2012 SolarPACES Report

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Section 1: Introduction

SolarPACES 2012 reported back on the industry developments from the past year, which were dominated by the installation of tower plants, such as Gemasolar and Crescent Dunes, that continue to surpass the scale of previous plants by close to an order of magnitude. Other research was generated by the industry's expansion into new regions such as North Africa and India, the practicalities of construction in these countries, and the economic and policy barriers presented by these new markets.

Industry players presented forecasted conditional LCOE cost reductions that are in line with Australia's most optimistic estimates, as presented in recent reports (Lovegrove, 2012).

These projections were supported by evidence of current and ongoing incremental efficiency gains and cost reduction opportunities, for all aspects of commercialised technologies: field, receiver, powerblock, heat transfer material and storage.

Academic research papers and emerging concepts reflected a renewed focus on the use of CSP to develop transportable fuels including hydrogen, syngas, and novel fuels like solar-generated sulphur. There was also a large amount of presentations on alternative thermal energy storage (TES) mediums, especially phase change materials (PCM) including metal alloys, and alternative heat transfer mediums (HTM) like steam.

Solar resource assessment occupied a significant proportion of presentations, with accurate DNI prediction being required for the feasibility assessment of proposals especially North Africa and India.

Section 2: General Industry Developments

The falling cost of PV was recognised throughout the conference as a driver that is likely to determine the direction of CSP industry development in terms of technology type and application context. Industry research focused on achieving near and mid-term cost reductions, and on taking advantages of CSP's points of difference, especially its dispatchability. Policy and marketing presentations had a focus on quantifying the value of CSP's dispatchable capacity. Niche applications for CSP, like solar fuels and chemical commodities, process heat, and hybrid systems were also a focus.

Industry bodies presented estimates of potential 2020 CSP LCOE figures with the US Department of Energy predicting a LCOE cost reduction to 6c by 2020 (30% of current costs) ESTELA citing 10 – 12 euro cents by 2020 (50% of current costs, with the caveat that this depends on 30GW being installed worldwide by this date.) These estimates exceed or are in line with the most optimistic cost reduction scenario presented in IT Power's 2011 report on CSP in Australia. (Lovegrove, 2012) Although these projections depend on an optimistic scenario of continuing global investment in CSP projects, they indicate that CSP represents an energy option for Australia that could become commercially competitive without subsidy in the near term (between 2015 and 2020.)

Many presentations stressed the bias of LCOE as an indicator towards variable generators like PV, in that it does not accommodate the market value of dispatchable electricity. (Richert, 2012.)

Modelling has demonstrated the value of dispatched CSP electricity in the Australian NEM in 2011, and these figures were presented at the conference (Lovegrove 2012)

This point was extended in presentation of modelling by Brightsource (Helman, 2012.) This study based on California's renewable targets, shows that as the penetration of solar generators grow, the value of variable PV-generated electricity will fall to be lower than the average market price, (it is currently higher) while dispatchable CSP-generated power will increase further above average.

The increasing importance of storage as a point of difference between CSP and solar PV, is a driver for the increased industry focus on tower technologies. Gemasolar, the largest operational solar tower includes 15 hours of storage, and Abengoa reported on six months of operation. The plant had experienced limited downtime and with the energy storage system performing correctly. Gemasolar will be surpassed as the largest operational tower in 2013, by the 110MW Crescent Dunes Plant being developed by Solar Reserve in Nevada. Brightsource has received early stage approvals for a 500MW development consisting of two 250MW plants in California. It was noted that tower plant sizes were unlikely to continue to grow, and are approaching this mark of maturity as commercial technologies.

Linear Fresnel systems demonstrated commercialisation, with a 12MW linear Fresnel plant being installed as the first large-scale plant in France, the first direct steam generation plant in Thailand and the 44MW Kogan Creek Solar Boost Project. Fresnel systems occupy the same niche as trough systems in terms of their storage capacity and their applications. It is expected that they will be able to offer lower costs.

Direct steam generation has the advantages of enabling higher fluid temperatures than thermal oil systems (500°C) as well as eliminating heat exchangers. The first commercial direct steam generator have been completed by Solarlite in Thailand (5MW,) and in Spain (a linear Fresnel plant by Novatec Solar.) These plants have separate fields to preheat and superheat the steam. DLR and Solarlite are researching an alternative "once-through" configuration, which would not require two separate fields, which is expected to achieve further gains in efficiency.

2.1. Opportunities for Australia

Remote diesel minigrids in Australia are identified as an excellent context for the application of solar PV, and PV is being deployed in remote communities across northern and western Australia. Where this leads to a high penetration of PV, the value of dispatchable CSP electricity will increase.

2.2. Barriers to Deployment in Australia

Low cost PV will compete with CSP in many contexts in Australia, as it will generally around the world.

Section 3: Solar Resource Assessment

A significant proportion of presentation time was dedicated to resource assessment. This was driven by the experience of commercial projects in the past that had found DNI levels lower than anticipated after construction, as well as the industry's expansion into poorly surveyed regions in India, the Middle East and North Africa.

Many of these presentations were relevant to two research projects currently being undertaken by CAT Projects, which investigate respectively the effect of spectral factors on the lifetime output of PV generators, and the effect of spacial distribution of PV generators on the integration of PV generators into a small grid.

A large amount of academic and industry research attempted to improve translational models that allow DNI to be estimated from satellite GHI data, of which there are a large amount of reliable high-resolution sources, especially for the Northern Hemisphere.

Many papers identified the disinclusion of aerosols as being a major cause of overestimating DNI in earlier models based on satellite GHI. Various models proposed to incorporate data from aerosol databases such as Aerosat (Singal, 2012) (Hosni, 2012) (Cebecauer, 2012.) There was a general consensus that models should be developed for each climatic zone separately, within a country, and that these should be calibrated against ground stations.

The inability of satellite data to distinguish between airborne sand and a ground surface of the same colour was demonstrated as a specific challenge. (Hosni 2012.)

Significant government funding in India, and efforts in Mediterranean countries (Syria, Jordan, Israel, Lebanon, Egypt, Libya, Tunisia, Algeria, Morocco, Palestine, Mauretania and Turkey) were being directed at the development of a solar atlas based on a significant number of groundstations measuring DNI, as well as GHI.

3.1. Opportunities for Australia

The finding that aerosols, and in particular airborne dust in sandy deserts, have a major impact on the output of CSP plants is likely to increase the relative value of the solar resource in Australia's arid zone which has fewer dust events than other deserts, and low aerosol levels from other sources.

3.2. Barriers for Australian Deployment

Australia has relatively few ground-based weather stations measuring DNI, (currently 8 stations,) leaving resource assessment strongly dependent on modeling and satellite data. Papers presented the limitations of this approach, especially where models have not been specifically developed for local climatic zones, calibrating satellite data against ground station measurements.

NASA satellite data covers Australia, but only has a one degree (lat, long) resolution. DLR's Solemi database covers part of Western Australia only. Services such as 3Tier and Meteonorm incorporate groundbased and satellite data, so will be similarly impacted by the lack of ground-based measurement in Australia. A lack of reliable data could reduce investment confidence in the case of large-scale CSP rollout.

Section 4: Hybrid applications

Hybrid CSP plants have historically been configured as primarily CSP plants with some fossil backup to provide dispatch capacity. At SolarPACES 2012 this was acknowledged in a number of papers as a developmental phase that was unlikely to be continued, because of its inefficient use of fossil fuels.

However, the conference presented the advantages of using CSP as a hybrid add-on to new or existing primarily fossil fuel plants. Presently, commercialised hybrid plants either use CSP to preheat feedwater, as in the Kogan Creek Solar Boost project, or are configured as Integrated Solar Combined Cycle Plants, which have been demonstrated in the USA (Martin Next Generation 75MWe) and Morocco (Ain Beni Mathar 32MWe) (Peterseim, 2012.)

It was demonstrated that the solar fraction could be increased by incorporating solar thermal input in various other stages of the generation process: such as a high and low pressure feedwater preheating, boost feedwater preheating after the plant's high pressure preheater, direct steam generation feeding the turbine, and solar preheating of combustion air. (Siros, 2012)

Steam generation towers directly feeding a turbine were proposed as an alternative that would allow a greater solar input than feedwater preheating, and that would save on the cost of a dedicated turbine for the solar generator.

Significantly, the conversion efficiency of the solar fraction of a solar pre-heater was demonstrated to acheive up to 42% conversion efficiency, higher than the record for stand-alone CSP plants – this makes a case for hybrid plants as an effective and realistic intermediary step or pathway for development in Australia. (Siros, 2012)

4.1. Opportunities for Australia

The advantages for deploying solar thermal technologies as hybrid add-ons to coal generators has been discussed in recent national assessments as being a realistic first stage of deployment for CSP in Australia. (Lovegrove, 2012) The use of CSP in this context is continuing to be developed, and promises to represent a significant opportunity for Australia to upgrade the large amount of coal generation in operation.

4.2. Barriers for deployment in Australia

Barriers to this is a discrepancy between the best solar resource and most coal power stations – although solar resource in most parts of Australia has the capacity to make CSP feasible.

Section 5: Process heat

CSP generators are being deployed successfully to supply process heat in industry, laundries, etc. Most of these plants were on a smaller scale than the plants generally featured at SolarPACES, but small trough systems are being used in these contexts as a mature technology.

Probably of most relevance to Australia is the potential of CSP process heat for the mining industry. A copper mine in Cyprus is conducting advanced feasibility and planning for a trough plant that will both supply electricity and process heat to the mine (to increase extraction by raising the temperature of the copper processing fluid.) (Stukenbrock, 2012)

5.1. Opportunities for Australia

Remote mines in Australia have already been identified as an ideal context for CSP application in Australia, with barriers being the general risk aversion of mining companies as well as the short lifetime of many mines. The potential to increase production by providing process heat may significantly increase the value of CSP generation, via increased commodity production. This extra value may have the potential to overcome the strong pathway barriers to using CSP in this context, and demonstrate the practicality of CSP to the industrial consumers.

5.2. Barriers for deployment in Australia

The characteristic risk aversion of the mining industry, and the short lifespan of many mines, have been identified as barriers to the deployment of CSP in a mining application.

A lack of widespread expertise in CSP deployment in commercial companies in Australia constitutes a barrier to the deployment of CSP for process heat applications, which require context-specific design and engineering.

Section 6: Solar Towers

The commercialisation of solar tower technologies is advancing, with continuing increases in the scale of plants and single tower systems. The increased importance of CSP's potential for efficient storage, caused by the decrease in PV costs, was driving an industry focus on tower technologies for large-scale utility generation.

Proposals for incremental design improvements were presented that related to the optimal heliostat size, improved systems to design heliostat field layout, as well as a proposal for smaller, modular tower sizes.

Cost reductions were presented through simplified flat heliostat designs, and a cheaper tower with structural guy ropes.

Emerging design concepts for future towers under research include higher-temperature salt models, direct steam generators, air and experimental solid particle receiver systems.

Volumetric air receiver plants were seen to be moving from research to early commercialisation stage. Pressurised air receivers - able to feed gas turbines were being advanced towards commercialisation, including in a project from CENER, for a decoupled ORC bottoming cycle with storage.

A concept proposed to eliminate high costs from storage mediums and materials including the need for a receiver window, is a solid particle receiver, ie falling sand - being pursued by Sandia and DLR. DLR propose the potential for 89% efficiency of the receiver at 800°C. (Gobereit, 2012)

6.1. Opportunities for Australia

Solar tower technologies, with the most straightforward potential for implementing CSP with storage, represent an opportunity for Australia in all the contexts where dispatchibility is valuable – small remote grids, as supporting plants for transmission lines approaching capacity, etc. Solar towers have the potential for a large amount of local manufacturing, with relatively simple field components. As a newly commercialised technology, Australia has an opportunity to establish a prominent role in the future deployment of this technology. The USA now leads deployment. Future development in the USA depends on ongoing government support, which is not guaranteed.

6.2. Barriers for deployment in Australia

The barriers for the deployment of solar towers are the same as the barriers for CSP deployment in Australia generally.

Section 7: Dishes

Dish technologies present less-straightforward storage options than towers and troughs. Given the current industry focus on dispatchability, there was less work presented on dishes than other technologies at SolarPACES 2012.

Rebecca Dunn from the Australian National University presented a summary of the potential storage options applicable for dish technologies. (2012)

Heliofocus presented a new Fresnel type big dish, with a 1MW commercial plant planned for Israel (air receiver to transfer heat to steam.)

7.1. Opportunities for Australia

Dishes are modular which is relevant to many Australian applications, such as remote small grids.

Australia has expertise in dish technology, through ANU's big dish, now being commercialised by Wizard Power, and Solar Systems/Silex's CPV dishes.

Section 8: Trough Systems

Trough systems are the most proven and therefore bankable CSP technology. This technology is now facing commercial competition from linear Fresnel plants, which apply to the same application contexts and which pose the potential to provide electricity at lower costs.

Troughs were pursuing economies of scale through larger troughs (Heliostat, SENERtrough, Ultimatetrough), and increased plant size, such as the 100MW SHAMS1 plant.

Technological developments included the pursuit of new heat transfer media to achieve higher temperatures – including new stable synthetic oils, commercialisation of direct steam generation, and demonstration systems for molten salt HTM.

Structural innovations towards cost reduction included concrete frames, and film mirrors. Schott released an improved noble gas evacuated tube.

The first commercial pilots using DSG were in operation in Thailand (Solarlite) and Spain (linear Fresnel by Novatec Solar.)) The Thailand plant has a separate solar field for pre heating and evaporating, and one for superheating, separated by a steam drum. DLR and Solarlite were also researching a "once-through" configuration, which would not require two separate fields, and which would increase efficiency.

As a mature technology there were a significant amount of papers addressing standardisation of testing and rating, long term component performance simulation testing, reducing the margin of error associated with breaking strength of the parabolic trough reflector panels

A novel trough was in the pilot plant phase in Morocco, using an inflated air collector on a concrete trough base. (Airlight) (Andrea Pedretti A 3MW thermal Concentrated Solar Power Pilot Plant in Morocco with the Airlight Energy Technology.) The potential to use gas as a transfer fluid was assessed in a number of research papers.

8.1. Opportunities for Australia

While storage capacity is limited, even without storage CSP troughs do not present the same instantaneous variability to the grid as PV does, that can cause integration issues with eg. diesel gensets, due to the thermal inertia of the heat transfer fluid, and components.

8.2. Barriers for deployment in Australia

The barriers for the deployment of solar troughs are the same as for CSP generally. These include a lack of transmission infrastructure to the best solar resources, inexpensive and abundant fossil fuel resources, fossil subsidies, and the current high costs of CSP deployment.

Section 9: Storage

Large capacities of molten salt storage are being applied successfully at Gemasolar, (15 hours storage,) with a larger system being developed for SolarReserve's Crescent Dunes project in Nevada. Molten salt storage was first used commercially in a parabolic trough plant, but is more efficient and can achieve higher capacities in tower plants.

Proponents for alternative storage mediums argue that molten salt storage is deployed primarily for its proven track record, and that other materials offer cost advantages, and may be more compatible with trough or dish technologies or direct steam generation.

Previous research, which had established that the greatest cost associated with commercialised storage options was in the cost of the material itself, was driving investigation of the use of low cost materials for storage – such as sand, gravel, concrete or recycled ceramic materials.

Single tank thermocline systems, to replace the current commercialised 2-tank salt storage systems, was also a focus. This configuration allows a cheap filler, eg quartz or concrete, to occupy the bulk of the tank, and reduce the amount of molten salt required.

Sand was also proposed as a novel heat transfer material, in application in a tower that would allow a simplified receiver without a window.

Phase Change Materials (PCM) were investigated as storage options with a higher energy storage density (and so requiring a smaller mass of material), and as being compatible with a wider range of technologies than molten salt. Contenders included metal alloys based on magnesium or aluminium, which also had the advantage of also having high thermal conductivity to simplify heat exchange mechanisms and processes.

Two caveats on the value of CSP's storage and dispatchability that were mentioned but not presented in detail were the emerging threat of low cost flow batteries, which, in conjunction with low cost PV, may present a lower cost fully dispatchable renewable source that would make CSP technologies redundant - and also the fact that CSP technologies were not yet dispatchable to the point where they were able to respond quickly enough to load changes to be deployed as load following plants.

These two factors would have to be assessed in any situation where CSP technologies were being considered as dispatchable generators.

Section 10: Solar fuels

New research towards the commercialisation of solar fuels was driven by factors such as Japan's post Fukishima efforts to diversify their energy sources, and the anticipated demand to transport renewably generated energy.

Alternative solar fuels presented included sulphur-based storage, storage based on the decomposition of ZnSO4, hydrolysis of CaO to make CaOH, thermal dissociation of ZnO and OnO2 compressed powders, hydrogen production (Kaneko 2012) from the reduction of metal oxides, or through the reforming of methane, and the production of syngas through processes such as reforming natural gas. Metal air batteries were proposed as offering very high energy densities, with potential transport application.

Solar fuel production is progressing from demonstration plants to early commercialisation. Pilot plants, such as a 100kW reactor at the Plataforma Solar de Almeria in Spain has demonstrated the thermal dissociation of zinc oxide, have been successfully established (Villasmil, W, 2012).

Jim Hinkley presented the process that will be undertaken to prepare the CSIRO's Solar Fuels Roadmap for Australia, due in the third quarter of 2013. (Hinkey, 2012)

10.1. Opportunities for Australia

Establishing a process by which solar fuels can be economically produced for export or for use in transport would allow Australia to take competitive advantage of its superior solar resources, while overcoming some of the major barriers to CSP deployment, such as a lack of transmission lines to Australia's best solar resources, and Australia's current access to cheap fossil fuels such as brown coal in Victoria that can't be transported.

10.2. Barriers for deployment in Australia

Solar fuels remain in early development, and are not yet cost effective.

Section 11: Conclusion

The key learnings from SolarPACES 2012 underline the findings of recent reports into the opportunities that concentrating solar thermal present for Australia: that the current moment presents a unique opportunity to develop a sustainable solar thermal industry in Australia with significant local content, and that the future benefits of dispatchability warrant current investment in CSP technology deployment.

Industry leader Spain has been forced to decrease its activity through widespread government spending cuts, and the USA may see decreased investment with a change of government. With a significant deployment program in Australia, it's feasible that manufacture, construction and engineering work could be based nationally.

This potential for development is supported by Australia's longstanding contribution to industry R&D, primarily through ANU and CSIRO.

The future value of CSP in a high penetration scenario, as demonstrated in papers such as Brightsource's model of the Californian grid, (Helman 2012) underline the importance of strategic policy and government investment in CSP specifically, separately from the procurement of least cost renewable generators through mechanisms such as the ACT's solar auction process.

Australian demonstrations of CSP plants will be a requirement for commercial investment in this generation technology when it becomes commercially competitive (in about 2017 according to the LCOE figures presented by ESTELA.) Most of the highest insolation sites in Australia lack local capacity for operation and maintenance, and are not adjacent to long term consistent loads.

Gaining an appreciation of the wide range of niche applications that could be served by CSP, most particularly in producing process heat and electricity for mining, highlighted the many contexts for CSP to be deployed in Australia in applications that could be investigated for economic feasibility now.

Alice Springs is a standout exception to this, as a site exposed to one of the best DNI levels in the world, having been established as a solar city with a wide range of photovoltaic and concentrating photovoltaic technologies installed, and with the constant load of a town of 27,000. A demonstration plant in Alice Springs would build local capacity, and demonstrate the potential of CSP in ideal conditions.

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