Report on the 2012 SolarPACES Conference

11-14th September, Marrakech, Morocco

1. Executive Summary

The 2012 SolarPACES conference saw over 700 delegates meet to discuss concentrating solar power (CSP) developments worldwide. Delegates were brought up-to-date on the status of the global CSP industry. Spain, currently the largest CSP market with 1,581 MW_e installed capacity and another 774 MW_e in advanced stages of construction, is experiencing a halt in new projects as the feed-in tariff has ceased for new projects, and new incentives are still under negotiation. In the US, five major commercial CSP projects are currently under construction on the back of Federal loan guarantees and additional incentives: SolarReserve's 110 MW Crescent Dunes power tower, Brightsource's 392 MW Ivanpah three-tower plant, Abengoa's Solana and Mojave parabolic trough plants (280 MW and 250 MW respectively), and NextEra's 250 MW Genesis Solar parabolic trough plant. Construction is also underway on five commercial projects in China and seven commercial projects in India. South Africa has three successful bids for CSP projects in the financing phase, while Morocco and Saudi Arabia have announced significant government programs for the construction of commercial CSP plants.

Innovative commercial developments were reported on at SolarPACES, including experiences from 16 months operation of the 20 MW Gemasolar plant in Spain – the first commercial CSP tower to operate with molten salt storage. Another first was the first air-cooled condenser to be used in a commercial CSP plant – the Shams One trough plant in Abu Dhabi which will use a GEA air-cooled condenser.

Research highlights of the conference included quantifying the value of CSP storage in an electricity grid. The US National Renewable Energy Laboratory reported that in a 33% renewables scenario, CSP with storage was twice as valuable as photovoltaics (PV). DLR presented modelling for a 90% renewables scenario for Germany, with 16 GW of CSP imported from North Africa. Technological innovations in storage were presented, such as the testing of a 24 MWh_t single tank storage prototype with a floating barrier to separate the hot and cold salt. The use of metal alloys was presented for the phase-change component of combined sensible and latent heat storage. Previously phase-change salts had been tested, but their low heat conductivity was a challenge.

A networking highlight of SolarPACES was the formation of the CSP Young Professionals Association.

What opportunities lie ahead for CSP in Australia? Kick-starting commercial CSP plant construction in Australia will require some financial incentives. However, as outlined by Deloitte (2011) in their report *Macroeconomic Impact of the Solar Thermal Electricity Industry in Spain,* the €185 million spent on premium feed-in tariffs for CSP plants in Spain in 2008-2010 was far-outweighed by the economic benefits: notably €407 million in additional tax revenue and avoided unemployment benefits and €1,650 million in contribution to GDP.

Moreover, due to the construction-based nature of CSP plants, a pipeline of commercial CSP projects in Australia is essential to ensure that Australia is a CSP technology leader all the way from R&D to turn-key EPC projects and plant operation, and to truly keep Australia at the "forefront of solar innovation".

Contents

2. Key Learnings from SolarPACES 2012

This section is split into a discussion of the state of CSP markets in the sun-belt as presented at SolarPACES (Section 2.1), followed by a discussion of innovative commercial developments reported at the conference, then research highlights, and an introduction to the newly-formed CSP Young Professionals Association.

2.1 Current State of the Global CSP Industry

The global installed capacity of CSP plants has now exceeded 2 GW_e. Preliminary results on cost reductions reported by the European Solar Thermal Electricity Association (ESTELA) during the SolarPACES conference indicate that once 30 GW_e capacity is installed worldwide, a levelised cost of energy (LCOE) of 10-12 c€/kWh is expected (based on a 150 MW plant with 4 h storage)[1]. However, to achieve such an installed capacity strong deployment policies are necessary in countries all around the sun-belt.

To assist the global development of the CSP industry the World Solar Thermal Electricity Association (STELA World[2]) was established in December 2011, with one of the founding member organisations being Australia's AUSTELA, along with the European ESTELA and South African SASTELA. The STELA World committee met during the SolarPACES conference with a view to expanding the organisation.

A summary of CSP developments in sun-belt countries as reported at SolarPACES follows.

Spain

Spain, the cradle of CSP industry expansion since 2007 has 35 commercial CSP plants currently operating, with a combined total of 1,581 MW_e installed capacity, and an estimated production of 4,200 GWh per year[3]. Out of these 35 plants in operation, 15 have storage of 7.5 hours or more at the rated plant output. Another 17 plants with combined capacity of 774 MW_e are in advanced stages of construction, and will produce an additional 2,090 GWh of electricity per year once complete.

The success of the Spanish CSP deployment was based on a feed-in tariff system. This was enacted by the Royal Decree 661/2007 which established a feed-in tariff of a flat rate of 27 c€/kWh or a variable rate of the pool price plus 25.4 c€/kWh for 25 years for plants under 50 MW_e capacity[4]. As discussed in Section 3, the financial benefits brought to the economy by constructing CSP plants far outweighed the expenditure on feed-in tariffs. However, the conservative Spanish Government elected in November 2011 has halted the granting of feed-in tariffs to new CSP plants under the Royal Decree Law 1/2012[5]. Existing plants (producing 4,200 GWh/a), those under construction (2,090 GWh/a) and those already approved (> 159 GWh/a) will still receive the tariffs.

While the incentives for commercial CSP plant construction within Spain are negotiated, there is an opportunity for the rest of the sun-belt countries, including Australia, to continue the leadership begun by Spain in CSP deployment. Any country that embraces this opportunity will see local CSP technology providers and EPC contractors move to the world stage.

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[1] Full cost reduction study soon to be released at www.estelasolar.eu
[2] http://www.stelaworld.org/
[3] http://www.protermosolar.com/boletines/23/Mapa.pdf
[4] http://www.csptoday.com/csp/pdf/CSPFITGUIDE.pdf
[5] http://www.minetur.gob.es/energia/en-US/Novedades/Paginas/RDL_suspension_preasignacion.aspx

USA

Federal loan guarantees, in addition to incentives such as income tax credits, production tax credits and renewable portfolio standards, have led to the construction of several commercial CSP plants since 2010. These include the following plants which are in various phases of construction:

- SolarReserve's Crescent Dunes project in Tonopah, Nevada. A 110 MW tower plant with molten salt storage, Crescent Dunes will produce approximately 500 GWh per year. Electricity generation is due to begin in late 2013. Equity partners include ACS Cobra and Santander, with EPC (Engineering, Procurement and Construction) contractor Cobra Thermosolar Plants.
- Brightsource's Ivanpah project in California comprises three direct steam towers with a combined capacity of 392 MW (no storage). Production is scheduled for late 2013. Equity partners include NRG and Google, with EPC contractor Bechtel.
- Abengoa's Solana plant near Phoenix, Arizona, comprises 280 MW of parabolic trough plant with 6 hours of molten salt storage. Production is scheduled for early 2013.
- Abengoa's Mojave project near Harper Dry Lake, California, is a 250 MW parabolic trough plant under construction (no storage).
- NextEra's Genesis Solar Project is a 250 MW parabolic trough plant with no storage located near Blythe, California. The first 125 MW turbine will begin production in 2013, with the second coming online in 2014.

In the meantime, the US Department of Energy is implementing its SunShot Initiative, which aims to "make solar energy [including CSP] cost competitive with other forms of energy by the end of the decade." While this is a courageous initiative likened to the Apollo program, recent and dramatic cuts to funds at the National Solar Labs are not in line with reaching the goals of this program.

China

In its 12th Five Year Plan, the Chinese Government has installation targets of 1 GW of CSP by 2015, and 3 GW by 2020. There are currently five commercial projects under construction in China, with a combined capacity of 342.5 MW, as outlined in Table 1 (Hernández, 2012). All of these will use parabolic trough collectors, and two of these plants, Jinta and Delingha, have received assistance from the Asian Development Bank (ADB). The project in Ningxia is part of an Integrated Solar Combined Cycle plant (ISCC). The Erdos plant was awarded a reverse auction feed-in tariff of 0.94 RMB/kWh. However, it appears that this bid was too optimistic, even for China, and a higher feed-in tariff is likely to be negotiated (Hernández, 2012).

Location (Province, City)	**Developer**	**Capacity (MW)**	**Storage**	**Status (Oct 2012)**	**Comments**
1. Gansu, Jinta	China Huadian	50	-	Initial construction work.	Assistance from ADB.
2. Inner Mongolia, Erdos	China Datang	50	Molten salt	Under construction	
3. Ningxia	Hanas	92.5	Yes	Under construction (ground breaking Oct 2011).	ISCC
4. Qinghai, Delingha	China GD Nuclear	50	Yes	Under construction	Assistance from ADB.
5. Qinghai, Geermu/Golmud	China Power Investment	50-100	Yes	Under construction	

Table 1. A summary of commercial CSP projects under construction in China from Hernández (2012).

India

Under India's National Solar Mission, seven commercial CSP plants are currently under construction for Phase I of the Mission (NRDC 2012, Lakhina 2012), as listed in Table 2. Under the original Mission guidelines, these plants were due to be operational by May 2013, however as some projects broke ground in August 2012, extensions are likely to be sought. Stakeholders have suggested that incentives be included in Phase II for storage, dry cooling, and sustainable biomass hybridisation.

Project	Developer	Type	Capacity (MW)	Bid (Rp/kWh)	Suppliers	EPC Contractor	Location
1. Aurum Renewable Energy	Aurum	Linear Fresnel	20	12.19	Sumitomo Shin, Nippon	Indure	Mitrala, Porbandar, Gujarat
2. Corporate Ispat Alloys	Abhijeet	Parabolic Trough	50	12.24	Siemens turbine & receivers	Shriram EPC	Nokh, Pokaran, Rajasthan
3. Diwakar Solar	Lanco	Parabolic Trough	100	10.49	Siemens	Lanco Solar & Initec Energía	Askandra, Nachna, Rajasthan
4. Godawari Green Energy	Hira Group	Parabolic Trough	50	12.20	Siemens, Schott Glass, Flabeg, Aalborg	Lauren, Jyoti Structures	Nokh, Pokaran, Rajasthan
5. KVK Energy Ventures	Lanco	Parabolic Trough	100	11.20	Siemens	Lanco Infratech	Askandra, Nachna, Rajasthan
6. Megha Engineering	Megha Engineering Limited	Parabolic Trough	50	11.31	GE	MEIL Green Power Limited	Anantapur, Andhra Pradesh
7. Rajasthan Sun Technique	Reliance	Compact Linear Fresnel	125	11.97	Areva	Reliance Infrastructure	Dahanu, Pokaran, Rajasthan

Table 2. CSP projects under construction in India for Phase I of the National Solar Mission from NRDC (2012).

Morocco

Morocco, the host nation of the 2012 SolarPACES conference, is experiencing significant growth in energy demand, and intends to address this largely with renewable energy. Morocco's renewable energy target is 42% of installed capacity by 2020; including 2,000 MW of CSP and PV combined by 2020. Earth works are currently underway for a centre-piece solar park at Ouarzazate, supported by loans from the World Bank and the Global Environment Facility.

South Africa

In the face of power shortages and outages, South Africa has also turned to renewables to provide the shortfall in generation due to the short construction time for renewable projects (~18 months for wind or CSP). Three CSP projects have been awarded in rounds I (Dec 2011) and II (May 2012) of bidding for the CSP component of the Renewable Energy Independent Power Producer Program (REIPPP) as follows[6]:

- KaXu Solar One (Round I) – a 100 MW parabolic trough plant at Bokpoort by developer Abengoa with 3 hours of storage and dry cooling.
- Khi Solar One (Round I) – a 50 MW tower plant at Upington by developer Abengoa with 2 hours of storage and dry cooling.
- Bokpoort Solar Facility (Round II) – a 50 MW parabolic trough plant, with 9 hours of storage and dry cooling, by developers ACWA and Solafrica Thermal Energy with EPC contractors SENER, Acciona, TSK and Crowie.

These projects are currently in the process of securing financing.

Saudi Arabia

Saudi Arabia has announced an impressive 25 GW target for CSP by 2032[7]. The first installment of CSP plants will be awarded by competitive auction, with 900 MW available for bidding in 2013, and a further 1,200 MW available by 2014. A technology-differentiated feed-in tariff will then come into place from as early as 2015.

Australia

There was much interest amongst delegates at SolarPACES in Australia as a future market. As outlined by Dr Keith Lovegrove in his plenary address, there are many small pilot CSP plants operational in Australia, as well as a 44 MW_e solar boost project under construction with Areva compact linear Fresnel concentrators at the Kogan Creek coal-fired power station in Queensland.

[6] http://www.csptoday.com/southafrica/pdf/CSPSouthAfricaMarketGuide.pdf
[7] http://www.renewableenergyworld.com/rea/news/article/2012/05/saudi-arabia-launches-massive-renewable-program-with-hybrid-fits

2.2 Innovative Commercial Developments

Several innovative commercial projects were reported on at SolarPACES 2012. Highlights of these commercial projects are summarised below.

Gemasolar Molten Salt Power Tower

Two presentations were given on the 16 months of operational experience of Torresol Energy's Gemasolar plant (Figure 1) – the first commercial CSP tower to operate with molten salt storage (Garcia and Calvo 2012, Burgaleta et al. 2012). For background, see Dunn et al. (2012). At the 2011 SolarPACES conference in Spain, delegates took a site tour to the Gemasolar Power Tower.

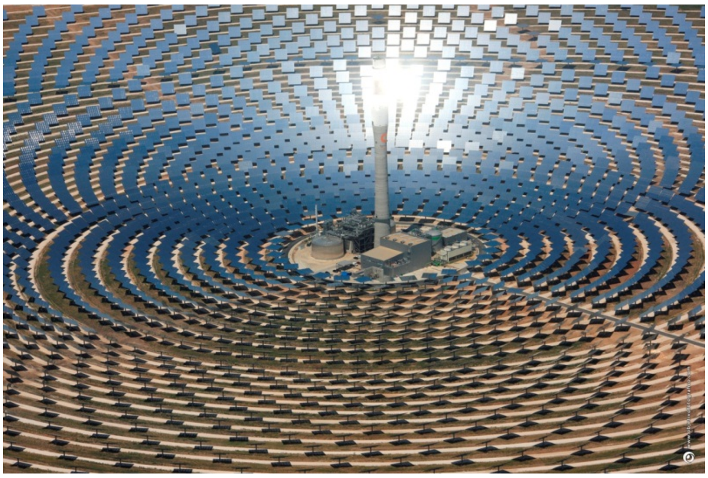

Fig. 1. The 20 MW_e Gemasolar tower plant with 15 hours of molten salt storage.

This year, Garcia and Calvo (2012) reported on the continuous operation of Gemasolar on a 24-hour basis over the summer, at or close to full turbine capacity (20 MW_e), for periods of over a week at a time. They also reported on the record time for receiver commissioning – less than one month – and the outstanding receiver availability (100%) and solar field availability (99%) achieved during the 16 months of operation to date.

Meanwhile Burgaleta et al. (2012) addressed issues including:

- Mirror cleaning – To date, mirror cleaning has been performed with high pressure water jets attached to an arm on a truck (Figure 2). This method has been able to adapt to different soiling levels on each heliostat to produce a highly reflective total field. However, due to water scarcity at many potential CSP plant locations, a cleaning method with substantially reduced water consumption was developed – the robot-based HECTOR system which brushes and wipes the mirrors (Figure 2).
- Estimation of the DNI (Direct Normal Irradiation) up to 48 hours ahead of time. This allows optimisation of plant generation.
- Daily start-up and shut-down of the receiver system.
- Operation of the plant under various conditions – full sun, long and short-term transients, night time or in the absence of direct radiation.

Fig. 2. Heliostat cleaning: Pressurized water jet cleaning with a truck (left, centre); and mechanical cleaning (sweeping/wiping) with the robot-based HECTOR system (right). Images from Burgaleta et al. (2012).

SolarReserve Crescent Dunes Plant

SolarReserve Chief Technology Officer, Bill Gould presented on overcoming the scale-up risk for the 110 MW_e Crescent Dunes power tower with 8 hours of storage (Gould 2012). The Crescent Dunes receiver has a thermal rating of 550 MW_t, compared to 120 MW_t for Gemasolar and 43 MW_t for the Solar Two molten salt power tower. Consequently, the up-scaling of the receiver, solar field and other components presented first-time risks. Measures used to address these risks – for example performing full-scale physical tests for the receiver – provided confidence for lenders, equity holders and clients to invest in the scaled-up version of a previously demonstrated pilot plant.

Air cooling

The Shams One 100 MW parabolic trough plant in Abu Dhabi will be the first commercial CSP plant in the world to operate with an air-cooled condenser, in this case supplied by GEA (Goebel 2012). The Shams One Plant will begin commercial operation at the end of 2012.

The use of air-cooled condensers in commercial CSP plants is an important step in CSP plant evolution, as many potential CSP sites around the world lack sufficient water for water-based cooling. As noted in Section 2.1, the three commercial CSP plants that have been selected for the first two rounds of the REIPPP in South Africa will also use dry cooling.

Molten Salt as HTF for Troughs

Building on from the Archimedes project, the Italian research centre ENEA presented on a project to incorporate the use of molten salt as heat transfer fluid (HTF) at up to 550ºC in parabolic troughs, along with biomass/biogas/waste hybridisation. The project, FP7 MATS, will be located in Egypt, and produce 5 MW_t output. In addition, Schott reported that they are now producing molten salt vacuum tube receivers, in competition with the Archimedes high temperature tube suppliers.

HelioTower – Solar Millennium Spin-Off

Following the financial receivership of Solar Millennium, its power tower development work has been spun off into a new company called HelioTower. HelioTower is offering design work for multi-tower molten salt solutions.

Anti-Soiling Coating

Flabeg reported on an anti-soiling coating for mirrors which reduces soiling by 50%.

2.3 Research Highlights

Value of Storage

Mark Mehos from NREL gave a plenary presentation on the value of CSP storage (Denholm and Mehos 2012), adding to a list of NREL publications on the value of energy storage[8]. In this presentation, the value of CSP storage was quantified in terms of capacity (firming) value, avoided fuel costs and ancillary services. Under a 33% renewables scenario in Colorado, the value of CSP with storage was twice that of photovoltaics (PV), and three times that of CSP with no storage.

In a related study (Denholm and Mehos 2011) it was shown that deploying CSP with storage complements photovoltaics (PV), and in fact allows higher penetrations of PV to be integrated into the grid without curtailment.

The value of storage was approached in terms of energy shifting in a presentation by the company Brightsource Energy (Helman and Kroyzer 2012). Although their current technology – i.e. that under construction at Ivanpah – does not involve storage, their quantitative analysis has shown that a tower plant with storage can obtain 6-13% higher value from energy and ancillary service markets in the US. In addition, a cost of at least $6/MWh that would be needed for grid integration of PV is also avoided.

Dr Keith Lovegrove presented a storage value for the Australian electricity market, showing that the market values energy from dispatchable plant operation during peak times at twice the value compared to producing in a non-optimised regime (Lovegrove et al. 2012).

Technological Innovations in Storage

Progress was reported on several familiar topics of storage R&D: advanced molten salt systems, new combinations of salts, combined latent and sensible heat storage, a solid particle receiver, and various thermochemical reactions for storage. The “new” topic this year[9] was the use of phase-change metal alloys, which have high thermal conductivity, in place of phase-change salts for combined latent and sensible heat storage. Two presentations addressed aluminium-silicon alloys (Kotzé et al. 2012, Hunt and Carrington 2012), which are suitable for temperatures high enough for Brayton cycle operation. Results for a magnesium-zinc alloy were also presented (Blanco-Rodríguez et al. 2012). Other highlights from innovations in storage were:

- Results from SENER for a 24 MWh_t thermocline tank prototype in operation at the commercial Torresol Valle 2 parabolic trough plant (Querol et al. 2012). This thermocline system (single tank) contains a floating barrier to separate the hot and cold salt, and is operating in parallel with a conventional two-tank salt storage system.
- The concept for a three-tank molten salt storage system, in lieu of two separate two-tank systems (i.e. four tanks in total) at large (> 200 MW) parabolic trough plants (Rossi et al. 2012).
- News from Abengoa and Brightsource on the development of steam-to-molten-salt storage for their tower systems.

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[8] For example Denholm and Mehos (2011), Madaeni et al. (2011), Sioshansi and Denholm (2010), and Sioshansi and Denholm (2012).

[9] Metal alloys were proposed for thermal energy storage as early as the 1980s.

90% Renewable Electricity for Germany

Researchers from DLR and CIEMAT presented modelling for a 90% renewables scenario for Germany as part of the BETTER project – Bringing Europe and Third Countries Closer Together through Renewable Energies (Fichter et al. 2012). This scenario included 16 GW of electricity from CSP imported from North Africa, and complements previous studies incorporating CSP into high renewable penetration scenarios. For example, the Zero Carbon Australia 100% renewables plan for Australia (Wright and Hearps 2010), and the NREL Renewable Electricity Futures Study which detailed scenarios of up to 90% renewables for the US (NREL 2012).

Central Receiver Power Plants (Power Towers)

Central Receiver developments included:

- The development of standards by NREL for performance acceptance tests for EPC contractors or owners of power tower plants prior to commercial operation (Kearney et al. 2012).
- The development of a new Abengoa heliostat – the ASUP140 – with new structure, facets, drives, controls and lean manufacturing.

Policy and Marketing

A major theme of Policy and Marketing sessions was local content. Brightsource reported that their Ivanpah plant is using a majority of US supplied components, from 17 US states. Policies were also discussed that would ensure that countries with emerging CSP markets such as India, Morocco, South Africa and Saudi Arabia can ensure local economic benefits from local CSP plant construction.

Dish Systems

Aside from presentations pertaining to the ANU's 500 m^2 SG4 dish concentrator, a new 500 m^2 dish was presented which was constructed in Israel by Heliofocus and Schlaich Bergermann und Partner, with spherical curved mirrors in a Fresnel-like arrangement on a flat support structure (Keck et al. 2012).

2.4 CSP Young Professionals Association

Students and young professionals had previously held a dinner informally at each SolarPACES conference since 2009. This year the CSP Young Professionals Association[10] was officially formed, and the inaugural dinner held. The association will form an important forum for networking amongst young CSP Professionals, as well as a target audience for career and research advertisements.

[10] http://cypeurope.org

3. Opportunities for the development of CSP in Australia

Kick-starting commercial CSP plant construction in Australia will require some financial incentives, whether this comes from the Federal budget, or electricity price levies. However, as illustrated by the example of Spain, the cost of their feed-in tariff system was far outweighed by the economic benefits of CSP plant construction. In the plenary panel for the Global CSP Market, the President of the European Solar Thermal Industry Association (ESTELA), Dr Luis Crespo, cited costs and benefits of the CSP industry in Spain. These were calculated in the study *Macroeconomic Impact of the Solar Thermal Electricity Industry in Spain,* commissioned by Protermosolar and completed by Deloitte (2011). Over the period from 2008-2010, €185 million was received as premium feed-in tariffs by CSP plants operating in Spain. This cost was far-outweighed by the economic benefits, which can be broken down as follows:

- €407 million in fiscal contributions (corporate tax, personal income tax, and avoided social security payments).
- €1,650 million in contribution to GDP – 89.3% in construction, 2.7% from R&D and the rest from plant operation.
- €24 million in avoided import of fossil fuels.
- €5 million in avoided CO_2 emission permits.

Moreover, by 2010, there were 23,844 people employed in the CSP sector in Spain, many of these from construction industries which were otherwise suffering substantial unemployment due to the economic crisis. In addition, Spanish companies are now a major force in the global CSP industry – Abengoa Solar, SENER, Torresol Energy, Cobra Energía, Aries, Acciona etc.

Siemens Executive, Adrian Wood, added to this topic citing data from Siemens' construction experience:

- If only one CSP plant was to be constructed in a country, you could expect 30-40% local content.
- However if several CSP plants were to be constructed at once, you could expect 60-70% local content, because the investment in new local manufacturing infrastructure would be justified.

Both the Spanish and Siemens experiences highlight the economic benefits that Australia would experience from the deployment of a pipeline of commercial CSP projects in Australia. Additionally, there is a high level of interest from established CSP developers, EPC providers, owners and operators in the Australian market due to the world-class DNI resource and ample terrain.

As the global CSP industry is still in the early stages of development, establishing a pipeline of commercial CSP projects in Australia now, with appropriate policies for local content and R&D collaborations, would ensure that Australia is a CSP technology leader all the way from R&D to turn-key EPC projects and plant operation.

4. Challenges for the development of CSP in Australia

Research and Development in CSP is quite strong in Australia, and this has been further developed by the assistance of the Australian Solar Institute. What is critically lacking in Australia is the deployment of a pipeline of commercial projects. Due to the construction-based nature of CSP plants, a pipeline of local commercial projects is necessary to drive many of the innovations that will improve efficiency and cost effectiveness of this technology, as well as keeping Australia at the "forefront of solar innovation".

Further, the key advantage of CSP plants – dispatchable power generation through thermal storage – is not currently incentivized under programs such as the Renewable Energy Target, or even Solar Flagships.

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