInternational, Mar 2008 & Others

Solar PV – End User Prices

Indicative Installed Off-grid and Grid-connected Solar Energy Prices in Selected Countries in 2007

Country	Off-grid (EUR or USD per W)				Grid-connected (EUR or USD per W)			
	<1 kW		>1 kW		<10 kW		>10 kW	
	EUR	USD	EUR	USD	EUR	USD	EUR	USD
AUS	12.2-15.2	16.7-20.8	11-14	15-19.2	6.1-7.3	8.3-10	4.9-6.1	6.7-8.3
AUT	8-15	11-20.5	8-15	11-20.5	4.8-6	6.6-8.2	4.8-5.5	6.6-7.5
CAN	10.2	14	5.3	7.2	5.8	7.9	6.8	9.3
CHE	10.4-13.4	14.2-18.3	9.1-10.4	12.5-14.2	5.7-5.9	7.8-8	4.6-5.5	6.3-7.6
DEU	-	-	-	-	4.4-5.2	6-7.1	4.3	5.9
DNK	9.4-12	12.9-16.5	20.1-26.9	27.6-36.8	4.7-11.4	6.4-15.6	6.7-13.4	9.2-18.4
ESP	15-20	20.5-27.4	15-20	20.5-27.4	7-9	9.6-12.3	5.5-7	7.5-9.6
FRA	11-19	15-26	13-15	18-21	5.5-6.5	7.5-9	5.5	7.5
GBR	7.3-11	10-15	7.3-16.1	10-22	5-13.6	6.8-18.6	6.7-13	9.2-17.8
ISR	6-9	8.2-12.3	-	-				
ITA	10-14	13.7-19.2	-	-	6-7	8.2-9.6	5-6	6.8-8.2
JPN	-	-	-	-	4.3	5.9	3.9	5.4
KOR	-	-	-	-	6.6-7.2	9-9.8	6.4	8.7-8.8
MEX	10.8	14.8	-	-	5.8	7.9		
NOR	15.5-22.4	21.3-30.7	-	-	11.2-15	15.4-20.5		
PRT	8-10	11-13.7	8-10	11-13.7	5-6	6.8-8.2	4.2-5.5	5.8-7.5
SWE	10.3	14.1			5.2-6.5	7.1-8.9	6.5	8.9
USA	7.3-14.6	10-20	7.3-14.6	10-20	5.1-6.6	7-9	4-5.5	5.5-7.5

Notes : Additional information about the systems and prices reported for most countries can be found in the various national survey report on the IEA PVPS website, Excludes VAT and sales taxes, More expensive grid-connected system prices are often associated with roof integrated slates or tiles or one-off building integrated designs or single projects and figures can also relate to a single project

Source: IEA, 2008

Expected PV Generation Costs for Roof-top Systems at Different Locations

(In US \$)

Country	Sun shine hours	2007	2010	2020	2030
Berlin	900	0.60	0.47	0.27	0.18
Paris	1000	0.53	0.42	0.24	0.16
Washington	1200	0.45	0.35	0.20	0.14
Hong Kong	1300	0.41	0.33	0.19	0.12
Sydney, Buenos Aires, Bombay, Madrid	1400	0.38	0.30	0.18	0.11
Bangkok	1600	0.34	0.27	0.15	0.09
Los Angeles, Dubai	1800	0.30	0.23	0.14	0.09

Source: Greenpeace / EPIA Report, 2008

Notes:

- Sunshine hours = peak sun hours/ day
- h/a: Hours of sun per annum
- 900 h/a corresponds to northern countries of Europe

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- 1800 h/a corresponds to southern countries of Europe
- 1 US\$ taken equal to 0.738 Euro

1.4 Solar Thermal

The Solar Thermal Industry

The energy contribution from the solar thermal plants has been a much smaller one so far, when compared to the solar PV plants.

However, a note is in order. In some ways, it can be said that the solar thermal industry's has been vastly underestimated because so far the data that have been considered are only the energy output of the concentrating solar plants (CSP). The contributions from the end-use markets such as solar water heaters, solar house heating systems and the like have not been captured while calculating the total contribution of solar thermal segment to the worldwide energy output.

There have been studies that indicate that with some suitable assumptions the solar thermal energy's total installed capacity worldwide would be far higher than that of solar PV (in the order of 75 GW for thermal vs 8 GW for PV). However, because these are not official estimates, for this report we too consider only the energy capacities and output of concentrating solar power (CSP) segment of the solar thermal industry.

Solar Thermal Trends

Worldwide Installed Concentrated Solar Power Plants Capacity – 2000-2008

Year	Added capacity (MW)	Cumulative Capacity (MW)
2000	-10	356
2001	0	356
2002	0	356
2003	0	356
2004	0	356
2005	0	356
2006	1	356
2007	100	456
2012 (projected)		6400

Source: Earth Policy Institute, 2008

Notes for the above table:

1. The numbers are only for concentrated solar power plants, and do not include solar thermal energy used for water heaters, solar heating of buildings and solar architectural design.
2. The projection for 2012 has been arrived at using some proposed solar thermal power plants that are likely to come online in the next few years.

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Solar Thermal Trends - USA

- In the US, the home market has been the major buyer of solar thermal collectors, with almost 90% of all solar collector shipments (by area of collector) bought by this segment (2006 data).
- In the US, most of the market in 2005 was dominated by low temperature collectors, mainly for heating water in swimming pools. (2006)
- The industry remained highly concentrated, with 92 percent of sales made by the 5 largest companies. (2006)

Annual Shipments of US Solar Thermal Collectors (1996-2005)

Year	# of companies	Collector shipments (in '000 sq ft) – includes imports and exports
1996	28	7616
1997	29	8138
1998	28	7756
1999	29	8583
2000	26	8354
2001	26	11189
2002	27	11663
2003	26	11444
2004	24	14114
2005	25	16041

Source: Energy Information Administration, USA

US CSP Project Pipelines By 2012

Total = 2855 MW

(units in MW)

Items	2007	2008	2009	2010	2011	2012
Central Receiver (Power Towers)				115	110	200
Parabolic Trough	60		50	150	560	525
Dish Engine				320		525
Linear Fresnel				160		
Hybrid / ISCC				40	40	
Total	60	0	50	785	710	1250

Estimations for the above based on data from Emerging Energy Research.

Solar Thermal Trends - EU

- In the EU, the market exhibited a solid growth of 26% in 2005, and almost passed the 2 millions m2 mark (1,400 MWhr of new capacity)

- The dominance of the German, Austrian and Greek market (representing over 70% of the EU market) is not diminishing, but others such as France are catching up (2006 data).
- An important development is the growing share of combined (hybrid) systems that produce domestic hot water and support space heating, leading to higher energy savings.
- The EU has a new National Solar Obligation (revision of the CTE -Technical Building Code) - From September 2006 onwards, almost all new buildings have been required to cover 30-70% of their domestic hot water demand with Solar Thermal energy.

Sources: EIA & other data

Trends in the Various CSP Technologies

Among the five technologies (viz Central Receiver, Parabolic Trough, Dish Engine, Linear Fresnel & ISCC), parabolic trough technology's decades of proven operation is expected to keep it in good stead for the next few years, but the technology's head start could start diminishing as the potential of central receiver and other technologies are realized at a commercial scale, according to some studies. In about 3 years' time (by end of 2010), it is expected that the real potential of the other three main technologies - Central Receiver, Dish Engine, and Linear Fresnel – will be much more clear.

1.5 Key Observations & Analysis of the Solar Energy Market

- While solar thermal has been contributing an insignificant percentage of the total solar energy worldwide, its contribution could be much higher in future. As this domain is less mature than the solar PV domain, entrepreneurs might find it useful to explore this domain more for opportunities. Solar thermal could start seeing higher rates of adoption especially from the utilities companies, much more than those for the retail and residential segments. According to a recent (Jun 2008) report by Lux Research, by 2012 new annual solar thermal installations (CSP) will reach 3.26 GW, accounting for almost \$10 billion in revenue.
- In Dec 2007, Emerging Energy Research (EER) released a study on CSP. EER argued that CSP is now the fastest growing utility-scale alternative energy source after wind, and expects US\$20 billion to be poured into the sector over the next 5 years. The two hottest geographical markets for the CSP at the moment, according to the study, are the Southern US and Spain. These two markets alone will install about 7,500 MW of CSP between now and 2020, while other southern European nations will install about 3,200 MW over the same time period. Much potential also exists in North Africa and the Middle East. According to the aforementioned study, outside of Spain and the US, Italy, France, Portugal, and Greece are on the cusp of breaking through with CSP developments, along with Middle East and North Africa.
- Entrepreneurs keen on exploring the solar thermal (CSP) domain should also be updated on the latest in Linear Fresnel technology as that could start gaining market share fast if the market expectations about the technology are proven.

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- Unlike in many other emerging fields, for solar PV countries such as the Germany, Spain & Japan are more significant markets than the USA in the near term, going by the total amount of solar energy installations made in the past few years. But this works both ways, because the fact that the USA is way behind the other leading countries in its total PV installation also means that there is scope for extra-ordinary growth in the US market, given that the US economy (measured in its GDP) is over ten times as large as that of Spain, over five times as that of Germany, and over three times as large as that of Japan.
- Costs from solar generated electricity (both PV & CSP) could get grid parity sooner in countries such as India and China where deployment costs are lower. This makes it imperative for entrepreneurs to pay special attention to the developments in solar energy industry in these countries.
- Within the solar PV industry, the % of total power generation from grid connected solar systems have increased dramatically over the past decade, and this growth is expected to continue. What this means for entrepreneurs is that there could be a number of emerging opportunities in assisting the centralized solar PV power plants industries – as component suppliers, consultants, turnkey implementers and more.
- Concentrated PV is currently almost insignificant in its contribution to electricity, but this segment needs to be observed carefully. While there are companies such as SunRGI that claim to have superior products in this area that will be commercialized soon, the real-life commercial success of this technology is yet to be seen. Should this technology be proven to work on a commercial scale at prices claimed (some claim a price of 5 cents per kWh), it could prove to be one of the fastest adapted solar energy technologies and could really prove disruptive. However, observations from a recent Lux Research report suggests that the immediate future for CPV is not attractive owing to the technological challenges faced by this segment, though the products could become mature enough by 2010. The report predicts that the market for CPV by 2012 will still be only about \$ 1 billion.
- For entrepreneurs considering investing in solar panel manufacturing, thin film solar panels appear to be the most attractive avenue. However, within this, entrepreneurs might want to explore CIS/CIGS technology further – currently, this technology constitutes less than 5% of the thin films market, which is why its growth could be exponential should it prove to be commercially better qualified. However, those exploring these thin-film technologies should also keep in mind that there could be shortage and scarcity of raw materials needed for these films production.
- Those considering entering the solar PV panels market (either as manufacturers or as distributors of parts or end products) should note that there could be an oversupply of solar panels in the near future, driving down costs and profit margins (*Reference: Lux Research*)
- It is not clear whether organic PV cells will start making an impact any time soon, as these still at the research & development stages.

2. Solar Energy Opportunities

The summary section of the first chapter provided insights on some of the key trends in the solar energy industry. These trends will offer ideas to entrepreneurs on the most attractive segments in this industry now, and for the future.

This chapter provides more details on opportunities, in the following sections

- 2.1 A Framework for Solar Energy Opportunities**
- 2.2 New Developments in the Solar Energy Industry**
- 2.3 Solar Energy Products**
- 2.4 Market Strategies & Policies for Development of the Solar Energy Market**
- 2.5 Other Opportunities**

2.1 A Framework for Solar Energy Opportunities

A wide range of entrepreneurs and businesses can benefit from the opportunities unfolding in the solar energy industry.

We classify the solar energy opportunities along the following dimensions:

Dimension 1: Investment Required

Dimension 2: Type of Industry

Investment Requirements

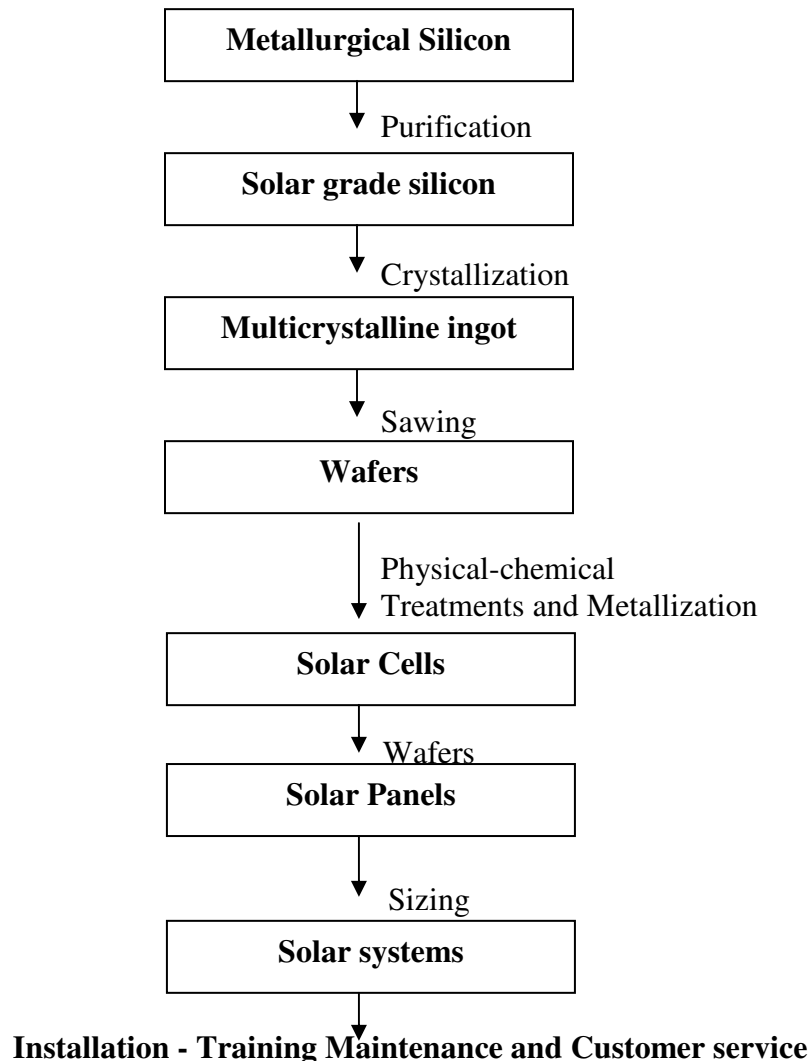
Scale of Investment	Type of Opportunity
Low	<ul style="list-style-type: none">• Installing solar panels• Selling solar energy products• Training people for the solar energy industry
Medium	<ul style="list-style-type: none">• Setting up medium scale solar panel manufacturing plants• Setting up manufacturing plants for components and accessories for the solar PV and solar thermal industry• Setting up manufacturing units for a range of solar energy related products
High	<ul style="list-style-type: none">• Setting up large-scale solar panel manufacturing plants• Setting up large solar power plants or large-scale solar panel/collector installations<ul style="list-style-type: none">○ Centralized grid-connected solar PV plants○ Centralized grid-connected solar Thermal plants○ Installing large-scale distributed solar PV panels○ Installing large-scale distributed solar thermal collectors

Type of Industry

Industry Type	Type of Opportunity
Manufacturing	<ul style="list-style-type: none"> • Solar panels manufacturing • Manufacturing of raw materials, components and accessories for solar PV and thermal
Trading	<ul style="list-style-type: none"> • Trading of solar panels, solar thermal collectors and a range of solar energy products
Services	<ul style="list-style-type: none"> • Installation and maintenance of solar panels and solar energy products • Training people for the solar energy industry

The reader can get more insights into the value addition points of the industry from the Solar PV Value Chain provided below.

The Photovoltaics Value Chain



2.2 New Developments in the Solar Industry

A number of technological and product innovations are taking place in the solar energy industry. Some of the recent and emerging trends in solar energy are provided below:

- **Concentrated Solar PV (CPV)** - This mechanism for focusing light on small areas of photovoltaic material could make solar power in residential and commercial applications cheaper than electricity from the grid in most markets in the next few years. CPV is not exactly a new technology, but its deployment has been so far in very limited domains, and there have been no large commercial deployment of this technology.
 - **Xtreme Concentrated Photovoltaic (XCPV):** Energy Company Sunrgi's Xtreme Concentrated Photovoltaics promises a low-cost, high-efficiency system with a low projected energy pricing of 5 cents per kilowatt. This breakthrough puts solar on par with the cost of coal, natural gas, and other non-renewable energy sources. The XCPV system is based on the following principle: use a magnifying glass to concentrate the sun's energy into a single high efficiency solar cell. Each unit features a lens that magnifies the sun's rays 2,000 times, focusing it onto a solar cell that converts more than 37% sunlight to energy (this is about 175% more than that for a conventional PV). The result is a system that maximizes the potential output of each solar cell while minimizing cost and space required. (May 2008)
- **Nano-size Carbon Molecules Dubbed Buckyballs:** Silicon-based solar cells represent 92% of today's photovoltaic market, but some producers are betting on different, much cheaper materials for the future. One is a conductive polymer salted with nano-size carbon molecules dubbed buckyballs. Which when applied a very thin coating of the buckyball mixture on a plastic film produce a solar cell that topped 5% efficiency - the best yet for an organic solar cell. The cost of these solar cells would be a fraction that of their silicon cousins, so a homeowner could buy five or ten times the surface area and still save money.
- **Dye Sensitized Thin-Film Solar Panels** - A different type of thin-film solar panels is made using a light-absorbing dye. The anode is made from a glass plate coated with a conductive layer and a layer of titanium dioxide. The plate is then dipped into a dye which bonds to the surface of the titanium dioxide molecules. The cathode is made from a plate coated with a conductive layer and an iodine electrolyte. Both plates are joined and the edges sealed to help prevent the electrolyte leaking out. Light photons that are absorbed by the dye molecules create free electrons that cross over to the titanium dioxide, where they move up to the conductive layer on the anode. Meanwhile, the dye gains an electron from the iodine electrolyte, which later recovers it from one of the returning electrons at the cathode.

- **Organic Solar Coatings** are under development at companies such as General Electric Co. (GE) and IBM (IBM). Organic solar cells are also the focus of multi-million \$ research efforts in Europe.
- **SPR-315 Solar Panel:** SunPower Corporation's solar panels, based on the new Gen 2 Solar Cells the SPR-315, will get a whopping 22% photovoltaic (PV) efficiency - over 10% more than the standard 7-12%. (2006 news)
- **Thin-film Solar Cells:** The basic technology has been around for decades, but Silicon Valley-based Nanosolar created the manufacturing technology that could make that promise a reality. PowerSheet solar cells are made with printing-press-style machines that set down a layer of solar-absorbing nano-ink onto metal sheets as thin as aluminum foil, so the panels can be made for about a tenth of what current panels cost and at a rate of several hundred feet per minute.
- **Dish Technology:** The Stirling dish technology converts thermal energy to electricity by using a mirror array to focus the sun's rays on the receiver end of a Stirling engine. Each panel tracks azimuth and elevation to keep the sun's rays focused at greatest intensity possible. This is almost twice as efficient as other solar technologies. A 20-year purchase agreement between Southern California Edison and Stirling Energy Systems signed in 2005, Inc. will result in 20,000+ dish array, covering 4,500 acres, and capable of generating 500 MW -- more electricity than all other present U.S. solar projects combined.
- **Transparent Electronics:** Oregon State University (OSU) and HP's Xtreme Energetics are working together on transparent transistors and optoelectronics technology. This technology converts sunlight to electricity at twice the efficiency and half the cost of traditional solar panels. HP has funded some of OSU's research in advanced materials, collaborated with the university to invent transparent transistor technology, and is now making that technology available worldwide through its intellectual property licensing group.
- **PowerCube Makes Solar Energy Installation Simple** - The PowerCube makes deployable renewable energy simple by integrating the latest solar energy, power storage and power management technology. It is engineered for home use, emergency response, construction, and any other remote power needs. It's large size (72 x 124 x 50 inches) enables it to produce 600 watts of solar power. (Jul 2008)
- **Aussie Hybrid Panel Could Halve Solar Cost** - Scientists have invented a new breed of solar panel which generates electricity and hot water at the same time – and could halve the cost of going solar. Household roofs would be kitted out with rows of mini-troughs, made of mirrors, if the project gets off the ground. (Sep 2008)
- **Solar Panels That Can be Applied to Windows and Canopies** - A thin polymer photovoltaic layer called Powerglass can be applied to windows, canopies and roofs to turn them into mini power plants to supply electricity. Huge high rise buildings have much more surface area in the form of windows than they do on top of their roofs. This means that Powerglass is poised to be an attractive idea and potentially can increase the use of solar panels dramatically. (2005)

- **3-D Solar Panels** - Unique three-dimensional solar cells that capture nearly all of the light that strikes them could boost the efficiency of photovoltaic (PV) systems while reducing their size, weight and mechanical complexity. The new 3D solar cells capture photons from sunlight using an array of miniature “tower” structures that resemble high-rise buildings in a city street grid. The cells could find near-term applications for powering spacecraft, and by enabling efficiency improvements in photovoltaic coating materials, could also change the way solar cells are designed for a broad range of applications.
- **String Ribbon Approach to Manufacturing Solar Panels** - Reducing the cost of solar power requires slashing the cost of manufacturing the silicon wafers on which solar cells are built. A technique first proposed in the 1980s by Professor Emanuel M. Sachs is doing just that by doubling the number of wafers made per pound of expensive silicon. Making silicon wafers currently accounts for 45 percent of that total cost. The conventional way to make silicon wafers is to cast a solid brick of silicon and then slice it into wafers. But slicing makes dust, and in this case the dust is expensive silicon, no longer pure enough to be recycled. So Sachs came up with an approach that does away with slicing. Instead of making bricks, his String Ribbon process makes long sheets of silicon just the thickness of a wafer. No slicing, no waste. In 1994, Evergreen Solar, Inc., began manufacturing crystalline silicon PV modules using the String Ribbon approach.
- **Companies such as Sharp** have been working on breakthrough technologies to incorporate **advanced surface texturing processes** for manufacturing solar panels. These technologies result in panels that have increased light absorption and overall efficiencies.
- **Enerize Corporation of Florida** has claimed a major breakthrough in improving the performance of photovoltaic module with transparent polymers to replace glass. The photovoltaic module designs use proprietary polymer protective coating materials to replace conventional glass can increase conversion efficiency by more than 20%, due to high transparency and concentration of incoming light, while providing resistance to degradation by UV and ionizing radiation, lower cost, reduced weight, and improved mechanical strength. (May 2008)
- **Photoelectrochemical (PEC) PV Cells** - Unlike other PV cells that use solid crystal layers to absorb light, PEC cells are liquid. They absorb light with a dye sensitizer and use it to create electrical current in a nanocrystalline titanium dioxide semiconductor layer. The cells are encased in a carbon layer on the back and are contained in glass on both sides. A number of companies are developing this technology and they could be introduced commercially in the near future. These cells are expected to compete by significantly reducing the cost of PV cells. (Aug 2008)

2.3 Solar Energy Products

- Solar panels
- Solar water heaters
- Solar pool covers
- Solar pool heaters

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- Solar panel components & accessories such as inverters
- Solar water pumps
- Solar cookers
- Solar energy training kits
- Solar energy systems adapted to specific industries (solar powered equipments for use in remote oil rigs) and functions (eg: Solar powered traffic signals)
- Solar dryers
- Solar energy to power small tools and appliances
- Solar PV for electric fences
- Unique products like solar powered attic vending fans - to eliminate heat and moisture from your attic
- Other products such as solar radio, solar battery chargers, solar exotica such as solar powered bags, solar powered lanterns and lights

2.4 Market Strategies & Policies for Development of the Solar Energy Market

Aspect	Market Development Strategies
Technology & Manufacturing	<ul style="list-style-type: none"> • Improved economies of scale • Advances in technology and manufacturing
Policy	<ul style="list-style-type: none"> • Large, long-term government purchase orders • Government purchase guarantees • Bulk purchases from home builders, universities, others
Finance	<ul style="list-style-type: none"> • Solar-friendly tax credits and policies • Solar futures market • Secondary markets

2.5 Other Opportunities that Require Thought

While entrepreneurs could come up with new ideas in solar energy using the framework and the data provided earlier in this chapter, the following inputs could be used while exploring new business avenues in this domain:

- Large sections of the developing world do not have electricity at all. This could mean investing opportunities for some specific types of investors.
- Possibility to come up with niche ideas for solar energy use and build products around these. While products such as solar water heaters and solar cookers could have high competition and hence lower profit margins, there is excellent scope for businesses to come up with unique and niche products, some of which could fetch high premiums. Some recent examples of such products are solar bicycles, solar bags etc. The world is going green, so capitalize on it.
- Building brands around your solar energy service. Branding opportunities are possible for usually unbranded services such as solar panel installation and

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- maintenance. In fact, such branding could make all the difference between your business staying local and going global.
- Check out if there are new solar energy related incentives provided by your federal or state governments that can give your business a jump-start. While on this, also check if there are assistance programs under organizations such as UN, World Bank etc., for solar energy related activities in your region.

3. Solar Energy Problems

This chapter comprises the following sections

3.1 Problems for Producers

3.2 Problems for Consumers

Not all is well with the solar industry. Else everyone will be using solar energy to produce electricity worldwide!

The most significant problems faced by the providers and consumers of solar energy are listed. Analysis of these problems and possible solutions could result in newer opportunities to entrepreneurs and businesses.

3.1 Problems Faced by Producers

- Silicon, the main raw material of a solar cell, pushes up costs as a high degree of purity is required. Just seven companies worldwide produce most of the polysilicon used in solar panels. This will explain why any problem regarding scarcity of polysilicon could get very difficult, especially if all the producers happen to be facing similar manufacturing bottlenecks (Jun 2008)
- Even if the silicon price falls, other bottlenecks may well appear for producers of solar panels. The first step in making solar cells is to shape silicon into ingots and then slice it into wafers. Ingot- and wafer-makers also have a lack of capacity. There is also apprehension whether there will be enough of the specialist chemicals that coat cells. The searing expansion of the industry is bound to cause more growing pains - (according to an article from The Economist, Aug 2008)
- Many of today's top solar panel companies have risen rapidly on the backs of favorable long-term contracts with raw material and component suppliers. But owing to shortage of raw materials, solar panel manufacturers struggle to provide even a third of what customers want. The shortage came about because of the solar boom. The industry has grown by more than 30 percent per year since the mid-1990s, with recent years seeing 50 percent growth. Government programs in Germany, Japan, and California, as well as the fossil fuel price shocks, touched off the boom
- Solar panel manufacturers need economies of scale to deliver low costs - hence much higher investment required. In addition, new technologies such as thin film solar panels & amorphous thin film solar panels have high equipment costs. Add to that the costs of consumables. Solar thin film equipment suppliers such as Applied Materials (AMAT) of the U.S. and Oerlikon of Switzerland are selling amorphous silicon technology. Equipment costs in the neighborhood of \$200 million to make 60 MW of panels (2008 data).
- The solar industry as a whole is still heavily dependent on government incentives in order to provide energy at competitive prices
- Rapid technological evolution and consequent obsolescence makes investment risky in solar cell manufacture

- Manufacturing bottlenecks of concentrating photovoltaics - The emerging CPV industry is currently experiencing supply chain issues where not everything it needs is readily available. However, the bottleneck is not the cells. The bottlenecks will be in the supply of lenses and mirrors, where vast areas, square kilometres initially, many thousands of square kilometres possibly, must be covered in optics of excellent quality. (Feb 2008)
- Thin-film solar panels are hard to mass-produce cost-effectively because of the difficulty of coating large areas of glass. (2005)
- Large-scale solar electric systems need large amounts of land to collect solar energy. This may cause conflicts if the land is in an environmentally sensitive area or is needed for other purposes.
- While organic photovoltaics are flexible, lightweight, and potentially less expensive than traditional solar cells, their main drawback is that these cells are nowhere near as efficient at converting light into electricity as silicon cells (2004 data)
- While concentrated photovoltaics appears to be a very promising area with excellent future potential, one of the key problems with concentrators is heat. Not all the energy that falls on the cell gets converted electricity, some of it is waste heat. Photovoltaics get less efficient as they get hot, so cooling a concentrator array is a significant technology challenge.

3.2 Problems Faced by Consumers

- Whether in the form of water-heating solar panels, or photovoltaic to generate electricity from sunlight, the solar energy technology is relatively expensive compared to, say, coal-fired power plants. Electricity costs in the United States average 8 cents per kilowatt-hour. The actual cost of electricity from solar energy is more expensive than this.
- High upfront costs - Even with tax incentives and rebates, cost is still a major factor for many. For instance, the \$20,000 - 25,000 price tag for the average solar system in the US remains a fair chunk of change for most, and increased prices for panels in 2006 and 2007 made this a bit more difficult, though these price increases could be a temporary phenomenon. Cost is, by far the most important bottleneck for the consumer of solar energy, especially the residential consumers
- Maintenance & repair costs - Residential solar panels can be costly not only from an upfront cost component, but also because of maintenance costs
- Very long payback period - depending on where you are and the types of incentives offered by the government, the payback periods could sometimes be as high as 20 years
- Solar energy is not available at night and is less available during cloudy days, making it necessary to store the produced electricity.
- Distributed solar energy is not a very suitable system today to operate large machinery

4. Solar Energy Projects & Companies

This chapter comprises the following sections

4.1 Solar Energy Projects

4.2 Solar Industry Suppliers

4.1 Solar Energy Projects

Top Proposed Solar Thermal Energy Projects Worldwide (as of June 2008)

Location	Company	Project	Proposed capacity (possible expansions) MW	Scheduled Year of Completion
California, USA	Solel Solar Systems, Ltd.	Mojave Solar Park	553	2011
California, USA	Stirling Energy Systems	Solar One	500 (850)	2011
California, USA	BrightSource Energy, Inc.	Ivanpah Solar Electricity Generating System	400 (900)	2011
California, USA	Stirling Energy Systems	Solar Two	300 (900)	not set
Andalucía, Spain	Abengoa Solar	Solúcar Platform	300	2013
Florida, USA	Ausra, Inc.	Not available.	300	2011
Arizona, USA	Abengoa Solar	Solana	280	2011
California, USA	Beacon Solar, LLC	Beacon Solar Energy Project	250	2011
California, USA	Harper Lake, LLC	Harper Lake Energy Park	250 (500)	2010
Ramat Negev, Israel	Not available	Not available.	250	2011

Source: Compiled by Jonathan G. Dorn, Earth Policy Institute, June 2008

Top Solar PV Energy Projects Worldwide – Operational & Proposed

(Data collected year: 2008)

- **The Solar Energy Generating Systems:** This massive 354 MW project is a conglomerate of nine individual solar power stations operating in the Mojave Desert in California, USA. These use concentrated sunlight to superheat steam in order to drive turbines. These stations also function during night time hours due to efficient heat storage.
- **By 2011, Deming, New Mexico, USA will be the home of the world's largest solar power plant.** This 300 Megawatt solar facility will be 15 times the size of the current largest solar plant on the planet. New Solar Ventures and Solar Torx are the companies behind the project. The solar energy plant will cover as many as 1,300 hectares and employ between 300 and 400 people. The project's planners estimate that the plant will supply enough energy to power 240,000 homes
- **China's massive Solar Generator** looks set to take the limelight with a multi-stage concentrated solar power plant that will be generating 1000 MW by the year 2020. The first phase will provide 50 MW and will commence construction shortly. This future solar energy project is to be located in the northern Inner Mongolia region
- **The Solana solar plant**, 70 miles from Pheonix, near Gila Bend, Arizona, USA, will compliment the Deming plant when both begin operations in 2011. It will produce 280 megawatts of energy, provide 1,500 jobs, and cover an area of 769 hectares. The solar power facility will be the child of Abengoa Solar and Arizona Public Service Company. However, the project depends on the United States Congress to renew clean energy tax credits, which would otherwise expire at the end of 2008
- **Australia may briefly capture the prize for biggest solar with a plant near Mildura, Victoria, Australia.** It will go into operation in 2010 and continue to grow in size until its completion in 2013. A project of TRUenergy and Solar Systems, the plant will generate 154 Megawatts of solar energy.

Notable Recent Investments by Companies for Setting up Solar Energy Plants

The following data are provided to provide an idea of the types and quantum of investments being made by companies in recent years in setting up ventures in solar energy.

PV Panels Manufacturing

- **TF SolarPower and its Partners will be Setting Up** a production unit to manufacture thin-film photovoltaic panels in Hyderabad, India. The initial fab capacity will be 52MWp with an investment of Rs 600 crores (\$ 150 million) for the first fab of the project. The plant will have a capacity to produce 350MWp in phase I and the total project cost is estimated at Rs 2,800 crores (\$650 million)

- within 4 to 5 years. The solar fab will be deploying 3D cell design and manufacturing technology (Apr 2008)
- **Solar Equipment Manufacturing Plant Announced for New Mexico** - A new plant that will manufacture photovoltaic modules and receiver tubes for concentrating solar power generation will be built near Albuquerque, New Mexico, this year. The new complex is expected to bring approximately \$100 million of foreign investment to New Mexico - January, 2008
 - **Schott Solar to Unveil New Solar Panels** - Schott Solar, a leading German company that manufactures solar panels is investing \$100 million to build a 200,000-square-foot plant at Mesa del Sol. The facility will manufacture both photovoltaic solar panels and concentrated solar power collectors. The proposed plant has a capacity of manufacturing 70 megawatts of solar panel per year (Oct 2008)
 - **Hyundai Corp. Subsidiary Hyundai Heavy Industries has Announced Plans** to invest 300 billion won (\$270 million) in the expansion of its solar panel and solar cell production line by 2009, and last year completed a \$30 million, 20-megawatt solar panel plant in Umsung, South Korea – Sep 2008
 - **Tuas (Singapore) Solar Plant to Begin Output in 2010** - A Norwegian firm REC is building a massive \$6.3 billion solar panel plant at Tuas. Building of phase one, which involves an investment of \$3.4 billion, will cover an area of about 1 sq km at Tuas View. REC in 2007 picked Singapore over almost 200 other possible sites to locate the plant. The plant will make wafers, cells and modules used to generate solar power. Once it is fully operational, the facility will be able to produce products that can generate up to 1.5 gigawatts of energy every year - Jun 2008
 - **High Technology Solar Manufacturing Plant Will Create 350 Jobs** - A German solar technology company announced plans to build a massive manufacturing plant at Mesa del Sol in Albuquerque, New Mexico. Schott Solar, a division of the huge German company, Schott AG, plans to break ground next month on a \$100 Million, 200,000 square-foot facility. The plant manufacture 64 Megawatt photovoltaic modules and the receivers that generate power for concentrated solar thermal power plants facilities - Jan 2008

Solar Power Plants & Solar Energy Installations

- **The government of Abu Dhabi will Build a \$350-million Solar Power Plant.** The 500 megawatt plant, expected to begin operations in 2009, is part of Abu Dhabi's drive to cut dependence on hydrocarbon power generation
- **Duke Energy Eyes Residential Rooftops** - Duke Energy has applied for regulatory approval to spend \$100 million installing solar panels at homes, schools, stores, factories and other locations in North Carolina, Duke's first large-scale distributed solar power generation deal. The company plans to spend two years installing 20 megawatts of solar panels at 850 sites - June, 2008
- **Hawaii Plans for 34 Megawatts of Solar Power at State Sites** - Hawaii government has announced one of the largest state government solar initiatives in

the nation, which includes 12 large solar arrays in separate sites across the islands. Combined, the installations could generate a total of 34 megawatts of electricity and provide power for 9,000 homes per year - January, 2008

4.2 Solar Industry Suppliers

Solar PV Panel Manufacturers

Top Solar PV Cell Producers by Market Share for 2006-07

Company Name	Marketshare %
Sharp	17.1
Q-Cells	10.0
Kyocera	7.1
Suntech	6.3
Sanyo	6.1
Mitsubishi	4.4
Schott Solar	3.8
BP Solar	3.4
Motech	4.0
Solar World	3.5
Others	34.3

Top Solar Photovoltaic Manufacturers – by Capacity

Company	Origin Country	Cell Technology	Capacity MW 2008 (announced)
Sharp Electronics	Japan	Crystalline	870
Q-Cells	Germany	Crystalline	834
Suntech Power Holdings Ltd.	China	Crystalline	590
First Solar	USA	Thin-film	484
SolarWorld	Germany	Crystalline	460
Sanyo	Japan	Crystalline	365
BP Solar	UK	Crystalline	480
Kyocera	Japan	Crystalline	300
Motech Industries Inc.	Taiwan	Crystalline	330
Solarfun Power Holdings	China	Crystalline	360
SunPower Corp.	USA	Crystalline	414
Gintech Energy Corporation	Taiwan	Crystalline	300
E-TON SOLAR TECH	Taiwan	Crystalline	320
Yingli Green Energy	China	Crystalline	400
CEEG Nanjing PV Tech Co.Ltd.	China	Crystalline	390
China Sunergy Co. Ltd	China	Crystalline	320

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Mitsubishi	Japan	Crystalline	280
Ersol Solar Energy AG	Germany	Crystalline	220
Jing Ao Solar Co Ltd.	China	Crystalline	175
Moser Baer Photovoltaic	India	Crystalline	120
Total (in MW)			8012
Total for Top 10			5073

Source: EDN Magazine

Some Key Solar PV Panel Manufacturers & Material/Technology Used

Company	Technology Used
SunPower	Polysilicon
Suntech Power Holdings	Polysilicon
Sharp	Polysilicon
Kyocera	Polysilicon
Solarfun	Polysilicon
JA Solar Holdings	Monosilicon
Trina Solar	Mono & Polysilicon
Evergreen Solar	String Ribbon
EMCORE	GaAs Concentrated Solar System
Energy Conversion Devices	Amorphous Silicon Thin Film
First Solar	CdTe Thin Film
DayStar Technologies	CIGS Thin Film
Ascent Solar	CIGS Flexible Thin Film

Solar Thermal Suppliers

The following is a list of key developers of solar thermal plants (CSP) – 2007 worldwide data

Company	Country
Abengoa	Spain
Abu Dhabi Water & Electricity Authority	UAE
Acciona Solar Power	Spain
Albiasa Solar	Spain
Ausra	USA
BrightSource	USA
EECH AG	Germany
Endesa	Spain
ENEA	Sweden
Enel-Union Fenosa	Spain
Enerstar	Canada
Ener-T Global	Israel

Environmission	Australia
Epuron	Germany
Eskom	South Africa
Iberdrola	Spain
IDEA Ciemat	Spain
Inland Energy	USA
SAMCA	Spain
Sener	Spain
Sky Fuel	USA
Solar Millennium	Germany
Solar Power Group	Germany
Solel	Israel
Stirling Energy Systems	USA
Tube Sol Murcia	Spain

5. Solar Energy Financing and Investments

This chapter comprises the following sections

5.1 Investment Trends in Solar Energy

5.2 Venture Capital Companies / Entities that Have Recently Been Active in Solar Energy

5.3 Summary & Highlights

5.1 Investment Trends in Solar Energy

Global investment in sustainable energy was \$148.4 billion in 2007, an increase of 60% over 2006. In 2007, solar energy increased its share in almost every investment category. Between 2006 and 2007, the sector increased its overall share of new investment from 16% to 24%, of asset finance from 6% to 21%, and of VC/PE from 21% to 30%. Solar, which attracted new investment of \$28.6 billion in 2007, has also been the fastest-growing sector, averaging annual growth in investment of 254% since 2004.

Solar Energy Investments in 2007

Type of energy	Total investments (in \$ billion)
Solar	28.6
All renewable energy	148.4

Global New Investment by Energy – 2007

Energy Source	% share of new investment
Wind	43
Solar	24
Biofuels	17
Biomass & Waste	9
Other Renewables	3
Energy Efficiency	2
Other Low Carbon	2

Source: New Energy Finance

Note: This table does not take into account some reinvestments and small-scale projects

Recent Investments in Solar Energy

USA

- US Cleantech Investment Climbs 41% in 2nd Quarter of 2008 to Nearly \$1 Billion, the Highest Quarter on Record – Venture capital investments in US

- cleantech companies grew by 41% to \$961.7 million in Q2 2008, up from \$683.5 million in Q1 2008, according to an Ernst & Young report. The top three deals of the quarter were solar-related companies. The deals included, SunEdison, in Beltsville, MD, which raised \$131 million, eSolar, in Pasadena, CA, which raised \$130 million and BrightSource in Oakland, CA, which raised \$115 million. It is also worth noting that corporate investors were involved in all of these deals
- The U.S. Department of Energy is putting up cash for solar energy, announcing that it will invest up to \$24 million in projects that are designed to accelerate the penetration of solar photovoltaic systems in the country. Combined with industry cost share of up to \$16 million, the DOE said more than \$40 million in total could be invested in these projects. Some of the companies receiving the funding include Bethel, Conn.-based Apollo Solar, Hauppauge, N.Y.'s Nextek Power Systems and SmartSpark Energy Systems in Champaign, Ill. The DOE's Sandia National Laboratories in Albuquerque, N.M., will provide project management support to the projects. The agency plans to award additional contracts in fiscal 2009 and beyond
 - Investments in solar have already reached about \$1.2 billion until Nov 2007 - a record amount for any greentech sector. \$400 million in VC investments for the whole of 2006 and less than \$200 million in 2005. Average deal sizes also have increased from \$11 million in 2005 to \$17 million so far in 2007 \$8 million in 2005 to \$9 million in 2006, then staying flat at \$9 million in the first three quarters of this year – Source: GreenTechMedia
 - Ausra aims to build biggest solar thermal plant, raises \$40M - Ausra, an ambitious Silicon Valley company wanting to build a solar thermal electric power plant double the largest ever built, has raised somewhere north of \$40 million in a first round of capital – Sep 2007
 - In the first three quarters of 2005, U.S. venture-capital firms funneled \$67.7 million into the solar-energy sector, up from \$31.4 million for all of 2004, according to the National Venture Capital Association, an Arlington, Va., trade group

Rest of the World

- Venture investors have made big bets on thin film in 2008, investing \$671 million in these technologies through July, according to Lux Research. During that time period, they invested \$2.09 billion in solar energy companies as a whole. Investors are keenly interested in thin film technology in part because, unlike crystalline silicon, thin film is so new that companies are still trying innovative new approaches
- Cyrium is on the threshold of developing solar cell technology that will enable CPV systems to achieve grid parity. For its new investment, the Quercus Trust led the round, and was joined by return backers BDC Venture Capital, Chrysalix Energy Venture Capital, and Pangaea Ventures. This investment is what Cyrium needs to commercialize its solar cells and enable CPV to be more competitive, thus promoting massive deployment of renewable solar energy. Funds from the

- Series B round will be used to further the development and testing of Cyrium's photovoltaic solar cell products and establish volume manufacturing (Aug 2008)
- Duke Energy plans \$100M investment in solar. That will include a \$100 million investment in rooftop solar energy, a program that will involve working with commercial and even residential customers – (May 2008)
 - Intel Capital is reported to be lining up a \$38 million investment in Berlin-based Sulfurcell, which produces modules for the photovoltaic generation of energy. It has a pilot production line for solar modules using Copper-Indium-Sulfide (CIS) as an absorber material. The German company is currently planning a new production facility with capacity of 75MW per year (Jul 2008)
 - According to The Cleantech Group in 2008 Q2 investments in North America, Europe, China and India, investments in solar technologies and second-generation biofuels, including concentrated solar thermal and algae companies, primarily drove the results. Solar thermal companies eSolar, BrightSource Energy, SkyFuel, Infinia and Sopogy raised a total of US \$278 million in venture capital. Combined with the US \$100 million acquisition of Stirling Energy Systems by NTR plc and the US \$165 million in venture capital raised by Solel, Infinia and eSolar in Q1 2008, solar thermal companies have raised, year-to-date, US \$543 million
 - Investment in solar power once again led the VC charge in Q1 2008 with more than \$280M invested in 15 VC financing rounds. Solar investment is still hot but thin film solar is not receiving the same magnitude of investment as it did in 2006 and 2007
 - Early-stage venture capital investment surged 112% to \$2 billion in 2007, boosted by interest in emerging renewable technologies, rather than just those on the brink of commercialisation, as competition for deals intensified.. Solar attracted by far the most VC/PE investment (\$3.7 billion), both for new technologies and for manufacturing capacity expansion
 - Clean energy companies more than doubled the amount of money they raised on the world's public markets in 2007, raising \$27 billion. Solar companies continued to raise significant amounts of capital (\$9.4 billion), particularly Chinese manufacturers tapping the US markets
 - Financing of sustainable energy assets grew by 61% in 2007 to \$108 billion, most of it for new generation projects. Solar was the fastest growing new capacity sector in 2007, increasing 250% to \$17.7 billion. Solar investment was subsidy-driven, with Germany remaining the dominant market for new capacity.
 - About \$1.7 billion was invested as private equity and venture capital in the solar industry in 2006 - mostly private equity for factories in China and investment in technology companies in the U.S. and Germany. In addition, \$4.5 billion was invested in publicly quoted solar companies in 2006 - BusinessWeek
 - Clean Edge said that in the overall market for fossil fuel alternatives, biofuels represent the largest portion, at \$20.5 billion in 2006 spending. Wind and solar power saw \$17.9 billion and \$15.6 billion in spending, respectively, while \$1.4 billion in funding went into fuel cell technology last year. Those four energy technologies grew in aggregate by 39 percent in 2006, year over year, to \$55.4 billion. Clean Edge forecasts that solar power will grow more rapidly than wind,

- as solar manufacturers scale up their operations. The solar market, representing both products and services, will expand to nearly \$70 billion, and wind will be a \$60 billion market in 2016, the research group forecast – March 2007, CNET
- With backing from Google’s founders and \$20 million from the U.S. Department of Energy, Nanosolar’s first commercial cells rolled off the presses this year - 2007 news

5.2 Venture Capital Companies / Entities that Have Recently Been Active in Solar Energy

- Advanced Equities Inc.
- Battery Ventures
- BDC Venture Capital
- Chrysalix Energy Venture Capital
- CMEA Ventures
- Convexa
- Draper Fisher Jurvetson
- EQUUS Total Return Inc.
- Evergreen Venture Partners
- GLG Partners
- Google
- HIG Ventures
- Idealab
- Intel Capital
- Israel Cleantech Ventures
- Khosla Ventures
- Kleiner Perkins Caufield & Byers
- Masdar Clean Tech Fund
- New Enterprise Associates
- Oceanshore Ventures
- Pangaea Ventures
- Pitango Venture Capital
- Power Play Energy LLC.
- Quercus Trust
- Redpoint Ventures
- RockPort Capital Partners
- Scatec Adventure AS
- Virgin Green Fund
- Vulcan Capital
- Wexford Capital LLC

5.3 Summary & Highlights

1. Solar energy has been one of the fastest growing renewable energy segments with regard to investments across all types of investors.

Solar Energy Report

2. 2008 saw some very large venture capital investments in solar energy – (SunEdison - \$131 million, eSolar - \$130 million and BrightSource - \$115 million)
3. All the top three VC investments (by amount invested) for Q2 2008 in the US were for solar energy companies.
4. Recent (2007 and 2008) VC trends indicate the following :
 - a. Solar thermal is hot – three large VC deals for solar thermal were done in 2007 and 2008, two very large ones in 2008 alone.
 - b. Investments in solar PV is picking up
 - c. Investments in solar thin film appear to be slowing down.

6. Solar Energy Apex Bodies

Apex bodies related to solar energy industry are provided for the following countries:

- **USA**
- **Canada**
- **Japan**
- **China**
- **Germany**
- **UK**
- **France**
- **India**

USA

Apex Bodies For Solar Energy in USA			
Name of the Apex Body	Address	Telephone Number	Website/ Email ID
California Solar Energy Industries Association CALSEIA	Po Box 782, Rio Vista, CA, USA - 94571	Tel:916-747-6987 707-374-4767	
Solar Living Institute (SLI)	13771 S. Hwy. 101 P. O. Box 836 Hopland, CA 95449	Tel:707.744.2017	www.solarliving.org/
American Solar Energy Society(ASES)			http://www.ases.org/ , bchowe@ases.org
Solar Alliance		Tel: (415) 385-240	http://www.solaralliance.org/ , info@solaralliance.org
Solar Electric Power Association	SEPA Headquarters: 1341 Connecticut Avenue, NW, Suite 3.2 Washington, DC 20036	Tel: 202-857-0898 Fax: 888-249-0525	http://www.solarelectricpower.org/ , info@solarelectricpower.org

Canada

Apex Bodies For Solar Energy in Canada			
Name of the Apex Body	Address	Telephone Number	Website/ Email ID
SESCI	Suite # 173 207 Bank Street Ottawa, ON K2P 2N2 Canada		http://www.solarenergysociety.ca/ bruce@techonfoot.com
Canadian Solar Industries Association(CANSIA)	2378 Holly Lane #208 Ottawa, Ontario Canada K1V 7P1	Tel 613-736-9077 (or) 866-522-6742 Fax: 613-736-8938	http://www.cansia.ca/info@cansia.ca
Solar Nova Scotia	83 Old Scotts Road McGraths Cove, N.S. B3Z 3V2	Tel: (902) 852-758 Fax: (902) 852-789	http://solarns.ca/info@solarns.ca

Japan

Apex Bodies For Solar Energy in Japan			
Name of the Apex Body	Address	Telephone Number	Email ID, Website
Japan Photovoltaic Energy Association (JPEA)	Terada Bldg., 4-29-6, Shinbashi, Minato-ku, Tokyo 105-0004, Japan	Tel.+81-3-3459-6351 Fax.+81-3-3459-6595	URL : http://www.jpea.gr.jp/ E-mail : jpea@jpea.gr.jp
The Photovoltaic Power Generation Technology Research Association (PVTEC)	Nissay Takanawa Bldg. No.2, 16-37 Takanawa 2-chome, Minato-ku, Tokyo 108-0074, Japan	Tel 81-3-5447-0460 Fax 81-3-5447-0464	
OM Solar Association	435-0031 Shizuoka prefecture Hamamatsu mayor crane town 158-1, Japan	Tel: 81 053-460-5111 Fax: 81 053-460-5102	http://www.omsolar.co.jp/
New Energy Foundation (NEF)	Shuwa Kioi-cho Park Building 6F, 3-6 Kioi-cho, Chiyoda-ku, Tokyo, 102-8555, Japan	Tel: 81 (03) 5275-9822 Fax: 81 (03) 5275-9831	http://www.nef.or.jp/research@nef.or.jp
Japan Solar Energy Society	2-44-14 Yoyogi, Shibuya-ku, Tokyo 151-0053, Japan	TEL: 81 3 3376 6015 FAX: 81 3 3376 6720	http://wwwsoc.nii.ac.jp/jses/ , jses@tky.3web.ne.jp

China

Apex Bodies For Solar Energy in China			
Name of the Apex Body	Address	Telephone Number	Email ID, Website
Solar Photovoltaic Power System of Standardization Administration of China	Zhushan Industrial Dalang Town Dongguan City Guangdong Province P.R.China	Tel:+86-769-86261866-610 Fax:+86-769-83189158	http://www.cnsolar.net.cn solar@cnsolar.cc sue@quoncion.com
Chinese Renewable Energy Industries Association(CREIA)	No.A2106 Wuhua Plaza, CheGongZhuang Street A4, XiCheng District, Beijing, 100044 China	Tel: +86 10 68002617-18 Fax: +86 10 68002674	creia@creia.net

Germany

Apex Bodies For Solar Energy in Germany			
Name of the Apex Body	Address	Telephone Number	Email ID, Website
The Fraunhofer Institute for Solar Energy Systems ISE	Freiburg Heidenhofstraße 2 79110 Freiburg imBreisgau	Phone +49 (0) 761 / 45 88-0	http://www.ise.fhg.de/
International Solar Energy Society (ISES)	Villa Tannheim Wiesentalstr. 5079115 Freiburg Germany	Tel.: +49 - 761 - 45906-0 Fax: +49 - 761 - 45906-99	http://www.ises.org/hq@ises.org

UK

Apex Bodies For Solar Energy in UK			
Name of the Apex Body	Address	Telephone Number	Email ID, Website
Solar Trade Association The National Energy Centre	Davy Avenue, Knowlhill Milton Keynes MK5 8NG	Tel.: 01908 442290 Fax: 01908 665577	enquiries@solar-trade.org.uk
Solar for London	SEA/RENUE 84 Long Lane, London SE1 4AU	Tel:020 7089 6989	info@solarforlondon.org

France

Apex Bodies For Solar Energy in France			
Name of the Apex Body	Address	Telephone Number	Email ID, Website
E.A.F. – Electricité Autonome Française	Bernard Weber Anne-Marie Roussel La Boursidière BP 48 92357 Le Plesis Robinson FRANCE	Tel: +33.146.30.28.28 Fax: +33.146.30.52.63	www.federation-af.org eaf@tiscali.fr
HESPUL	Maguite Chichereau Marc Jedliczka 114, Bld du 11 novembre 69100 Villeurbanne FRANCE	Tel: +33.437.47.80.90 Fax: +33.437.47.80.99	www.hespul.org infos@hespul.org

India

Apex Bodies For Solar Energy in India			
Name of the Apex Body	Address	Telephone Number	Email ID, Website
Solar Energy Society of India	Director General A-14, Mohan Cooperative Industrial Estate Mathura Road New Delhi – 110044	Tel: +91.11.65649864, 26959759 Fax: +91.11.26959759	http://sesi.in info@sesi.in
Malaviya Energy Consultancy	Address: B24, Ujwal Park, NIBM Road, Kondhwa, Pune - 411048, Maharashtra India 411013	Telephone: +91-20- 26833399, +91-9890033399	