

Concentrated Solar Power

THEME

In a cost race with PV

Research Analysts

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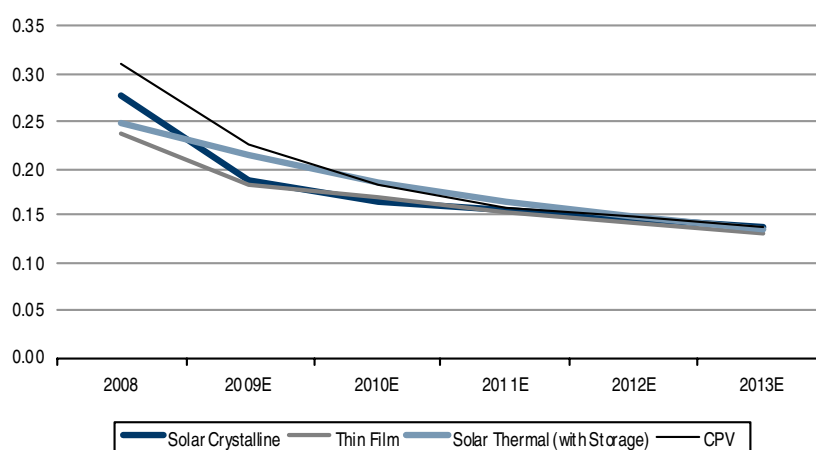
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- **Implications for European PV companies of ongoing pricing pressure:** Falling poly prices are likely to have a negative impact on Wacker (Underperform, TP €80) where consensus is still forecasting stable profit margins in solar. The need for higher efficiencies should benefit equipment suppliers (CTN, Outperform, TP €37 and R&R, Outperform, TP €26) that are providing the necessary technology.
- **A tight race:** Based on our analysis of the cost-reduction potential of the different solar technologies competing in the market for ground-mounted solar power, we expect a tight cost race between conventional PV (c-Si and thin film) and Concentrated Solar Power (solar thermal and CPV). Despite some delays caused by the financial crisis, we expect Concentrated Solar Power to mature further and eventually take a significant share of the solar power market. We conclude that c-Si prices are likely to continue their fall—not only due to the current oversupply but also to keep up with competing solar technologies.
- **Margin pressure in the PV sector to move upstream:** We think poly prices in particular have to come down to ensure the long-term competitiveness of c-Si. We also expect increased efforts to improve cell efficiency—the ‘easiest’ way to reduce PV costs.
- *Credit Suisse will be hosting a Solar Technology Day in Frankfurt on 7 October that will focus on the competitiveness of conventional PV vs CSP.*

Figure 1: LCOE of different solar technologies in Arizona: A tight cost race
\$/kWh



Source: Credit Suisse research and estimates

Concentrated Solar Power is real

In the past, PV did not compete against Concentrated Solar Power (CSP) due to CSP's large utility-like scale and centralised power production. Following the capacity build-out and falling prices in the PV industry, however, the technologies are increasingly in direct competition for large scale solar power plants.

We have conducted a detailed analysis of the cost reduction potential of the different solar technologies, including conventional photovoltaic (c-Si and thin film), concentrated solar thermal (CST) and concentrated photovoltaic (CPV). While we have written often about conventional PV, we also include some background on the CSP sector in this report.

- **CSP is too big to be ignored:** From an impressive list of announced CSP projects (see later in the report) some may never be realised due to financing issues. However, we see a 'serious' list of >100 projects with a total size of >20 GW to be realised over the coming years. The CSP pipeline is just too big to be ignored by PV companies. Despite the differing nature of the technologies we expect competition between conventional PV and CSP in the market for ground-mounted solar power. Although the choice of technology will also depend on many 'soft' factors such as security of supply and some political factors, *cost* will in the end be a decisive factor.
- **Cost race:** Different regions will favour different solar technologies. Following the recent panel price declines, c-Si and thin film offer the lowest 'levelized cost of electricity' (LCOE) even in sunny regions. Yet, CSP technologies are not standing still. While c-Si and thin film are likely to keep their cost advantage in less sunny regions (annual insolation below 2000 kWh/m²), CSP will likely regain its cost advantage in very sunny regions (annual insolation well above 2000 kWh/m²).

Implications for European solar companies

- **c-Si:** Falling profit margins are driving LCOE reductions in 2009/10. While margin pressure started downstream, we expect it to move further upstream, thereby affecting poly suppliers such as Wacker. Beyond 2010E we expect improved conversion efficiency to be the main driver for cost reductions. In Europe, key enablers of high-efficiency cells are solar equipment companies such as Centrotherm, Roth & Rau and Manz.
- **Thin film:** European thin film companies are still in a start-up phase. Progress was delayed by the credit crisis but in many cases not cancelled. We still expect a significant capacity ramp-up of European thin film companies that are aiming for sufficient scale to reduce costs. Interestingly, among the public companies Q-Cells now has the highest exposure to thin film. Following its c-Si restructuring, >35% of its capacity is related to different thin film technologies.
- **Solar Thermal (CST):** Due to its long lead-times and focus on large-scale installations, CST project developments suffer most from ongoing financing constraints, although we do expect renewed momentum with the increased availability of credit. Learning curve and scale will be important factors in reducing the costs of CST. We think the storage and hybrid option remains a key advantage. European stocks with meaningful exposure to CSP include Abengoa and Acciona (only 2% of installed capacity but growing). Solar Millennium is so far the only pure CSP play. Derivatives plays include Pfeiffer Vacuum (although the CSP exposure is still below 10%).
- **Concentrated PV (CPV):** The market was moving from proof of concept to volume production just when the credit crisis started. The technology promises a very competitive cost position, however, and could still find its place in mid-sized installations in very sunny regions. Most European CPV companies are still private. Among public companies Aixtron has a small exposure to the sector.

Figure 2: Credit Suisse solar coverage

	P/E 09	P/E 10	EV/EBITDA 09	EV/EBITDA 10	EV/Sales 09	EV/Sales 10	Currency	Closing Price	Rating	Target Price
Equipment:										
centrotherm photovoltaics AG	14.2	11.8	5.4	4.9	0.8	0.7	EUR	30.1	OUTPERFORM	37
Manz Automation AG	151.4	21.7	19.6	8.4	1.5	1.2	EUR	46.3	NEUTRAL	50
Roth & Rau AG	19.7	13.2	7.2	5.2	0.9	0.8	EUR	23.7	OUTPERFORM	26
Pfeiffer Vacuum AG	15.1	13.3	8.8	7.8	2.1	2.0	EUR	52.9	OUTPERFORM	53
GT Solar	6.5	8.3	5.1	5.8	1.4	1.5	USD	4.0	NEUTRAL	4
Poly/Wafer:										
Renewable Energy Corporation ASA	37.6	18.1	11.7	5.7	2.9	1.9	NOK	42.1	NEUTRAL	40
Wacker Chemie AG	15.7	10.8	6.1	4.6	1.2	1.1	EUR	86.6	UNDERPERFORM	80
MEMC Electronic Materials Inc	67.0	21.9	16.0	7.2	1.2	1.1	EUR	16.6	NEUTRAL	17
OCI (DC Chemical	14.7	11.6	8.9	6.7	3.1	2.8	KRW	244000	OUTPERFORM	300000
Tokuyama Corp	-37.9	19.3	5.2	3.9	1.1	7.7	JPY	705	NEUTRAL	630
ReneSola Ltd	1427.7	137.8	7.9	3.6	1.2	0.8	USD	5.6	OUTPERFORM	8
Sino-American Silicon Products Inc	14.4	11.8	12.2	9.0	2.3	1.7	TWD	72.5	UNDERPERFORM	44
Wafer Works Corp	15.0	12.5	19.4	15.0	2.6	2.1	TWD	47.1	UNDERPERFORM	29
Cell/Module:										
Suntech Power Holdings Co Ltd	-165.8	22.8	17.1	9.6	1.9	1.5	USD	14.9	NEUTRAL	13
JA Solar Holdings Co Ltd	-44.7	75.7	9.7	5.3	1.0	0.8	USD	3.5	NEUTRAL	4
Q-Cells SE	-2.8	58.1	-75.5	7.0	1.1	0.9	EUR	11.0	NEUTRAL	9
Solarworld AG	16.8	16.9	7.0	6.5	1.6	1.2	EUR	14.7	UNDERPERFORM	14
Sunpower	28.2	19.8	3.0	2.6	0.5	0.4	USD	26.1	NEUTRAL	32
Trina Solar	22.6	14.6	7.2	4.8	1.1	0.9	USD	26.4	OUTPERFORM	40
Motech Industries Inc	112.4	25.7	18.0	12.6	1.5	1.1	TWD	90.7	NEUTRAL	75
Gintech Energy Corp	-12.1	83.7	-23.1	13.9	1.1	1.0	TWD	43.2	UNDERPERFORM	36
Thin film:										
First Solar Inc	15.4	17.7	11.1	10.9	4.9	4.2	USD	121.5	NEUTRAL	135
Energy Conversion Devices	44.9	-22.2	6.2	12.9	1.2	1.2	USD	10.4	NEUTRAL	10

Source: *Closing price as of 07/09/2009, Credit Suisse estimates

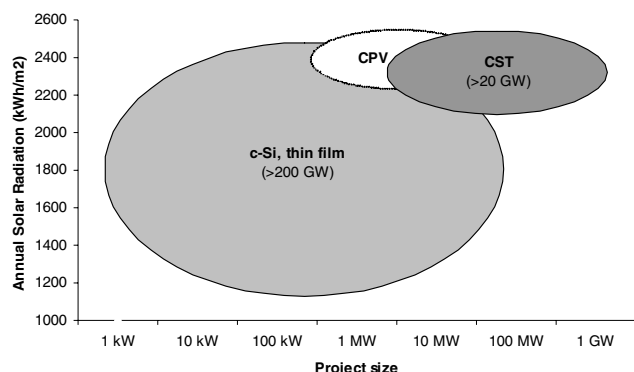
Where to use solar power

Figure 3: Comparing different solar power technologies

	Conventional PV		Concentrated Solar Power	
	c-Si	Thin Film	Concentrated PV	Solar Thermal
Pros	Lowest distribution costs Scalability (small systems possible) Short lead time			Hybrid (with gas) possible Storage option
Cons		Best diffuse light performance	Direct irradiation required (direct sunlight and tracking)	Levelled area required Water supply
Efficiency				
Cell efficiency	typically 15-16%		36-38%	
Module efficiency	c. 14%		c. 27%	
System efficiency (AC)	11-12%		c. 23%	c. 16% average efficiency c. 25% peak efficiency

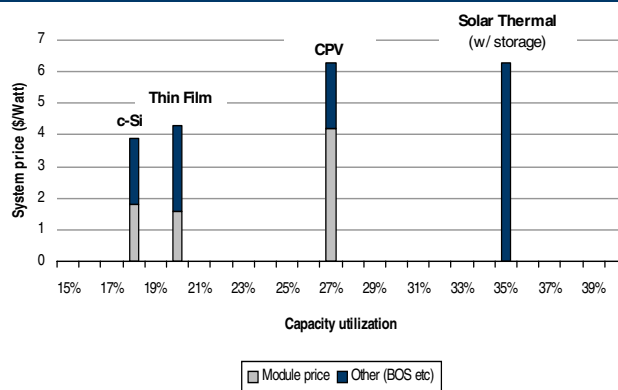
Source: Credit Suisse research

Figure 4: Addressable market



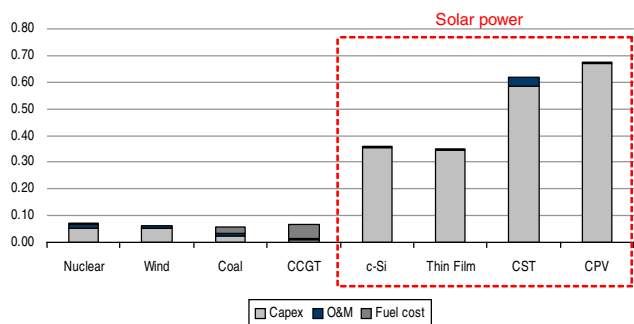
Source: Credit Suisse research and estimates

Figure 5: System prices over utilisation factor (in Arizona)



Source: Company research and estimates

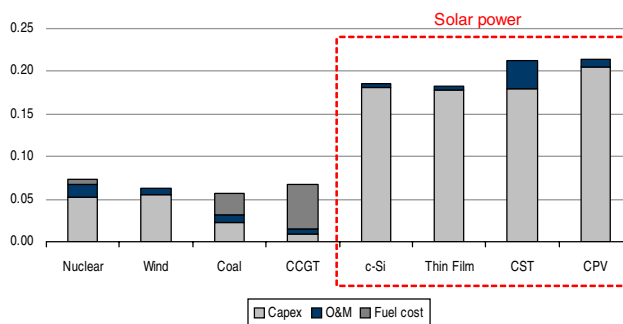
Figure 6: Levelized cost of electricity (LCOE) in Germany \$/kWh



* as of end of 09, w/o subsidies and carbon costs

Source: Credit Suisse research

Figure 7: LCOE in Arizona \$/kWh



* as of end of 09, w/o subsidies and carbon costs

Source: Credit Suisse research

LCOE model

Very often solar companies quote LCOE figures (levelized cost of electricity) that are based on very different input variables. For instance, the underlying cost of capital is an important parameter that can result in very different cost numbers. The aim of our model is to provide for a 'fair' *relative* comparison of electricity generation costs for different technologies. We are not aiming for an ultimate *absolute* cost figure. The model considers total cost per kWh of electricity produced, including capital cost and O&M (operation and maintenance). The present value of these costs is compared against the present value of total electricity produced over the life time of the system. Our model calculates the LCOE of different technologies installed in different years and regions.

Cost parameters

- For CAPEX costs (panel costs etc) we have started with current market prices and assumed a digression as described in the chapter Cost roadmap.
- We took O&M costs for the different technologies as reported by leading operators.
- In our base case scenario, we assumed a cost of capital of 7% for all technologies.

Electricity production parameters

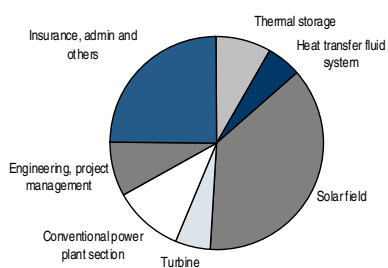
Electricity produced is a function of the utilisation factor (sunshine, conversion efficiency) the system efficiency (incl. inverter etc) and the life of the assets:

- We took the insolation data for different regions from data published by NASA and split it between direct (used by CSP) and diffuse insolation.
- In our base case scenario, we assume an asset life of 25 years.
- For c-Si we have assumed no tracking. For CSP we have considered both systems with and without storage.

Exclusion of subsidies

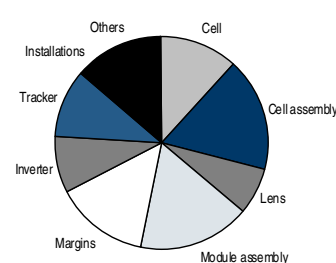
In our calculations we have excluded subsidies (FIT, ITC etc) in order to derive a fair comparison of the cost potential of different technologies.

Figure 8: CAPEX split for CST



Source: Credit Suisse research

Figure 9: CAPEX split for CPV



Source: Credit Suisse research

Cost roadmap

c-Si costs mainly driven by cell efficiency

We expect c-Si costs to be driven by a combination of increased cell efficiency, reduced wafer thickness, larger factories and increased factory yield. We have not modelled any increase in wafer size yet. Among these factors, improved cell efficiency is the most important driver, as it not only reduces cell cost itself but also the whole systems cost including BOS costs. Specifically we assume:

- Cell efficiency to increase from 15.5-16.0% currently to >20% over the next 10 years
- Wafer thickness to fall from 180/200µm currently to 120µm over the next 5 years
- Processing equipment throughput to increase from typically 2400 wph (wafer per hour) currently to 3600 wph in 5 years; combined with larger factories and overhead savings this will drive CAPEX/watt savings of >10% p.a.
- Factory yield to increase from c80% currently to >90% in 5 years, driven by reduced breakage and improved equipment uptime
- Stable wafer sizes of 156x156mm²

Thin film

For most thin film start-ups with proven technology, scale is the most important driver to reduce costs. Improvement in conversion efficiency is the second most important factor. For the next 2-3 years at least, we expect First Solar to remain the cost benchmark for the thin film sector and we have taken its cost roadmap as a guide to our modelling.

CST

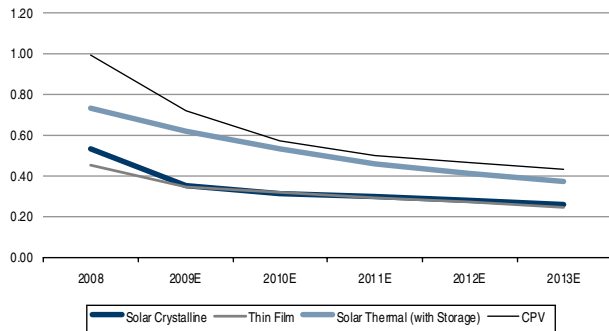
Scale will be the main cost driver for CST plants. As a rule of thumb CAPEX costs per Watt fall by about 15% when doubling the size of the power plant. Therefore, costs will fall considerably when moving from the typical <50MW project size in Spain to >200MW projects in the US. This applies particularly for the conventional power plant section including the turbine. For example we assume costs for the turbine fall from c. \$0.4/Watt for 50MW plants to \$0.15/Watt for 200MW plants. In addition there is scope to improve efficiency by *evolutionary* improvements in equipment. We have not factored in any disruptive *revolutionary* change in system design that some companies are working on (such as direct steam generation, 'magic fluid' allowing for substantially higher temperatures, and many others).

CPV

The CPV industry is still at a very early stage. Significant cost reductions from scale could be expected provided this industry gets the opportunity to ramp up into real volume production. Cell cost can be reduced by moving production from 100mm to 150mm wafers and increasing the production yield. Assembly costs (cell and module) should come down significantly when introducing high-scale fully automated volume production. Finally, module efficiency can be improved from typically 23-25% currently to >30% by optimising the optics and increasing the underlying cell efficiency from 36-38% to >40%, in line with the compound semiconductor technology roadmap also used for LED and space solar cell production.

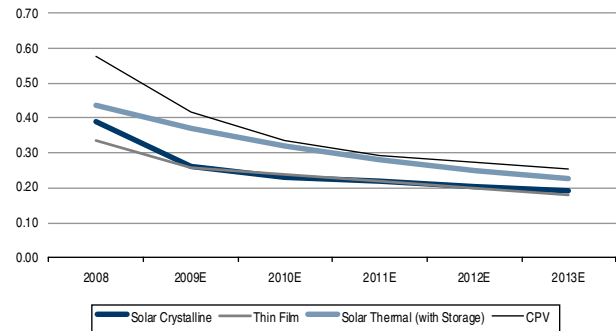
LCOE in different regions

Figure 10: LCOE in Frankfurt, Germany
\$/kWh



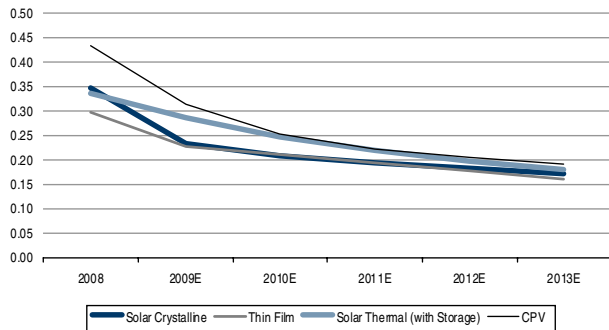
Source: Credit Suisse research and estimates

Figure 11: LCOE in Osaka, Japan
\$/kWh



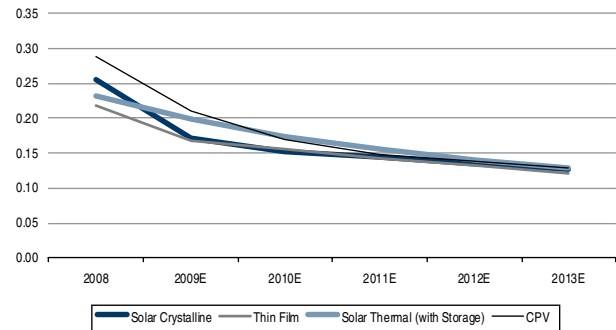
Source: Credit Suisse research and estimates

Figure 12: LCOE in Beijing, China
\$/kWh



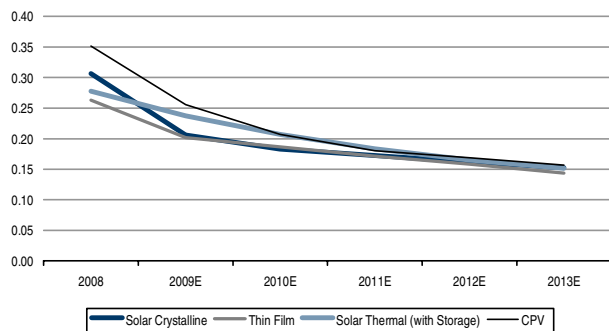
Source: Credit Suisse research and estimates

Figure 13: LCOE in Bombay, India
\$/kWh



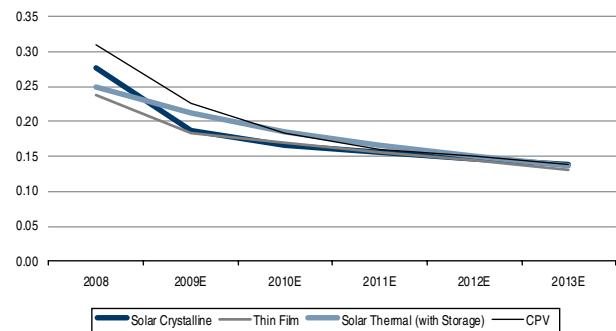
Source: Credit Suisse research and estimates

Figure 14: LCOE in Sevilla, Spain
\$/kWh



Source: Credit Suisse research and estimates

Figure 15: LCOE in Phoenix, Arizona
\$/kWh



Source: Credit Suisse research and estimates

Subsidy schemes

Spain was the first country to introduce feed-in-tariffs for solar thermal power plants in 2002. Since then many countries have followed. By now the list of countries subsidising CST plants is almost as long as the list of countries supporting PV. Many countries, especially in the south of Europe, have prepared the ground for CST deployment, although to date only for small scale systems. Most European projects are located in Spain where a revision of the existing legislation is due to begin in the short term. This will be an important event for the industry. We describe the different feed-in schemes below. Other forms of subsidies include the 30% investment tax credit that is provided in the US.

Feed-in-tariff

Feed-in-tariff is a scheme to encourage the production of electricity using renewable sources, by guaranteeing the purchase of electricity by the established utilities companies at a guaranteed rate (higher than market) for a fixed period of time. These utilities companies are permitted to pass on the extra costs of purchasing renewable power to its customers by spreading such extra costs across the price of all (renewable and non-renewable) electricity generated.

Germany

Germany has Europe's highest feed-in-tariffs for solar power but is not an attractive location for CSP due to its low level of direct sunshine.

Spain

Spain introduced feed-in-tariffs for solar thermal power in 2002. This was revised in 2004 with Royal Decree 436. The decree guaranteed a tariff rate of €0.18 per kWh for a period of 25 years. In 2007 the amount was revised to €0.269 per kWh for 25 years for installations up to 50MW by Royal Decree 661. This rate will increase yearly, at the rate of inflation minus one percentage point. The power plant operator has a choice between two feed-in arrangements. It can opt for a fixed tariff or sell the electricity at the market price. If it chooses the second option, the operator receives an additional premium of €0.25/kWh on top of the market price. In May 2009 Spanish legislators changed the conditions for guaranteed feed-in-tariffs. Project developers must provide key permissions and the procurement of key components. Projects of more than 4GW have been registered with Spanish authorities and a decision about the approval of these projects is due by the end of September 2009.

Italy

In 2008 Italy published a feed-in tariff scheme for CSP plants, providing between €0.22/kWh and €0.28/kWh. The FIT is for the solar proportion of a plant's output and is related to the percentage share of solar operation of the plant (the highest tariff is for over 85% solar operation). The tariff applies to plants the operation of which is due to start before 31 December 2012 and is provided for a period of 25 years.

Portugal

The feed-in tariff for solar electricity published in 2007 granted 0.27 €/kWh for CSP plants up to 10MW and 0.16-0.20 €/kWh for CSP plants beyond 10MW for a period of 15 years.

Greece

The "Gazette A' 129", published in 2006, grants solar energy employing a technology other than that of photovoltaic with an installed capacity up to 5MW a FIT of 0.25 €/kWh on the main land and 0.27 €/kWh on non-interconnected islands for a period of 20 years. For projects with capacity above 5 MW the feed-in tariff is reduced by two cents for both mainland and island.

France

A new feed-in tariff for solar electricity was published in France on July 26, 2006, granting 0.31 €/kWh (0.41 €/kWh in overseas) plus extra 0.26 €/kWh if integrated into buildings (+0.16 €/kWh in overseas). This tariff is limited to solar only installations with less than 12MW capacity and less than 1500hours/year operation. For production over this the tariff is 0.05 €/kWh.

Israel

In 2006, Israel's Public Utilities Authority (PUA) New Feed-in Incentives For Solar-Driven IPPs were published, valid from 3 September 2006 for a 20-year period. For plants with installed capacity larger than 20 MW, the tariff for the solar part only is approximately 0.163 \$/kWh for a period of 30 years. Maximum allowed fossil back-up is 30% of the energy produced in the plant. For smaller plants, in the range of 100 kW to 20 MW, the tariff is approximately 0.204 US \$/kWh for a period of 15 years.

Algeria

Algeria has implemented a feed-in tariff that provides a premium of 100% over the market price for a plant with a solar share of 5-10%. The premium increases to 200% for a plant with a solar share beyond 20%. For example, if the solar share is 25%, the price that would be received for all electricity generated by the plant would be three times the market price.

South Africa:

In March 2009, the National Energy Regulator of South Africa (NERSA) approved feed-in tariffs for renewable energies called REFIT. The feed-in tariffs based on the LCOE are 2.10 R/kWh. The period of FIT is 20 years. The REFIT will be reviewed every year for the first 5-year period of implementation and every three years thereafter, and the resulting tariffs will apply only to new projects.

India:

India provides for a feed-in tariff of up to 10 rupees per kWh (0.19 \$/kWh), for 10 years of operations, with a limit of 10 MW for each state.

Turkey:

Turkey introduced a feed-in-tariff for renewable energy generation facilities at 9.13 YKr per kWh in 2007, (approximately 0.052 €/kWh) for the first 10 years of operation. The amendment to the RES law includes a feed-in tariff for CSP of 0.24 €/kWh for 20 years for the first 10-year period, dropping to 0.20 €/kWh for the second 10-year period.

Figure 16: Existing feed-in-tariffs for CST (Concentrated Solar Technology) and PV (Photovoltaic, including Concentrated PV)

	CST-FIT				PV/CPV-FIT				
	Capacity	Tariff rate	Duration	Restriction	Capacity	Roof top	Ground Mounted	Duration	Restriction
Europe									
Germany		0.3194€/kWh	20 years		Up to 30 KWp 30 KWp - 100 KWp 100 KWp - 1000 KWp Over 1000 KWp	€0.4301/kWh €0.4091/kWh €0.3958/kWh €0.3300/kWh	€0.3194/kWh	20 years	Yearly reduction (between 8 - 10%) for both rooftop and ground mounted until 2011
Spain	Up to 50 MW	0.269€/kWh	25 Years	Up to 50 MW	Up to 2 MW for roof top and 10 Mw for GM	€0.33/kWh	€0.32/kWh	25 years	200MW for rooftop and 100 MW for ground mounted in 2009
Italy		0.22 - 0.28€/kWh	25 Years	SOP before 31 Dec 2012	Upto 3 KWp 3 to 20 KWp over 20 KWp	€0.4312/kWh €0.4116/kWh €0.392/kWh	€0.392/kWh €0.3724/kWh €0.3528/kWh	20 years	1200 MW till 2012; 3000 MW for 2016; 2% digression in 2009
France	Up to 12 MW 1500 hours/year	0.31 €/kWh 0.41 €/kWh	20 years		Continental Overseas BIPV	€0.32823/kWh €0.43764/kWh €0.60176/kWh for contine	€0.32823/kWh €0.43764/kWh €0.60176/kWh for oversea	20 years	
Greece	Upto 5 MW Over 5 MW	0.25 €/kWh 0.27 €/kWh 0.23 €/kWh 0.25 €/kWh	20 years 20 years	Mainland Islands Mainland Islands	Up to 100 KWp Over 100 KWp	€0.45/kWh for mainland €0.40/kWh for mainland	€0.50/kWh for island €0.45/kWh for island	10 years	for 2009
Portugal	Up to 10 MW Over 10 MW	0.27€/kWh 0.16-0.20 €/kWh	15 years		Up to 5 KWp Over 5 KWp	€0.55/kWh; upto 5 year €0.40/kWh; upto 5 year	€0.52/kWh €0.35/kWh	15 years or first 21 GWh/MWp	50MW for rooftop and 150 MW for ground mounted in 2009
Austria europe					Upto 5 KWp 5 to 10 KWp Over 10 KWp	€0.4599/kWh €0.3999/kWh €0.2999/kWh		10 years	Cap of 3.3 MWp
Belgium- Brusells					Upto 20 sqm 20 - 60 sqm Over 40 sqm	€0.15 - €0.65/kWh €0.15 - €0.50/kWh €0.15 - €0.32/kWh		10 years	Complex green certificate process
Belgium- Wallonia					Upto 5 KWp 5 to 10 KWp 10 - 250 KWp	€0.45 - €0.63/kWh €0.32 - €0.45/kWh €0.15 - €0.36/kWh		15 years	Complex green certificate process
Belgium- Flanders					No Size limitation	€0.45/kWh		20 years	will decrease to 0.35 €/kWh starting in 2010
Bulgeria					Upto 5 KWp over 5 KWp	€0.42/kWh €0.38/kWh		25 years	
Czech Republic					Upto 30 KWp over 30 KWp	€0.4867/kWh €0.4830/kWh		20 years	
Luxembourg					Up to 30 KWp 31 KWp to 1 MWp	€0.39/kWh €0.36/kWh		15 years	
Netherlands					0.6 - 15 KWp 15 KWp to 100 KWp	€0.29/kWh > €0.29/kWh		15 years	Cap of 25 MWp in 2011
Slovenia						€0.399/kWh		10 years	
Switzerland					Up to 10 KWp 10 KWp - 30 KWp 30 KWp - 100 KWp Over 100 KWp	€0.464/kWh €0.402/kWh €0.384/kWh €0.371/kWh	€0.402/kWh €0.334/kWh €0.316/kWh €0.303/kWh	25 years	Cap of 16 mn CHF
Romania					Over 1 MWp	€0.108 - €0.22/kWh		10 years	

Source: Credit Suisse research

Figure 17: Existing feed-in-tariffs for CST (Concentrated Solar Technology) and PV (Photovoltaic, including Concentrated PV)

CST-FIT					PV/CPV-FIT				
	Capacity	Tariff rate	Duration	Restriction	Capacity	Roof top	Ground Mounted	Duration	Restriction
North America									
Canada - Ontario					Up to 50 KWp	CDN\$0.42/kWh		20 years	
USA									
USA - California					Over 30 KWp	\$0.39/kWh		5 years	Needs approval from utilities
USA - Florida					< 25 KW > 25 KW	\$0.32/kWh \$0.26/kWh	\$0.32/kWh \$0.26/kWh	20 years	decrease by 5% beginning 2010; program cap of 4 MW per annum
USA - Washington		\$0.12 - \$0.54/kWh	2014	\$2000/project/annum		\$0.12 - \$0.54/kWh	\$0.12 - \$0.54/kWh	2014	\$2000/project/annum
Middle East									
Israel	Up to 20 MW Over 20 MW	0.204 \$/kWh 0.163 \$/ kWh	30 years 20 years		Up to 50 KWp		€0.40/kWh	20 years	Cap at 50 MWp
Turkey		€0.24 c/Kwh	10 years	drops to 20 cents for next 10 years					
Asia									
India		\$0.19 c/Kwh	10 years	10 MW for each state		€0.21/kWh			This is in addition to FIT paid at state level which ranges from €0.15/kWh to €0.27/kWh subject to a maximum of €0.27/kWh in total / 50MWp cap
South Korea					Up to 30 KWp over 30 KWp	€0.48/kWh €0.46/kWh		15 years	Previous 100 MW cap abolished; after 100 MW a new fixed price will be determined
China					10 MW		yuan 1.09/kwh		
Oceania									
Australia - Queensland & SA					Upto 10 KW upto 30 KW	AUD\$0.44/kWh AUD\$0.44/kWh		20 years	Single phase power Three phase power
Australia - Victoria					upto 2 KW Upto 100 KW	AUD\$0.60/kWh AUD\$0.15/kWh			Premium FIT - 2009 Standard FIT
Australia- ACT					Upto 10kWh 10kWh - 30kWh > 30 kWh	100% of premium rate 80% of premium rate 75% of premium rate			Premium rate is 3.88x Transitional Franchise Tariff
Africa									
South Africa		2.1 R/Kwh	20 years						
Algeria	ISCCS	100% price premium 200% price premium	lifetime	Solar share 5-10% Solar share >20%					

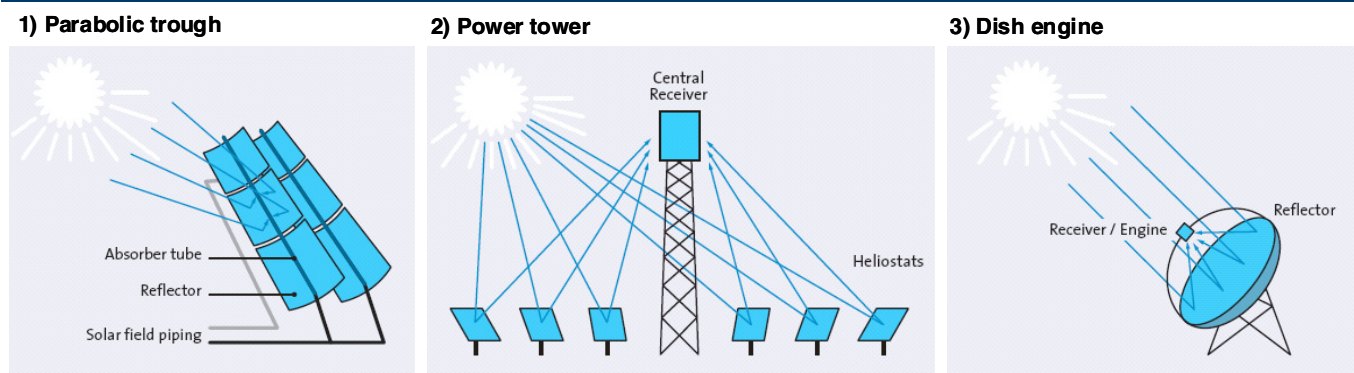
Source: Credit Suisse research

Solar Thermal (CST)

A solar thermal system is a type of CSP that captures solar energy from the sun by absorbing light as heat. Solar thermal power systems focus sunlight, usually with mirrors, to heat a fluid to high temperatures and drive a turbine. There are three different technologies—namely Parabolic Trough, Power Tower and Dish Stirling:

- **Parabolic Trough:** The parabolic trough is the most mature CSP technology available in the market with 688 MW of capacity already under operation and construction. The typical size for a trough plant is 50–200 MW but a few hybrid plants with capacity of less than 50 MW have also been developed. These plants have very specific land requirements in terms of flatness. The Fresnel technology is a derivative of the parabolic trough technology, sharing receivers between several mirrors while still using simple line-focus geometry with one axis for tracking. This simplifies the system and may potentially help to reduce costs. The receiver is stationary and so fluid couplings are not required (as in troughs and dishes). The mirrors also do not need to support the receiver, so they are structurally more simple.
- **Power tower:** The tower technology is suitable for capacity up to 50 MW. Although only 48 MW of capacity is under construction/operation, the planned capacity using tower technology is well above 500 MW. The advantage of this design above the parabolic trough is that it can achieve higher temperatures, converting electricity more efficiently and enabling it to be stored at a cheaper rate. The land requirements are also less stringent than trough technology as there is less need to flatten the ground area. However it has the disadvantage that each mirror must have its own dual-axis control, while in the parabolic trough design, one axis can be shared for a large array of mirrors.
- **Dish Stirling:** Currently only pilot Dish Stirling plants are in operation. There is no typical size for a plant as it can meet any individual demand. The dish system has the advantage of achieving high temperatures and promises the highest efficiency of all Solar Thermal technologies. This technology is suitable for stand-alone installations, off-grid and small grids, and can play its role in inland isolated areas and islands. The disadvantage is that in Dish System, heat-to-electricity conversion requires moving parts, which in turn require regular maintenance. Besides, the heavy engine is part of the moving structure, which requires a rigid frame and strong tracking system. Furthermore, parabolic mirrors are used instead of flat mirrors and dual-axis tracking is required.

Figure 18: Different CST technologies



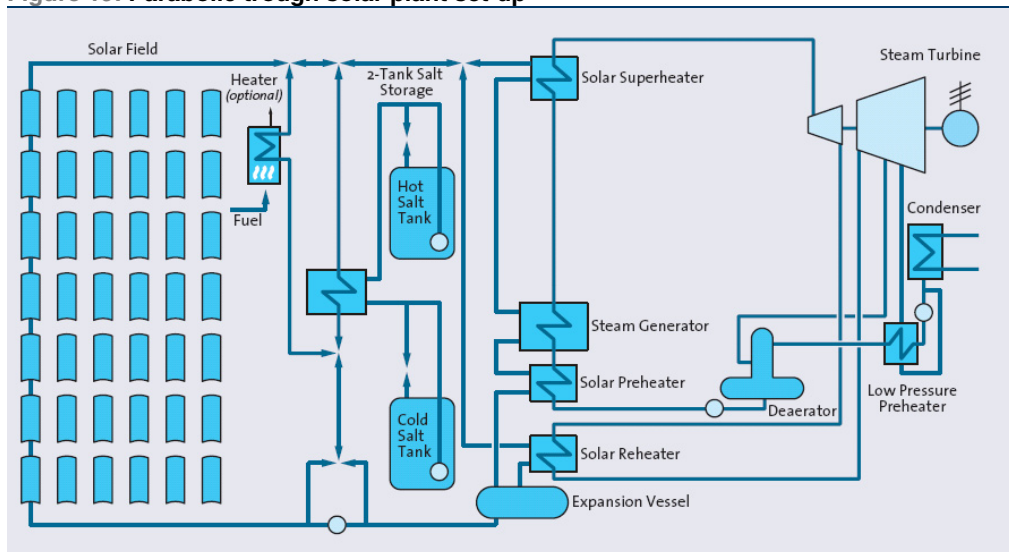
Source: SolarPACES, Credit Suisse research

Storage option a key advantage

A parabolic trough power plant with thermal energy storage consists mainly of three parts: the solar field with the heat transfer circuit, the storage system and the power plant block with turbine, generator and cooling circuit. The storability of thermal energy is a key advantage of these plants over other types of solar power plants. A typical storage system consists of an oil/salt heat exchanger, a hot salt tank and a cold salt tank. As the storage system is being filled up, cold salt is pumped into the hot tank through the oil/salt heat exchanger. During evening or cloudy days, the hot salt is pumped into the cold container, thus giving back the thermal energy to the oil circuit.

- **Operation in the mornings:** After sunrise, the collectors begin to follow the sun. Parabolic mirrors concentrate the solar radiation to absorber tubes, in which heat-resistant, synthetic oil circulates as heat transfer fluid. This fluid then transmits its thermal energy to heat exchangers. The steam that is generated there drives a turbine and electricity is generated by the connected generator.
- **Operation during the day:** If sun radiation is strong enough, the solar field supplies sufficient energy to generate electricity and fill up the storage system simultaneously. The storage system is filled with liquid salt. It consists of a 'hot' tank (approximately 380 °C) and a 'cold' one (appr. 280 °C). When the storage system is being filled up, cold salt is pumped into the hot tank through oil to salt heat exchanger.
- **Operation in the evening:** In the evenings or when the sky is cloudy, the solar field can supply the energy that is required to drive the turbine together with the storage system. For this purpose, the hot salt is pumped into the cold container, thus giving back the thermal energy to the oil circuit.
- **Operation at night:** After sunset thermal energy is exclusively supplied by the storage system. If the storage system and the solar field have been dimensioned accordingly, the power plant can be operated up to 24 hours with solar energy. Hybrid operation is also possible by the combustion of e.g., gas or biomass.

Figure 19: Parabolic trough solar plant set-up



Source: Solar Millennium, Credit Suisse research

CST landscape

The nucleus

Between 1984 and 1991 the American/Israeli company Luz International built parabolic trough power plants in California's Mojave Desert (SEGS I-IX) that are still in operation today. The company had to file for bankruptcy in 1991 due to falling gas prices and the removal of incentives. Technology and employees have spread across the industry and been the direct nucleus for some companies such as Bethel Energy (California), Brightsource (California), Ener-T (Israel) and Solel (Israel).

Project development/ engineering

Due to the existing subsidies in Spain the largest project developers for CST are currently located there. Solar Millennium (Germany) is the largest European engineering company outside of Spain. In the US there are a variety of companies with very differentiated but commercially unproven technologies.

- **Abengoa Solar** (Spain) has probably the most diversified CSP technology portfolio in the industry. It entered the field of solar technologies in 1984 with the construction of the Solar Almeria Platform in Spain. In 2007, Abengoa inaugurated the first commercial solar tower plant (PS10, 11 MW) and the world's largest low-concentration PV plant (Sevilla PV, 1.2 MW).
- **ACCIONA Energía** (Spain) is one of the largest developers and constructors of wind parks in the world. In 2006 Acciona purchased Nevada Solar One (the largest plant built in the US since SEGS) and took a 55% stake in Solargenix that was following a similar parabolic trough design as the SEGS plants.
- **ACS Cobra** (Spain) started out as a pure EPC provider partnering with Solar Millennium on the Andasol plants. In the meantime, ACS is also developing own projects.
- **Iberdrola Renovables** (Spain) is one of the world's largest operators of renewable energy plants, focusing on wind but also including solar energy.
- **Solar Millennium** (Germany) leads the wave of new parabolic trough plants through its Andasol I-III plants in Spain. The company is active in all parts of the value chain and places its regional focus on Spain, US, China and MENA (Middle East and North Africa).

Component suppliers

The receiver

The receiver is among the most critical components of a CST plant. It consists of a specially coated steel tube, surrounded by an evacuated glass tube. Absorptivity and breakage rates of the tubes are critical for overall efficiency and operating costs of the CST plant. The leading suppliers of receivers are Schott Solar and Solel. Emerging suppliers include Siemens' subsidiary Archimede Solar Energy (Italy) which is using molten salt instead of oil.

- **SCHOTT Solar** (Germany) is one of very few component suppliers that are active in both the CST and PV sector. It started production of CST components in 1983 and provided glass tubing as envelopes for the receivers at the SEGS power plants. In 2004, SCHOTT launched a self-developed new receiver which was supplied to Nevada Solar One and to the first parabolic trough power plants in Europe. The company has gained c50% market share since then.

- **Solel** (Israel) bought the manufacturing facility and technology rights from Luz in 1992. Its receiver technology has proven itself over the last 20 years with the continuous production of utility scale power in the SEGS solar fields. The company has not only been supplying receivers but is also involved in project planning.

Parabolic Mirrors

Low iron *glass* mirrors are expensive but have proved very reliable. The mirrors in the SEGS projects were supplied by Flabeg (Germany), which was spun out of the Pilkington Group in 2000. The group began activities in solar mirrors as early as the 1970s, as mirror suppliers to the very first CSP plants, which were built in California in the 1980s. Most commercially operating CSP plants are equipped with Flabeg mirrors. Emerging suppliers include Rioglass, Saint Gobain, Guardian and Solel (Finland).

Steam turbine

Steam turbines are supplied by well-known turbine suppliers such as Alstom, GE, MAN Turbo and Siemens (which supplies many of the Spanish projects).

New technologies

Whereas parabolic trough technology is relatively mature, there are a number of companies that are in the early stages of developing new technologies. Some of these companies have struggled during the credit crisis but have generally been able to raise further capital and continue their developments:

- **Ausra** (US) was trying to reduce CAPEX costs by employing a direct stream generation technology using compact linear Fresnel reflectors. It entered into a 177 megawatt solar thermal power agreement with PG&E. During the financial crisis Ausra has had to lay off about 10% of its staff and has refocused its business model towards the supply of critical equipment.
- **Brightsource** (Israel) and its Israel-based subsidiary Luz II (whose founder also started the original Luz) have experience with parabolic trough technology through the SEGS plants but are now focusing on Brightsource's proprietary central receiver design. Among other characteristics, Brightsource claims significantly reduced water consumption.
- **Skyfuel** (US) aims to reduce costs by using parabolic trough technology with a high-reflectance material called ReflecTech, which eliminates the need for heavy and expensive glass in the mirrors.
- **Stirling Energy Systems**, SES (US) combined mirrored concentrator dish with a high-efficiency Stirling engine specially designed to convert sunlight to electricity. SES is currently developing two solar sites in California.

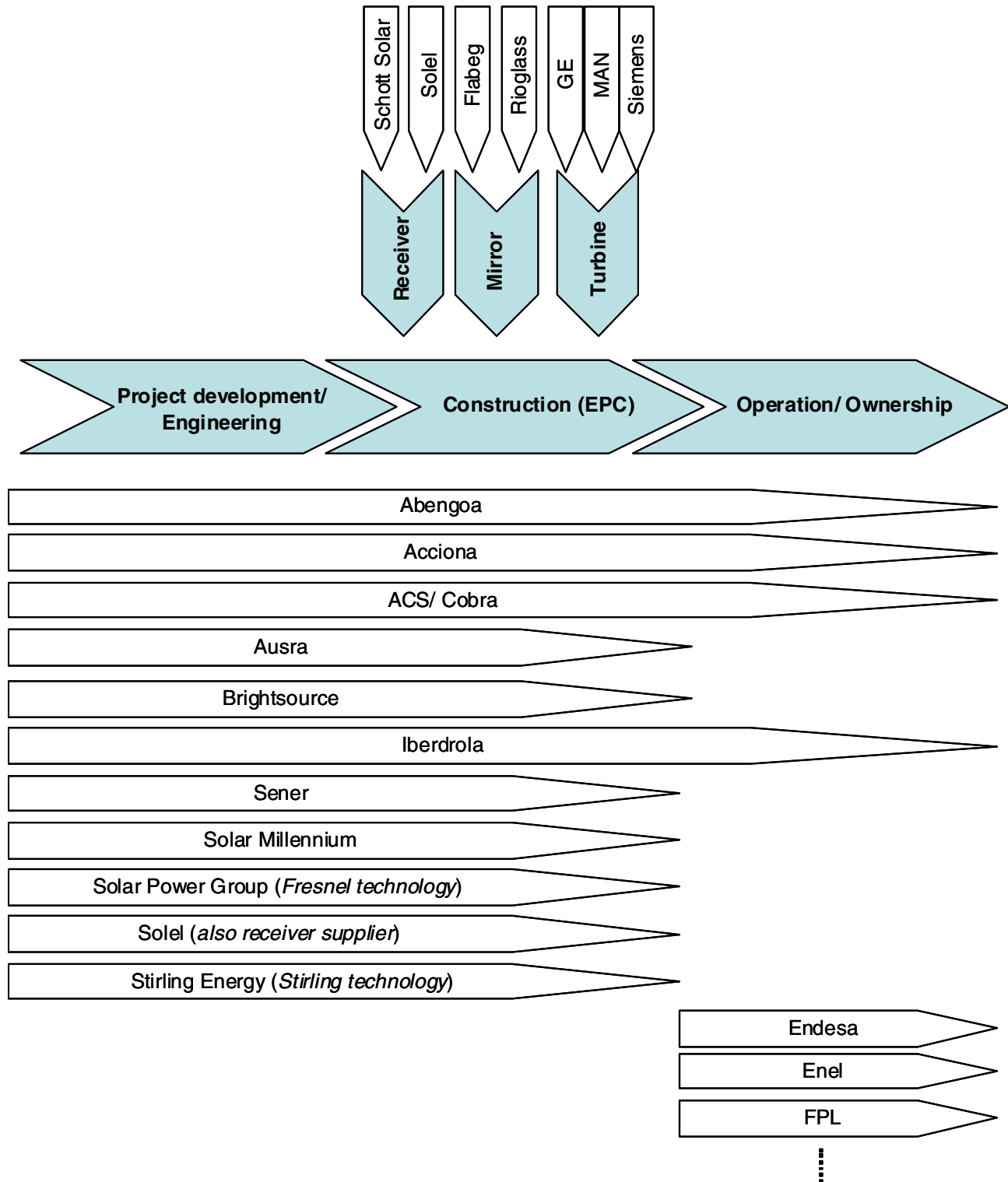
Other technology developers include Ener-T (Israel), ESOLAR (US), Novatec Bisol (Germany), Sener and Solar Power Group (Germany).

Figure 20: Technology developers

Fresnel	Central Receiver	Dish Engine
(Ausra)	Abengoa	SES
Solar Power Group	SENER	
Novatec Biosol	Brightsource	
	ESOLAR	

Source: Credit Suisse research

Figure 21: CST value chain



Source: Credit Suisse research

CST project overview

Figure 22: CST projects under operation and under construction

Plant	Location	Capacity	Technology	Company	Start of Operation
1) Under Operation					
SEGS I	Daggett, CA	13.8 MW	Parabolic trough design	Florida Power and Light(FPL)	1985
SEGS II	Daggett, CA	30 MW	Parabolic trough design	Florida Power and Light(FPL)	1986
SEGS III	Kramer Junction, CA	30 MW	Parabolic trough design	Florida Power and Light(FPL)	1987
SEGS IV	Kramer Junction, CA	30 MW	Parabolic trough design	Florida Power and Light(FPL)	1987
SEGS V	Kramer Junction, CA	30 MW	Parabolic trough design	Florida Power and Light(FPL)	1988
SEGS VI	Kramer Junction, CA	30 MW	Parabolic trough design	Florida Power and Light(FPL)	1989
SEGS VII	Kramer Junction, CA	30 MW	Parabolic trough design	Florida Power and Light(FPL)	1989
SEGS VIII	Harper Lake, CA	80 MW	Parabolic trough design	Florida Power and Light(FPL)	1990
SEGS IX	Harper Lake, CA	80 MW	Parabolic trough design	Florida Power and Light(FPL)	1991
Solar Energy Generating Systems (SEGS 1-IX)	USA Mojave desert California	354 MW total (from 14 to 80 MW each)	Parabolic trough design	Florida Power and Light(FPL)	1991
PS10 solar power tower	Spain Seville	11 MW	Power tower design	Abengoa Solar	Dec-05
Saguaro Station power plant	USA Arizona	1 MW	Parabolic trough design	ACCIONA Energia	Jan-06
Nevada Solar One	USA Nevada	64 MW	Parabolic trough design	ACCIONA Energia	Jun-07
Kimberlina solar thermal power plant	Bakersfield, California	5 MW	Fresnel reflector design	Ausra	Oct-08
Andasol 1 solar power station	Spain	50 MW with heat storage	Parabolic trough design	Solar Millennium	Nov-08
Liddell Power Station	Australia	35 MW	Fresnel reflector design	Macquarie Generation	May-09
PS20 solar power tower	Spain Seville	20 MW	Power tower design	Abengoa Solar	Apr-09
Julich Solar Tower	Julich, Germany	1.5 MW	Power tower design	Stadtwerke-julich	Dec-08
Keahole Solar power	Hawaii	1 MW	MicroCSP design	Sopogy Inc.	2009
Puertollano SA Solar Plant	Spain	50 MW	Parabolic trough	Iberdrola	May-09
Puerto Errado 1	Murcia Spain	1.4 MW	Linear Fresnel Reflector	Novatec BioSol AG	Apr-09
THEMIS solar power tower	Pyrenées-Orientales, France	1.4 MW	Power tower design	Pegase	2009
Total		595			
2) Under Construction					
Gema Solar: (Solar Tres Power Tower)	Spain	17 MW with heat storage	Power tower design	Torresol Energy	2011
Abantia power plant	Spain	25 MW	Parabolic trough design	Abantia	2011
Hassi Rmel	Algeria	25 MW steam input for gas powered plant	Parabolic trough design	Abengoa Solar	2009
Andasol 2 solar power station	Spain	50 MW with heat storage	Parabolic trough design	Solar Millennium	Jun-09
Alvarado 1/LA Risca 1	Spain	50 MW	Parabolic trough design	ACCIONA Energia	Jul-09
Palma Del Rio II	Spain	50 MW	Parabolic trough design	ACCIONA Energia	Apr-10
Majadas de Tiétar	Spain	50 MW	Parabolic trough design	ACCIONA Energia	Dec-10
Palma Del Rio I	Spain	50 MW	Parabolic trough design	ACCIONA Energia	Dec-10
Solnova 1 solar power station,	Spain	50 MW	Parabolic trough design	Abengoa Solar	Sep-09
Solnova 3 solar power station,	Spain	50 MW	Parabolic trough design	Abengoa Solar	Sep-09
Solnova 4 solar power station,	Spain	50 MW	Parabolic trough design	Abengoa Solar	Sep-10
Extresol 1	Spain	50 MW	Parabolic trough design	ACS/Cobra	Mar-10
Extresol 2	Badajoz, Spain	50 MW	Parabolic trough design	ACS/Cobra	Nov-10
Extresol 3	Badajoz, Spain	50 MW	Parabolic trough design	ACS/Cobra	Jul-11
Ecija 1	Ecija, Spain	50 MW	Parabolic trough design	Abengoa Solar	2011
Ecija 2	Ecija, Spain	50 MW	Parabolic trough design	Abengoa Solar	2011
Solaben 1	Logrosan Spain	50 MW	Parabolic trough design	Abengoa Solar	mid 2011
Solaben 2	Logrosan Spain	50 MW	Parabolic trough design	Abengoa Solar	mid 2011
Valle 1	Cadiz Spain	50 MW	Parabolic trough design	Torresol Energy	2010
Valle 2	Cadiz Spain	50 MW	Parabolic trough design	Torresol Energy	2010
Manchasol 1	Ciudad Real, Spain	50 MW	Parabolic trough design	ACS/Cobra	Mar-11
Lebrija plant	Lebrija, Spain	50 MW	Parabolic trough design	Solel	2010
La Florida	Alvarado Spain	50 MW	Parabolic trough design		
La Dehesa	LA Garovilla Spain	50 MW	Parabolic trough design		
Aste 1 A	Ciudad Real, Spain	50 MW	Parabolic trough design	Aries	
Aste 1 B	Ciudad Real, Spain	50 MW	Parabolic trough design	Aries	
Astexol 2	Extremadura, Spain	50 MW	Parabolic trough design	Aries	
El Rebozo 2	El Puebla del Rio (Seville)	50 MW	Parabolic trough design		
Serrezuela Solar 2	Talarubias (Badajoz)	50 MW	Parabolic trough design		
Arenales PS	Moron de la Frontera (Seville)	50 MW	Parabolic trough design		
Beni Mathar Plant	Morocco	20 MW	Parabolic trough design	King Mohamed VI	Jun-10
Martin Solar energy centre	USA florida	75 MW	ISCC; Fresnel reflector	FPL	Jun-10
Puerto Errado	Murcia Spain	30 MW	Linear Fresnel Reflector	Novatec BioSol AG	2009
Sierra Plant	Lancaster California	5 MW	Power tower design	Esolar	2009
Kuraymat Plant	Egypt	20 MW steam input for a gas powered plant	Parabolic trough design	Solar Millennium	Jun-10
Andasol 3 solar power station	Spain	50 MW with heat storage	Parabolic trough design	Solar Millennium	Feb-11

Source: Credit Suisse research

Figure 23: Planned CST projects

Plant	Location	Capacity	Technology	Company	Start of Operation
3) Planned					
Sonora	Mexico	30MW	Parabolic trough		2009
Essar plant	Rajasthan India	10 MW		ESAR power	
Acme plant	Rajasthan India	10 MW		Acme	
Entegra plant	Rajasthan India	10 MW		Entegra	
Nagpur plant	Nagpur India	10 MW			
Cloncurry solar power station	Australia	10 MW with heat storage,	Power tower design	Ergon Energy	early 2010
Victorville 2 Hybrid Power Project	Victorville, California	50 MW steam input for hybrid gas plant	Parabolic trough design	Inland Energy	Jun-10
Carrizo Solar Farm	USA California near San Luis	177 MW	Fresnel reflector design	Ausra	Aug-10
Barstow	USA California	59 MW with heat storage and back-up	Parabolic trough design		Oct-10
Solar two, Imperial valley	USA California	750 MW	Dish design	Stirling Energy Systems	Dec-10
Solar one, Pispah	USA California near Pispah north	850 MW	Dish design	Stirling Energy Systems	2010
Yazd Plant,	Iran	67 MW steam input for hybrid gas plant	Parabolic trough design	YSTPP	2010
Bethel 1	USA California	50 MW	Parabolic trough design	Bethel Energy LLC	2010
Bethel 2	USA California	50 MW	Parabolic trough design	Bethel Energy LLC	2010
Shams	Abu Dhabi Madinat Zayad	100 MW	Parabolic trough design		end 2010
Solenha	Aspres sur Buëch, France	12 MW	Parabolic trough design	Solar Euromed	end 2010
Marchasol 2	Ciudad Real, Spain	50 MW	Parabolic trough design	ACS/Cobra	Mar-11
San Joaquin Solar 1 & 2	USA California	107 MW	Parabolic trough design	Martifer Renewables	Jun-11
Beacon Solar Energy Project	USA California	250 MW	Parabolic trough design	FPL	Sep-11
Andasol 4	Granada Spain	50 MW	Parabolic trough design	ACS/Cobra	Nov-11
Mojave Solar Park	USA California	553 MW	Parabolic trough design	Solel	2011
Florida Solar thermal plant	USA Florida	300 MW	Fresnel reflector design	FPL	2011
Antelope Valley	USA California	240 MW	Power tower design	eSolar	2011
Alpine sun tower	USA California	92 MW	Power tower design	eSolar+NRG	2012
El Paso	Mexico USA	92 MW	Power tower design	eSolar+NRG	2011
Murciasol 1	Spain	50 MW	Parabolic trough design	Solar Millennium AG	2011
Andalucia power plants	Spain	200 MW	Parabolic trough	Endesa	2011
Upington	South Africa	100 MW	Power tower design	ESKOM	Mar-12
Palmdale hybrid gas solar	Palmdale, California	62 MW	Parabolic trough design		Jun-12
Negev Desert	Israel	250 MW			mid 2012
Ivanpah Solar	USA California	110 MW	Power tower design	Bright Source Energy	Oct-12
Solana solar power plant	USA Arizona southwest of Phoenix	280 MW	Parabolic trough design with	Abengoa Solar	2012
Gotasol power plant	Spain	10 MW	Fresnel reflector design	Solar Power Group	2012
Solnova 2 solar power station,	Spain	50 MW	Parabolic trough design	Abengoa Solar	2013
Solnova 5 solar power station,	Spain	50 MW	Parabolic trough design	Abengoa Solar	2013
Harper Lake Solar	Mojave USA	250 MW	Parabolic trough design	Abengoa Solar	
Alvarado II	Spain	50 MW	Parabolic trough design	ACCIONA Energia	2011
Jordan	Jordan	130MW	Parabolic trough design	Solar Millennium AG	2015
China Solar plant	China	1000MW	Parabolic trough design	Solar Millennium AG	2020
Thesus	Greece	50MW	Parabolic trough design	Solar Millennium AG	
Murciasol 2	Spain	50 MW	Parabolic trough design	Solar Millennium AG	
Andasol 5	Granada Spain	50 MW	Parabolic trough design	ACS/Cobra	
Andasol 6	Granada Spain	50 MW	Parabolic trough design	ACS/Cobra	
Andasol 7	Granada Spain	50 MW	Parabolic trough design	ACS/Cobra	
Helios 1	Ciudad Real, Spain	50 MW	Parabolic trough design	Abengoa Solar	
Helios 2	Ciudad Real, Spain	50 MW	Parabolic trough design	Abengoa Solar	
AZ 20	Sevilla Spain	20 MW	Power tower design	Abengoa Solar	
Aznalcollar TH	Sevilla Spain	80 KW	Dish design	Abengoa Solar	
Almaden Plant	Albacete, Spain	20 MW	Power tower design	Abengoa Solar	
Termesol 50	Seville Spain	50 MW with heat storage	Parabolic SENERtrough™	SENER Grupo de Ingeniería	
Arcosol 50	Cadiz Spain	50 MW with heat storage	Parabolic SENERtrough™	SENER Grupo de Ingeniería	
Enerstar Villena Power Plant	villena, Spain	50 MW	Parabolic trough design	EnerStar	
Aste 3	Ciudad Real, Spain	50 MW	Parabolic trough design	Aries	
Aste 4	Ciudad Real, Spain	50 MW	Parabolic trough design	Aries	
Astexol 1	Extremadura, Spain	50 MW	Parabolic trough design	Aries	
Solar Mission project	Australia	200 MW	Solar Chimney Technology	Enviromission	
Archimede	Siracusa, Sicily, Italy	28.1 MW	Parabolic trough design		
Ciudad Real Torre Solar	Spain	40 MW	Solar Chimney Technology		
Amargosa Solar Power Project	Nevada	250 MW	Parabolic trough		
Kingsman solar project	Mohave Arizona	200 MW	Parabolic trough	Albisa Corp.	2013

Source: Credit Suisse research

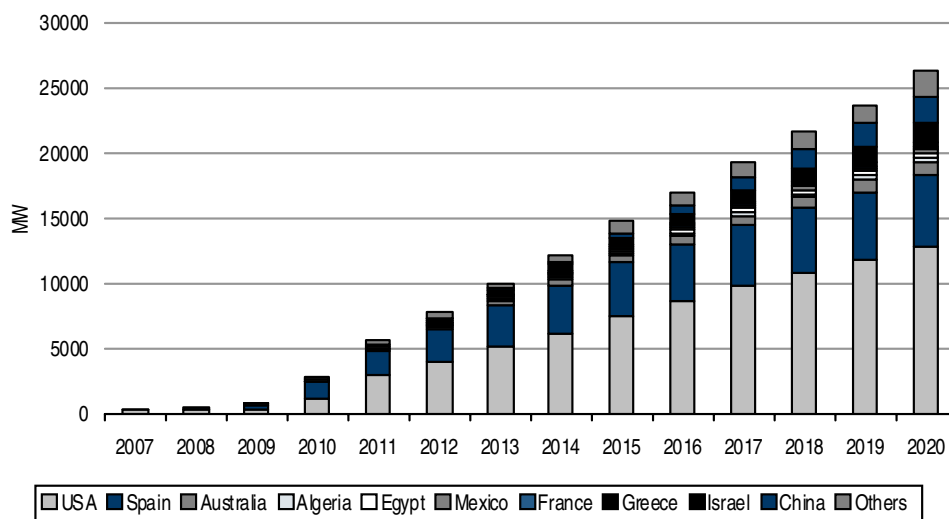
CST demand model by country

Figure 24: CST installed base by country

	2007	2008	2009E	2010E	2011E	2012E	2013E	2014E	2015E	2016E	2017E	2018E	2019E	2020E
USA	419	424	430	1211	2981	4065	5215	6285	7485	8685	9885	10885	11885	12885
% growth	0.0%	1.2%	1.4%	181.6%	146.2%	36.4%	28.3%	20.5%	19.1%	16.0%	13.8%	10.1%	9.2%	8.4%
Penetration	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.02%	0.02%	0.03%	0.03%	0.03%	0.04%	0.04%
Spain	11	61	362	1262	1954	2504	3144	3644	4144	4394	4644	4894	5144	5394
% growth	0.0%	0.0%	494.1%	248.3%	54.8%	28.1%	25.6%	15.9%	13.7%	6.0%	5.7%	5.4%	5.1%	4.9%
Penetration	0.00%	0.00%	0.00%	0.02%	0.06%	0.09%	0.11%	0.14%	0.15%	0.17%	0.17%	0.18%	0.18%	0.18%
Australia			35	45	75	105	305	405	505	605	705	805	905	1005
% growth			0.0%	28.6%	66.7%	40.0%	190.5%	32.8%	24.7%	19.8%	16.5%	14.2%	12.4%	11.0%
Penetration			0.00%	0.00%	0.00%	0.01%	0.01%	0.02%	0.02%	0.03%	0.04%	0.04%	0.04%	0.05%
Algeria			25	55	85	115	145	175	205	235	265	295	325	355
% growth			0.0%	120.0%	54.5%	35.3%	26.1%	20.7%	17.1%	14.6%	12.8%	11.3%	10.2%	9.2%
Penetration			0.00%	0.01%	0.03%	0.04%	0.05%	0.06%	0.07%	0.08%	0.09%	0.09%	0.10%	0.10%
Egypt			30	50	80	110	140	170	200	230	260	290	320	350
% growth			0.0%	66.7%	60.0%	37.5%	27.3%	21.4%	17.6%	15.0%	13.0%	11.5%	10.3%	9.4%
Penetration			0.00%	0.00%	0.01%	0.01%	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.03%	0.04%
Mexico			30	30	142	162	182	202	222	242	262	282	302	322
% growth			0.0%	0.0%	373.3%	14.1%	12.3%	11.0%	9.9%	9.0%	8.3%	7.6%	7.1%	6.6%
Penetration			0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%	0.02%
France			1	13	13	25	37	49	61	73	85	97	109	121
% growth			0.0%	857.1%	0.0%	89.6%	47.2%	32.1%	24.3%	19.5%	16.3%	14.1%	12.3%	11.0%
Penetration			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Greece						50	50	100	150	180	210	240	270	300
% growth						0.0%	0.0%	100.0%	50.0%	20.0%	16.7%	14.3%	12.5%	11.1%
Penetration						0.00%	0.01%	0.01%	0.02%	0.02%	0.03%	0.03%	0.03%	0.04%
Israel						250	300	400	500	700	900	1100	1300	1500
% growth						0.0%	20.0%	33.3%	25.0%	40.0%	28.6%	22.2%	18.2%	15.4%
Penetration						0.00%	0.07%	0.09%	0.11%	0.13%	0.18%	0.22%	0.26%	0.29%
China						50	100	200	400	600	1000	1500	1750	2000
% growth						0.0%	100.0%	100.0%	100.0%	50.0%	66.7%	50.0%	16.7%	14.3%
Penetration						0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Others		2	2	229	329	429	457	485	1055	1105	1155	1205	1255	2075
% growth		0.0%	0.0%	0.0%	43.8%	30.4%	6.6%	6.1%	117.6%	4.7%	4.5%	4.3%	4.2%	65.4%
Total	430	487	915	2895	5659	7865	10075	12115	14927	17049	19371	21593	23565	26307

Source: Credit Suisse research and estimates

Figure 25: CST installed base by country



Source: Credit Suisse research and estimates

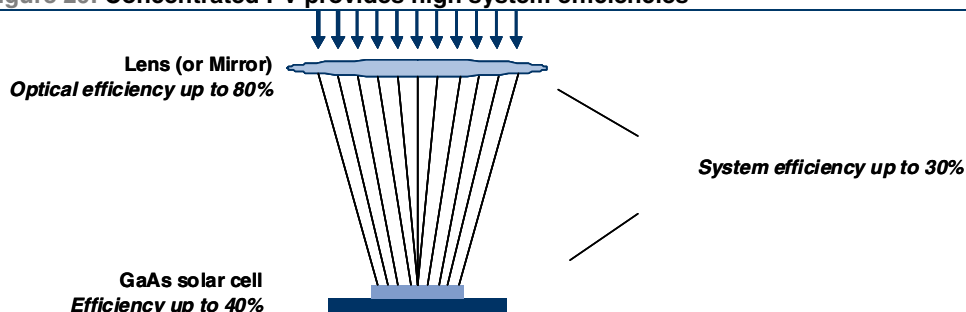
Concentrated PV

Concentrated Photovoltaic (CPV) produces power by concentrating sunlight onto a high-efficiency PV cell. Different concentrators such as lenses, mirrors, parabolic dishes or other optics, usually mounted on a solar tracking system, are used to keep the focal point upon the cell as the sun moves over the course of the day.

AC system efficiencies of above 25% have been shown to date. Efficiency up to 30% and more should be possible short- to mid-term, about twice as high as efficiencies in conventional PV. BOS costs in CPV are similar to conventional PV with the exception of the tracking system, which is more expensive. As BOS costs fall with high system efficiency, CPV modules can have a significant premium over PV modules and still offer lower total system costs.

Last year only about 10MW of CPV were installed worldwide. Most installations were done in Spain and some in the US and Australia. Despite the financial crisis many CPV companies are still able to raise money for further expansions. In our view, the technology could find its market place for mid-sized installations in very sunny regions.

Figure 26: Concentrated PV provides high system efficiencies



Source: Credit Suisse research

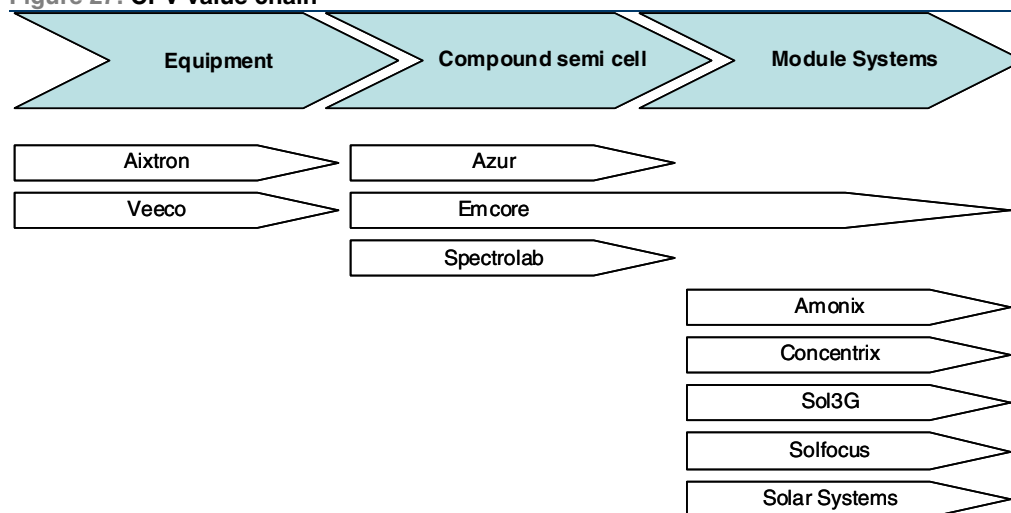
The idea of CPV has been around for many decades. The main hurdles so far were the availability of cost-efficient trackers (note that CPV requires higher precision tracking than conventional PV) and high-efficiency cells. In the past few years cost of trackers also fell thanks to developments in conventional PV. High-efficiency cells have become available with general improvements in compound semiconductor production technology, which is also driven by the LED industry. Here, we expect further improvement in the coming years.

The CPV industry can be segmented into three categories:

- **Low concentrated CPV** concentrates sunlight to intensities of 2-10 suns. Conventional silicon semiconductors are often used because of their affordability. The system does not require a cooling system as the heat flux is low, neither is tracking required as the acceptance angle of the optic is usually high.
- **Medium concentrated PV** concentrates sunlight to intensities of 10-100 suns. These systems often use Fresnel line lenses as concentrating optics. High-efficiency silicon cells are used instead of expensive GaAs semiconductors. The system requires tracking and cooling, which makes it more complex than low concentrated PV system.
- **High concentrated PV** concentrates sunlight to intensities of 200 suns and more. These systems often use Fresnel point lenses or dish reflectors as concentrating optics and multi-junction solar cells such as GaAs semiconductors. Cooling is important as the cell efficiency drops with increasing temperatures.

CPV landscape

Figure 27: CPV value chain



Source: Credit Suisse research

Module/system suppliers

- **Amonix** (US), founded in 1989, was a pioneer in using high-efficiency silicon solar cells and later turned to compound semiconductor cells. It has installed over 570 kW of its fifth-generation Amonix system over the last six years. The first three 20 kW units started operation during 2000. In contrast to many other CPV companies Amonix uses plastic lenses, which are cheaper than glass lenses but still have to prove that their long-term stability is sufficient.
- **Concentrix Solar** (Germany) was founded in 2005 as a spin-off company of the Fraunhofer Institute for Solar Energy Systems. Shareholders include Good Energies and Abengoa Solar. For addressing the Spanish and Portuguese markets, the joint venture Concentrix Iberia was founded with Abengoa in February 2008. The company's technology uses glass Fresnel lenses that are fabricated into a silicone film on the inside of the module top glass plate. From September 2006 until August 2008, Concentrix operated a pilot production line for manufacturing its concentrator modules. In September 2008, Concentrix was one of the first module manufacturers to start a fully automated production line with a production capacity of 25 MW.
- **Solar Systems** (Australia), founded in 1991, uses a dish-based system with reflective optics. Each dish has >100 mirrors. To date the company has installed >1MW in Australia.
- **SolFocus** (US) has installations in Arizona, California, Hawaii, India and is currently finishing a large installation in Greece. In July 2009 the company managed to raise US\$77m of new capital to increase capacity at its manufacturing site in Arizona and start production in China. SolFocus's technology uses a mini-dish design with a primary mirror to collect and focus the light onto a secondary mirror, which reflects the light back onto the cell.

Figure 28: Technology landscape

	Reflective optics	Refractive optics
Low concentrated	Abengoa Solar (Spain) JX Crystals (US) Solaria/Q-Cells (US) WS Energia (Portugal)	Archimedes (Germany)
Medium concentrated	CPower (Italy)	Entech (US)
High concentrated	GreenVolts (US) Isofoton (Spain) Solar Systems (Australia) SolFocus (US)	Amonix (US) Arima (Taiwan) Concentrix (Germany) Daido Steel (Japan) Delta Electronics (Taiwan) Emcore (US) Energy Innovations (US) ENEA (Italy) Guascor Foton (Spain) INER (Taiwan) Opel International (US) Pyron Solar (US) Sol3G (Spain)

Source: Credit Suisse research

Cell suppliers

The availability of high-efficiency cells has been a key concern for the industry in the past. To date, cell production has been being dominated by three companies—Azur, Emcore and Spectrolab—which also ship solar cells for space applications. Several emerging suppliers have plans to ramp up production but their technology and efficiency levels are still to be proven.

- **Azur Space** (Germany) began developing and producing solar cells for space applications as early as 1964, at that time as part of Telefunken GmbH. Space applications is still the main business area for the company today. In 1983 the company produced first terrestrial cells for concentrator applications. During the 1990s Azur started production of compound semiconductor cells. Current CPV customers include Concentrix, Daido Steel, Sol3G, Isofoton and Solar Systems.
- **Emcore** (US) is active in both cell and module manufacturing. The solar business was established in 1998 for space power, as one of the first suppliers to offer compound semiconductor cells (mostly replacing silicon cells).
- **Spectrolab** (US) is a subsidiary of Boeing. Spectrolab has been supplying solar array panels to the space industry for 50 years. In December 2006 it achieved 40.7% champion cell conversion efficiency.

Other cell suppliers include Arima (Taiwan) and Sharp (Japan).

CPV project overview

Figure 29: Planned CPV projects

Company	Location	Manufacturing capacity (MW/year)	Projects	Capacity	Operation date
Abengoa Solar	Spain, USA		Sevilla PV	1.2MW	May-06
			Casaquemada	1.9MW	Sep-08
Amonix	Torrance, CA, USA		APS Star Centre (west field)	170kW	2000-2003
			Glendale Arizona APS Site	100kW	Jun-01
			APS Star Centre (east field)	125kW	2002
			Prescott Arizona APS Site	175kW	2003
			University of Nevada in Las Vegas	25kW	Mar-04
			Nevada Power Company site in Las Vegas	75kW	Jul-06
Arima Ecoenergy	Taiwan	7.5	ISFOCs Spain	300kW	2009
Concentración Solar La Mancha	Ciudad Real, Spain	11	ISFOCs Spain	300kW	2009
Concentrix Solar	Freiburg, Germany	25	Castilla La Mancha	1MW	NA
			Small Power Plant, Lorca	17kW	Aug-07
			Casaquemada Power Plant, Seville Spain	100kW	Aug-08
	Italy		Electricité de France (EDF)	5.75kW	Sep-08
			ISFOC Power Plant	500kW	2009
Cool Earth	Livemore CA, USA			Prototype	NA
	Tracy			1.5MW	NA
	Central Valley			10MW	NA
Emcore	Albuquerque, USA	10	ExtraMadura	850kW	Jul-08
			Korea CPV Solar Park	20MW	2008
			ISFOC	300kW	2009
			Canada Pod Generating Group	60MW	2010
			Xiniao group, China	60MW	
			Sunpeak Solar	200-700MW	2013
Energy Innovations Solutions	Pasadena, CA, USA		Google, Mountain View	1.6MW	Jun-07
	West Coast		The North Face		2008
EnFocus Engineering	Sunnyvale, CA, USA				
Entech	Texas		CSW's West Texas Utility	100kW	1980's
			TU Electric Energy Park	100kW	1990's
Martin Marietta	Saudi Arabia		Soleras Plant	350 kW	1980's
Green & Gold Energy	South Australia			430 MW	
Greenvolts	San Francisco		Pacific Gas & Electric	2 MW	2010
Guascor Foton	Spain	15	IES / IDA	250kW	
			Caceres	1MW	
			I Navarre	2MW	
			Navarre II	5.8MW	
			Seville	1.5MW	
			Murcia	2MW	
Isofoton	Spain	10	ISFOC Power Plant	700kW	2009
Menova	Ottawa, Canada				
OPEL	Shelton, CT, USA		Solar Power Grid, South Korea	10MW	
Pyron Solar	San Diego, California				
Sharp Solar	Japan				
Sol3G	Spain	12	Ramón Escriche photovoltaic park,	800kW	Sep-08
			ISFOC Power Plant	400kW	2009
SolFocus	Spain & USA	50	ISFOC Power Plant	500kW	Oct-08
	Spain		EMPE Solar	10 MW	2010
	Greece		Samaras	10 MW	
Solar Systems	Victoria, Australia	5	White Cliff	40kW	1996
			Umawa Solar Power Station	220kW	Sep-03
			Hermannsburg	192kW	2005
			Yuendumu	240kW	2005
			Lajamanu	288kW	2005
			Victoria Power Plant	154MW	2013
Solartec AG	Munich				
Soliant Energy	CA, USA				

Source: Credit Suisse research

Companies Mentioned (Price as of 08 Sep 09)

Abengoa (ABG.MC, Eu18.66)
 Acciona SA (ANA.MC, Eu96.70, OUTPERFORM [V], TP Eu116.00, MARKET WEIGHT)
 AIXTRON (AIXG.DE, Eu14.50, NEUTRAL [V], TP Eu12.80, OVERWEIGHT)
 Centrotherm (CTNG.DE, Eu30.13, OUTPERFORM [V], TP Eu37.00, MARKET WEIGHT)
 Energy Conversion Devices (ENER, \$13.01, NEUTRAL [V], TP \$10.00)
 First Solar (FSLR, \$134.41, NEUTRAL [V], TP \$135.00)
 Gintech Energy Corporation (3514.TW, NT\$43.00, UNDERPERFORM [V], TP NT\$36.20)
 GT Solar (SOLR, \$5.43, NEUTRAL [V], TP \$4.00)
 Iberdrola Renovables (IBR.MC, Eu3.34, NEUTRAL, TP Eu3.30, MARKET WEIGHT)
 JA Solar Holdings (JASO.OQ, \$3.52, NEUTRAL [V], TP \$4.00)
 Manz Automation (M5ZG.DE, Eu47.00, NEUTRAL [V], TP Eu50.00, MARKET WEIGHT)
 MEMC Electronic Materials Inc. (WFR, \$15.98, NEUTRAL [V], TP \$17.00)
 Motech Industries (6244.TWO, NT\$89.00, NEUTRAL [V], TP NT\$75.00)
 OCI Company Ltd (010060.KS, W237,000, OUTPERFORM [V], TP W300,000)
 Pfeiffer Vacuum (PV.DE, Eu54.11, OUTPERFORM, TP Eu53.00, MARKET WEIGHT)
 Q-Cells (QCEG.DE, Eu11.56, NEUTRAL [V], TP Eu9.00, MARKET WEIGHT)
 ReneSola Ltd (SOL.N, \$5.55, OUTPERFORM [V], TP \$7.50)
 Renewable Energy (REC.OL, NKr41.38, NEUTRAL [V], TP NKr40.00, MARKET WEIGHT)
 Roth & Rau (R8RG.DE, Eu23.87, OUTPERFORM [V], TP Eu26.00, MARKET WEIGHT)
 Sino-American Silicon Products (5483.TWO, NT\$72.80, UNDERPERFORM [V], TP NT\$44.00)
 Solar Millennium (S2MG.DE)
 Solarworld (SWVG.DE, Eu15.15, UNDERPERFORM [V], TP Eu13.60, MARKET WEIGHT)
 SunPower Corp. (SPWRA, \$27.28, NEUTRAL [V], TP \$32.00)
 Suntech Power Holdings Co., Ltd. (STP.N, \$14.85, NEUTRAL [V], TP \$12.50)
 Tokuyama (4043, ¥708, NEUTRAL [V], TP ¥630, MARKET WEIGHT)
 Trina Solar Ltd (TSL.N, \$28.77, OUTPERFORM [V], TP \$40.00)
 Wacker Chemie (WCHG.DE, Eu87.85, UNDERPERFORM [V], TP Eu80.00, MARKET WEIGHT)
 Wafer Works Corp (6182.TWO, NT\$48.05, UNDERPERFORM [V], TP NT\$29.10)

Disclosure Appendix

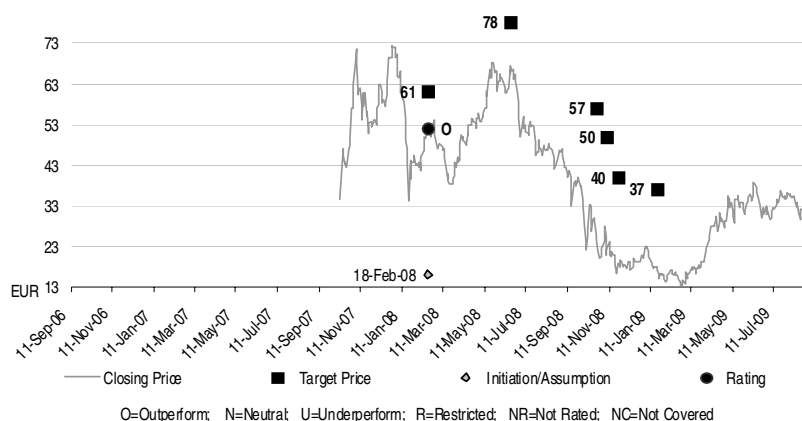
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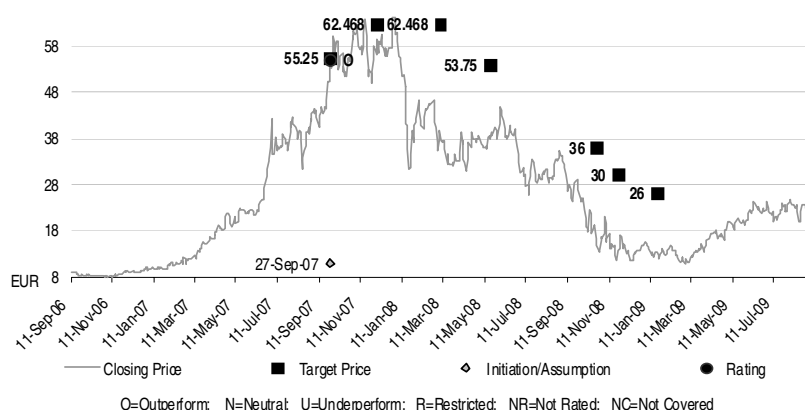
3-Year Price, Target Price and Rating Change History Chart for CTNG.DE

CTNG.DE	Closing Price	Target Price	Initiation/
Date	(EUR)	(EUR)	Rating Assumption
18-Feb-08	52.02	61	O X
18-Jun-08	65.34	78	
23-Oct-08	24.55	57	
07-Nov-08	22.11	50	
24-Nov-08	18.73	40	
20-Jan-09	17	37	

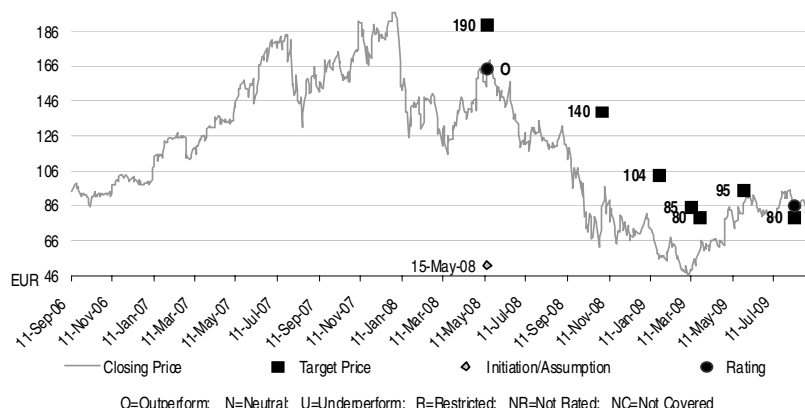


3-Year Price, Target Price and Rating Change History Chart for R8RG.DE

R8RG.DE	Closing Price	Target Price	Initiation/
Date	(EUR)	(EUR)	Rating Assumption
27-Sep-07	55	55.25	O X
05-Dec-07	59.485	62.468	
07-Mar-08	37.488	62.468	
19-May-08	38.65	53.75	
23-Oct-08	14.9	36	
24-Nov-08	13.95	30	
20-Jan-09	13.4	26	

**3-Year Price, Target Price and Rating Change History Chart for WCHG.DE**

WCHG.DE	Closing Price	Target Price	Initiation/
Date	(EUR)	(EUR)	Rating Assumption
15-May-08	164.79	190	O X
31-Oct-08	85.67	140	
22-Jan-09	58.04	104	
10-Mar-09	49.92	85	
23-Mar-09	59.46	80	
26-May-09	81.88	95	
10-Aug-09	86.29	80	U



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Method: Our target price is based on an EVA/DCF analysis, assuming a WACC of 11.5% and a terminal growth rate of 3%.

Risks: We see the following major risks: 1) A cyclical downturn in the solar industry would temporarily also affect equipment suppliers such as Centrotherm. 2) A change in solar legislation and feed-in tariffs might negatively impact the solar cell market. 3) A potential technology disruption by new (yet-to-be-developed) thin film technologies might impact Centrotherm's core c-Si business. 4.) The rapid market growth might attract new competitors, particularly from the semiconductor sector.

Price Target: (12 months) for (R8RG.DE)

Method: Our target price is based on an EVA/DCF analysis, assuming a WACC of 11.3% and a terminal growth rate of 3%.

Risks: We see the following major risks: 1) A change in solar legislation and feed-in tariffs might negatively impact the solar cell market. 2) A potential technology disruption by new (yet-to-be-developed) thin film technologies might impact Roth & Rau's core c-Si business. 3.) The rapid market growth might attract new competitors, particularly from the semiconductor sector. 4.) Roth & Rau might not be able to increase capacity fast enough to catch up with current strong market demand.

Price Target: (12 months) for (WCHG.DE)

Method: Our Eu80 target price for Wacker Chemie is based on an EVA/DCF analysis, assuming a WACC of 10.4% and a terminal growth rate of 3%.

Risks: We see the following major risks to our Eu80 target price for Wacker Chemie: 1) A stronger than expected cyclical downturn in the solar industry 2) A potential technology disruption by new (yet-to-be-developed) PV thin film technologies. 3) Cyclical risks for Wacker's semiconductor business and for Wacker's chemicals business 4.) Currency exchange rates movements might impact Wacker's margin structure, particularly in the semiconductor business.

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