Concentrating Solar Power Market Analysis

Report
April 2010

Clean Energy Council

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Contents

1. Executive Summary

This report provides an overview of the emerging concentrating solar power industry in terms of its technologies, its global growth and its Australian progress to date. It concludes with some forecasts for the industry in Australia.

Technology Review

Concentrating Solar Power (CSP) is divided into two sectors, Concentrating Solar Thermal Power (CST) and Concentrating Photovoltaic Power (CPV). Each of these sectors has several different technologies that are vying to become the dominant solution. These technologies are summarised below.

Concentrating Solar Thermal Power (CST) - Summary

	Mirrors	Solar Axes Tracked	HTF Used	Modular	Single Energy Transfer Point	Long term Operating Experience	Water Required	Flat Land Req'd
Solar Trough	Parabolic	1	Oil	Yes	No	Yes	Yes	Yes
SolarTower	Flat	2	Molten Salt	No	Yes	No	Yes	Yes
Solar Dish	Parabolic	2	No	Yes	No	No	Yes	No
Linear Fresnel	Flat	1	Water	Yes	No	Some	Yes	Yes

Concentrating Photovoltaic Power (CPV) - Summary

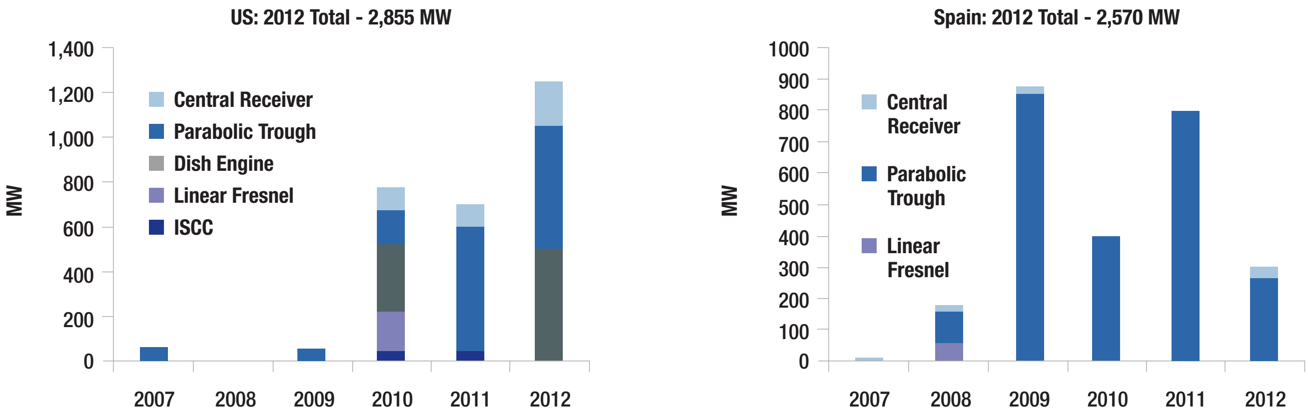
	Mirrors	Solar Axes Tracked	HTF Used	Modular	Single Energy Transfer Point	Long term Operating Experience	Water Required	Flat Land Req'd
Solar PV Dish	Parabolic	2	No	Yes	No	No	Yes	No
Linear Fresnel PV	Flat	1	No	Yes	No	No	No	Yes
HCPV - Tower	Flat	2	Yes	No	Yes	No	Yes	Yes

Overseas Market Trends

Global uptake of CSP technologies is set to grow very quickly over the next few years. This growth will drive economies of scale and the innovation that will drive down the unit cost of future developments. There are 11GW of concentrating projects under development globally, with the largest proportions being planned for the United States, Spain and North Africa.

The technologies that are currently being deployed to the greatest extent globally are Solar Troughs and Linear Fresnel systems, with some Dishes and Central Towers being developed at a demonstration level. Interestingly, as shown in the chart below, developments in Europe are more heavily swayed towards the use of Solar Troughs than in the United States.

US and Spanish Project Pipelines by 2012



Source: Emerging Energy Research

Globally investment in solar companies and technologies, including concentrating solar, has grown exponentially over the last few years. CleanEdge forecast that in the U.S. alone, the installed capacity will increase from 419 MW in 2007 to over 16 GW in 2020. Similar levels of growth are forecast for Europe and North Africa.

US Concentrated Solar Power Installations, Generations (Current and Projected)

Year	Annual CSP Installation (MW)	U.S Cumulative CSP Installed (MW)	Annual CSP Electricity Production at Capacity	CSP Share of Total U.S Electricity Generation
2007	64	419	921,800	0.02%
2010	168	783	1,722,600	0.04%
2015	1,194	4,030	8,866,994	0.20%
2020	3,467	16,471	36,235,965	0.79%
2025	6,613	42,832	94,230,906	1.94%

Australian Market

An assessment of the Australian energy market indicates that CSP is reducing in costs quicker than other technologies and will become cost competitive with other generation technologies between 2015 and 2025. Industry stakeholders have forecast that there might be several hundred megawatts of capacity installed by 2015 and that most of this will be driven by the Solar Flagships program. By 2020 however, the industry believes that there may be over 2,000 MW of installed capacity and that this will be growing quickly.

The slow growth is the result of only moderate government incentives through the capital subsidy of the Solar Flagships. Countries and regions that are experiencing higher growth rates are driven by feed-in-tariffs and mandated purchasing by energy companies. It seems unlikely that these types of measures will be introduced in Australia in the near term.

For the plants that will be built, it will be important to consider climatic conditions, to locate at sites with high insolation, low probability of high-wind events, infrequent cloud cover and low moisture levels. Prospective sites must also be close high voltage transmission lines and, for those considering gas/solar hybrid plants, also close to gas transmission pipelines. The site must have flat, cheap land and ideally be close to a load centre. The analysis in this report provides some indications of the ideal regions that are likely to see many of the future solar plants installations.

Industry Forecasts

It is forecast that there will be only slow growth in the CSP industry in Australia over the next five years. There may be some large projects subsidised by Federal, and probably State, Governments and some smaller CSP installations in remote areas and as part of hybrid power station developments. This will also be complemented by many smaller (1-10 MW) commercial groundmounted flat plate tracking photovoltaic systems.

At some stage between 2015 and 2020, the economics of CSP will become favourable and there is then likely to be strong growth in the Australian industry. The current favoured technologies in global developments are the lower temperature linear technologies such as troughs and Linear Fresnel systems. In the long run, it is likely that the higher temperature systems will become more efficient, but there are some significant developments that will need to take place before investors will be happy to accept the higher risk profile. Whether the cross-over in technology happens before of after the cross-over in energy economics will determine which technology will dominate the Australian market through its growth decade from 2020. In the meantime the large scale solar industry will comprise of commercial sized flat plate solar installations of 1-10 MW along with one or two Solar Flagships supported projects. We may also see several hybrid projects completed with a small (20-40 MW) solar application attached to a larger gas or coal fired plant.

2. Technology Review

There are two kinds of solar energy, solar photovoltaic and solar thermal energy, and each of these can be utilised for either small decentralised power generation or large scale centralised power plants.

Solar photovoltaic technologies convert solar energy directly into electricity with some of the technologies concentrating the solar energy before the conversion process. Solar thermal, by contrast, converts sunlight into heat by concentrating and magnifying sunlight. On a household level, solar photovoltaic technology is represented by flat plate generally silicon based panels. Increasingly there is development work being undertaken to develop Building Integrated Photovoltaic materials so that roofing or window materials can be installed with the solar panel already integrated. Solar thermal energy is represented at the household level by the simple solar hot water system.

This report however is focussed only on those technologies that can be used for large scale centralised power generation and which concentrate the solar power to greater intensities than is found on household units. There a number of competing Concentrating Solar Power (CSP) technologies that fall into the photovoltaic and solar thermal groups.

At a high level, concentrating solar thermal power (CST) simply concentrates sunlight to create high temperature heat to generate steam that drives a steam turbine that creates electricity.

Large scale concentrating solar photovoltaic (CPV) plants use various methods to concentrate the energy from the sun onto a cell that converts this concentrated sunlight into electricity.

The solar cells used for the CPV installations and some of the equipment in CST facilities need to be capable of withstanding very high temperatures and of maintaining their efficiencies over long periods. The ability to meet criterion is one of the general concerns with some of the emerging technologies in this area.

In comparison to the limitations of other renewable energy sources, large scale solar offers some distinct advantages including:

- Peak solar generation overlaps well with peak electricity demand;
- Location is less specific so plants can be located on cheap land close to existing power transmission lines; and
- Solar resources are more predictable than wind or wave and do not require a third party feedstock provider as with biomass and biogas.

The location of the best solar plants, whether CPV or CST, is in areas with the high direct normal radiation. Direct normal radiation generally occurs in desert areas within certain latitudes with both minimal cloud cover and minimal atmospheric moisture.

Clearly the biggest technical problem with solar is that, without using an energy storage device, it is not capable of providing 24 hour base load power. Energy storage capability and costs are improving with technologies such as molten salt storage, ammonia splitting and various battery technologies all offering good prospects to overcome this issue.

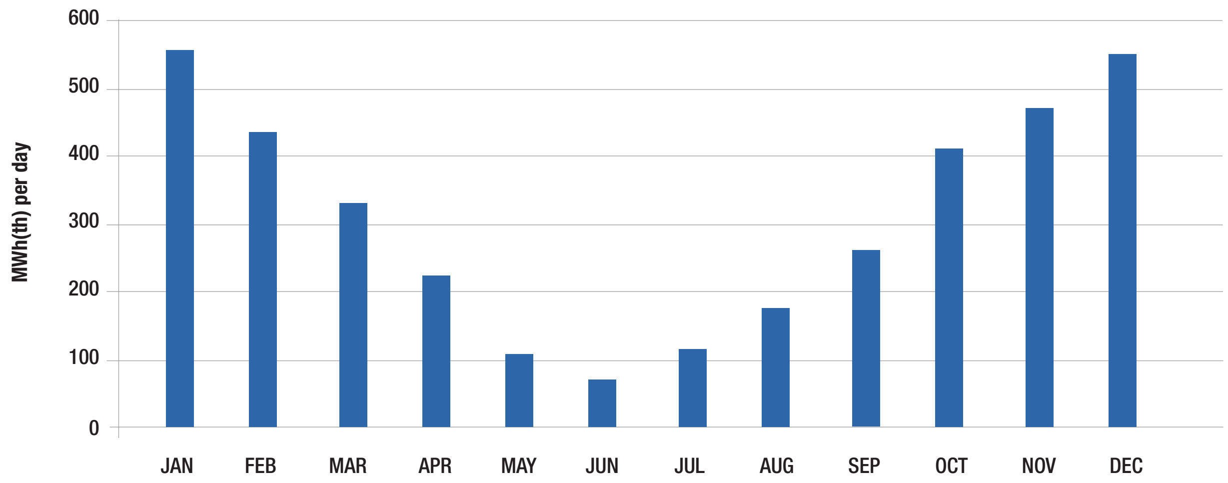
Solar also varies its output depending on the time of year with greater generation capacity during the summer months. The chart below shows the power generation capacity of Ausra's Liddell Power Stations installation throughout the year.

The remainder of this section will look at the technologies available for concentrating solar thermal and concentrating solar photovoltaic installation and then assess the relative advantages of the technologies.

Concentrating Solar Thermal Power (CST)

The CST technologies that have been reviewed are:

- Solar Troughs
- Solar Towers
- Solar Dishes
- Compact Linear Fresnel Reflectors



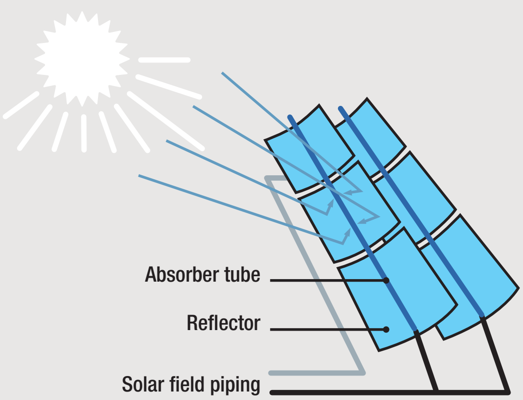
Source: Ausra, 2004

CST1 - Solar Troughs

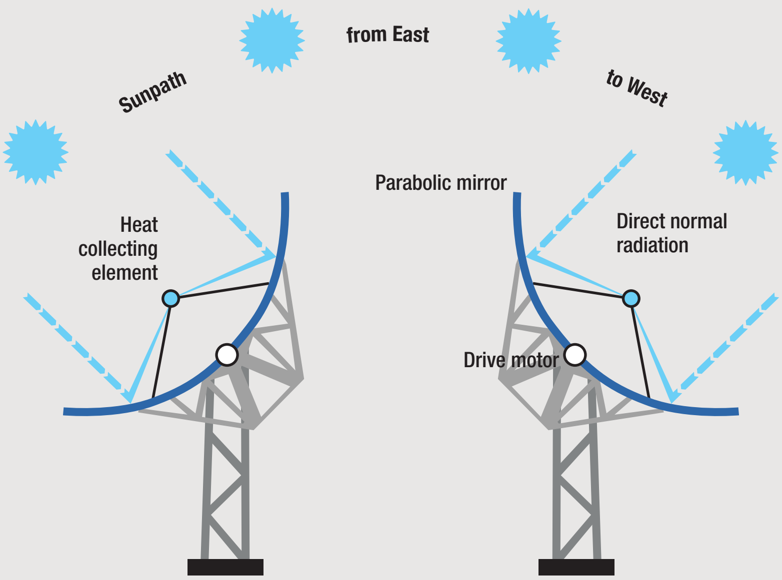
The graphic below illustrates how concentrating solar power works in the case of parabolic troughs, the most developed form of the technology. With parabolic troughs, concentrated sunshine is focused onto a central receiver pipe at the focal point to heat a Heat Transfer Fluid (HTF), which is usually oil to 400ºC. The heat is then used to create steam through a heat exchanger which in turn drives a traditional steam turbine.

Troughs often have single axis tracking so that the troughs stay pointed at the sun throughout the day and maximise efficiency. By combining solar troughs with traditional natural gas fired combined cycle gas turbines, then the overall plant efficiency is increased and it is possible to provide base load firm capacity power and extended operation to morning/evening peaks.

Compared with other CSP technologies, parabolic troughs have mid range efficiencies and mid range construction costs. Parabolic troughs currently have the advantage of a 25-year proven commercial operating record which the other technologies have yet to compile.



Source: ESTIA

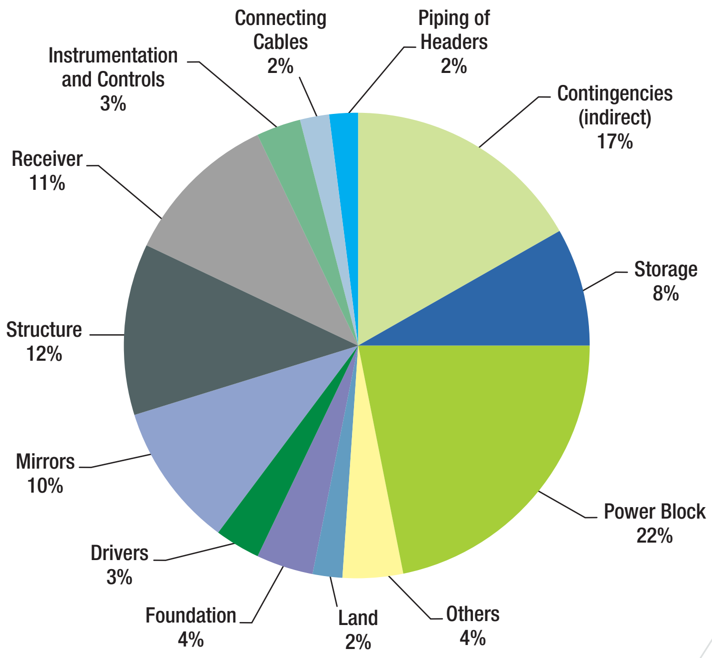


Source: ESTIA

Analysis has been completed by Pitz-Paal et al. in 2005 on a typical cost breakdown for components of a parabolic trough system. This shows that the solar field, including the receivers, mirrors (reflectors), structural support, drivers and foundations, comprises approximately 50% of the total installed project costs.

Receivers and mirrors each contribute approximately 10% to the total. The power block, which is not considered part of the solar field, normally has the highest cost of all the major components, contributing roughly 20% to the total.

Generic Parabolic Trough CSP Cost Breakdown



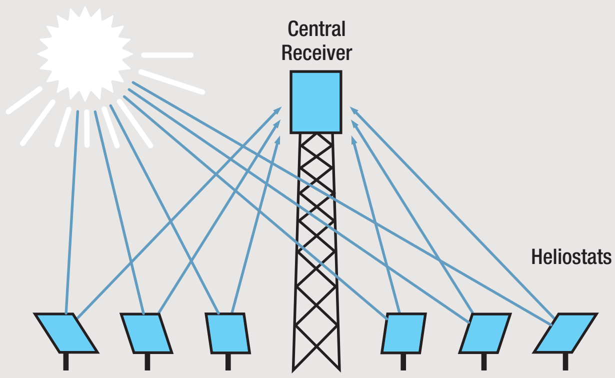
CST2 - Solar Towers

Numerous heliostats focus the sun on a central tower receiver. A heliostat is a flat, sun-tracking mirror. The central tower receiver contains molten nitrate salt, which is heated to 600-800°C and used to raise steam for power generation.

The two-axis tracking of the heliostats enhances sun concentration and temperature, raising the overall thermal efficiency for the plant above those obtained by solar trough plants.

By using a molten salt as the heat transfer fluid it is possible to link that directly with a thermal storage system without having further heat transfer losses.

Solar towers, with the solar dishes reviewed below, reach the highest efficiencies (ie highest temperatures), but also have highest manufacturing and construction costs.



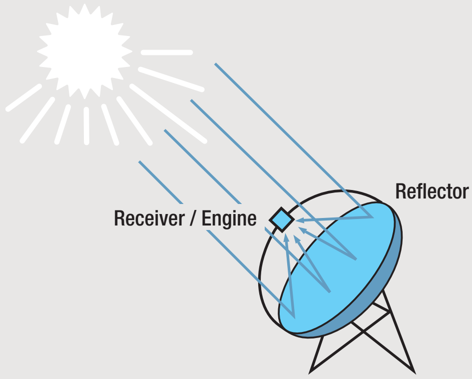
Source: ESTIA

CST3 - Solar Dishes

Solar dishes concentrate solar energy on the receiver which as at the focal point of the parabolic dish. The additional energy focussed from a large dish creates superheated steam that can be used to drive a turbine creating electricity. Dishes can be up to 400m2 in area, with larger versions in various stages of planning.

There are also versions of dishes that have an integrated high-efficiency "external" combustion Stirling engine (often called Dish-Engine technology). The engine has thin tubes containing hydrogen or helium gas that run along the outside of the engine's four piston cylinders and open into the cylinders. As the concentrated sunlight falls on the receiver, it heats the gas in the tubes to very high temperatures causing hot gas to expand inside the cylinders. The expanding gas drives the pistons. The pistons turn a crankshaft, which drives an electric generator.

Solar dishes, with the solar towers reviewed above, reach the highest efficiencies (ie highest temperatures), but also have highest manufacturing and construction costs.



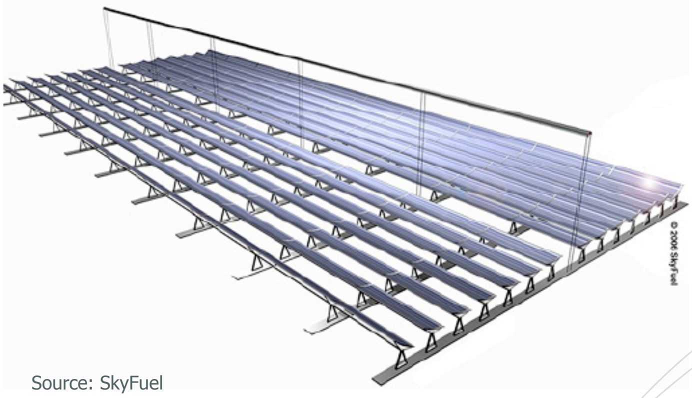
Source: ESTIA

CST4 - Compact Linear Fresnel Reflectors (Linear Fresnel)

The Compact Linear Fresnel Reflectors, such as those being developed by Ausra use 3mm low cost regular glass reflectors and have no moving joints, so are extremely low cost.

Heat is reflected from flat plates onto a water filled tube above. To achieve further cost savings, the heat is applied to the water directly (up to 370 or 450 for SPG technology) rather than using a heat transfer fluid.

All of this means that Fresnel reflectors have the lowest lower manufacturing and construction costs in comparison to other technologies, but also have the lowest efficiencies in power generation.



Source: SkyFuel

Concentrating Solar Thermal Power (CST) - Summary

	Mirrors	Solar Axes Tracked	Heat Transfer Fluid	Modular	Single Energy Transfer Point	Long term Operating Experience	Water Required	Flat Land Req'd
Solar Trough	Parabolic	1	Oil	Yes	No	Yes	Yes	Yes
Solar Tower	Flat	2	Molten Salt	No	Yes	No	Yes	Yes
Solar Dish	Parabolic	2	No	Yes	No	No	Yes	No
Linear Fresnel	Flat	1	Water	Yes	No	Some	Yes	Yes

Concentrating Solar Thermal Power (CST) - Technology Comparison

	Solar Trough	Solar Tower	Solar Dish	Linear Fresnel
Advantages	Steam cycle well understood Proven track record in California (354MW) 1 axis tracking algorithm simple to design/execute Ability to backup with natural gas attractive for intermediate operation Potential for thermal storage to enhance capacity factor Relatively simple to design/construct Credible equipment suppliers Modular construction	Two axis tracking enhances sun concentration: higher temperatures and increased thermal efficiency Ability to use molten salt as working fluid enhances thermal storage options, increasing capacity factor and dispatchability All the energy conversion takes place at one point (the central tower), avoiding complex energy transfer networks Flat mirrors make construction easier	Two axis tracking enhances sun concentration: higher temperatures and increased thermal efficiency Dish Stirling systems have highest demonstrated efficiency of any solar thermal plant Cost benefits of mass production greater than trough/tower technology. Does not require as flat land as trough or tower Modular construction	Steam cycle well understood 1 axis tracking algorithm simple to design/execute Relatively simple to design/construct Flat mirrors make construction easier Direct water heating reduces efficiency losses of heat transfer fluid Modular construction
Disadvantages	Water for steam cycle may be constrained depending on location Heat transfer fluid degradation issues above 300°C Requires flat land (<1% slope) at 2hectares/MW (no storage) 1 axis tracking limits sun concentration Parabolic mirrors expensive and require special fabrication	Currently very capital intensive compared to trough Water for steam cycle may be constrained depending on location Must be built as large units, without the modularity of troughs or dishes Requires flat land (<1% slope) at 4 hectares/MW (storage system) Complex tracking/receiver technology.	Currently very capital intensive compared to trough and tower Dish Stirling not amenable to thermal storage or gas boost Water for steam cycle may be constrained depending on location Requires ~2hectares/MW, slope <5% Parabolic dishes expensive and require special fabrication	Water for steam cycle may be constrained depending on location Requires flat land (<1% slope) at 4 hectares/MW (no storage) 1 axis tracking limits sun concentration

Concentrating Photovoltaic Power (CPV)

The CPV technologies that have been reviewed are:

- Solar PV Dishes
- Compact Linear Fresnel Reflectors using PV
- Heliostat Concentrator Photovoltaic (HCPV)

CPV1 - Solar PV Dishes

Solar PV dishes are very similar to the solar thermal dishes discussed above except that, at the focus point, rather than there being a fluid which gets heated up, there is a receiver made from a high efficiency (>35%) PV cell. An example is the cell manufactured by Boeing's Spectrolab.

The output from this cell is a high voltage DC current that is then transformed by a common inverter into AC current. The receiver incorporates a cooling unit (water cooled) to maintain low temperature despite the 500x solar concentration. The dish has twin axis sun-tracking that maximises the capacity factor.

CPV2 - Compact Linear Fresnel Reflectors using PV

The Compact Linear Fresnel Reflectors using PV are only slightly similar to the thermal fresnel technology above. The sun's energy is converted to electricity using a PV cell rather than through steam generation and the system uses refraction of sunlight rather than reflection to concentrate the energy.

This technology focuses the sun's rays by refraction through a lens and onto a PV cell behind each of the lenses. The concentration factor is around a multiple of 250. A module of this technology will have a greater number of PV cells required than a PV dish, but the solar cells do not have such a great concentration of solar energy and so do not get so hot and do not have to be so robust and expensive.

There is no water cooling with the cells relying on passive air cooling delivered through off-ground mounting. This reduces the cost and complexity of the units but may also reduce the efficiencies. Like the dishes, one of these units will track the sun along two axes to maximise its efficiency.

CPV3 - Heliostat Concentrator Photovoltaic (HCPV)

The Heliostat Concentrator PV system is again very similar to its thermal equivalent with numerous flat mirrors all concentrating the solar energy onto a central tower at a concentration multiple of 500.

The difference of course is that the central tower contains a PV cell rather than fluid that creates steam. Because only a single high efficiency cell is required and all of the mirrors are made from standard materials, the technology may be cheaper than others. It does however rely on the quality of the ultra powerful solar PV module.

The system also has a cooling system to keep solar cells operating at 60ºC to optimise the operation of the PV modules in a concentrated solar beam that can melt steel.

The heliostats track the sun on two axes for increased efficiency. Proponents state that because there is only a single cell involved it is easy to upgrade the plant as the efficiency of solar cells increases over time.

Concentrating Photovoltaic Power (CPV) - Summary

	Mirrors	Solar Axes Tracked	Single Receiver Cell Req'd	Modular	Single Energy Transfer Point	Long term Operating Experience	Water Required	Flat Land Req'd
Solar PV Dish	Parabolic	2	No	Yes	No	No	Yes	No
Linear Fresnel PV	Flat	2	No	Yes	No	No	No	Yes
HCPV - Tower	Flat	2	Yes	No	Yes	No	Yes	Yes

Concentrating Photovoltaic Power (CPV) - Technology Comparison

	Solar PV Dish	Linear Fresnel PV	HCPV - Tower
Advantages	Two axis tracking enhances sun concentration: higher solar concentration. Cell module is distinct, small and potentially lost cost part of much larger unit. Active cooling system as source of low grade heat for other applications.	Cell module is distinct, small and small proportion of overall cost. Optics can be controlled at time of manufacture without the need to be aligned in the field. Two axis tracking enhances sun concentration: higher solar concentration No failsafe provisions necessary to prevent damage from concentrated flux in event of erroneous sun-tracking Modules are sealed, flat panels making cleaning comparatively easy Cells are passively cooled: no fluids handling, failsafe provisions for loss-of-coolant events necessary.	Two axis tracking enhances sun concentration: higher solar concentration. All the energy conversion takes place at one point (the central tower), avoiding complex energy transfer networks. Flat mirrors make construction easier. Active cooling system as source of low grade heat for other applications.
Disadvantages	Concentrator performance under diffuse sunlight low. Complexity and parasitic load of active cooling system. Water for cooling may be constrained – desert location. Complex tracking/receiver technology.	Concentrator performance under diffuse sunlight low. Fresnel lens system lower concentration per m2 compared to dish/parabolic concentrator. Complex tracking/receiver technology.	Water for cooling may be constrained – desert location. Must be built as large units, without the modularity of dishes. Requires flat land (<1% slope) at 4 hectares/MW (storage system). Complex tracking/receiver technology.

3. Overseas Market Trends

Scale

Due to falling prices of concentrating solar power technology (both thermal and PV), the generous Government subsidies in some jurisdictions, the synergies with natural gas and the benefits of using heat storage, investment is flowing into the Concentrating Solar Power industry. Global capacity is expanding rapidly. In 2007, after a 15-year hiatus, the first new CSP capacity in the world went online: Acciona's 64MW "Nevada Solar One" solar trough project outside Las Vegas, Nevada. In Spain, a further 50MW of parabolic trough capacity named "Andasol 1" is also now online and its capacity is being tripled to 150MW.

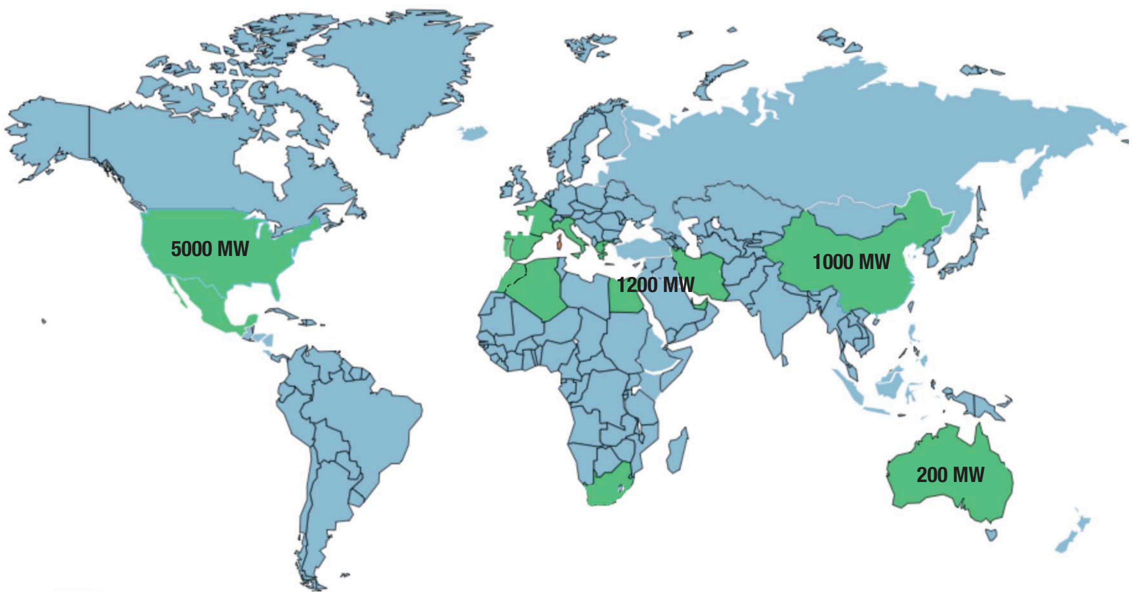
In the Middle East, natural gas rich Abu Dhabi is investing in CSP to provide electricity for its MASDAR 'green city.' In California alone, nearly 3,000MW of new CSP capacity is now before permitting authorities, and 7,000MW of new capacity is planned worldwide. Given that CSP plants take only 24 months to construct once approved, much of this new capacity could be online by 2013. This significant uptake of technologies is likely to lead to significant economies of scale and an acceleration along the experience curve for those technologies being installed. Planned capacity expansions worldwide are expected to expand the industry 15 times over in the next five years, providing a firm commercial platform for future growth.

The figures below provide details of:

- a map showing the locations of the 11,000MW of concentrating solar power that is forecast to be installed by 2012;
- installed and announced CSP plants worldwide by technology; and
- solar trough plants in the United States in 2007.

These figures together show that the largest installations are forecast to occur in the United States (5000MW), Europe, North Africa (1600MW) and the Middle East (1200MW). China is also forecast to have a reasonable quantity of CSP installations over the next 4 years with 1000MW. Australia, despite the having excellent solar resources is only forecast to have 200MW installed by 2012 and, currently, even this appears to be unlikely to be achieved.

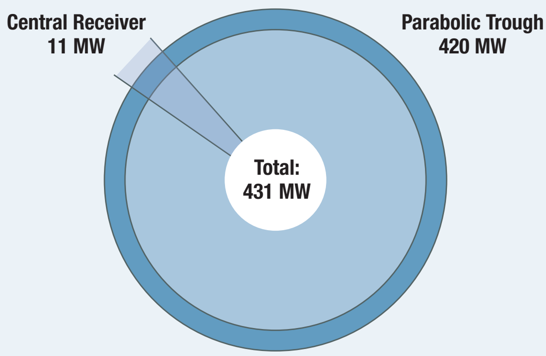
11GW of CSP Projects Currently under Development



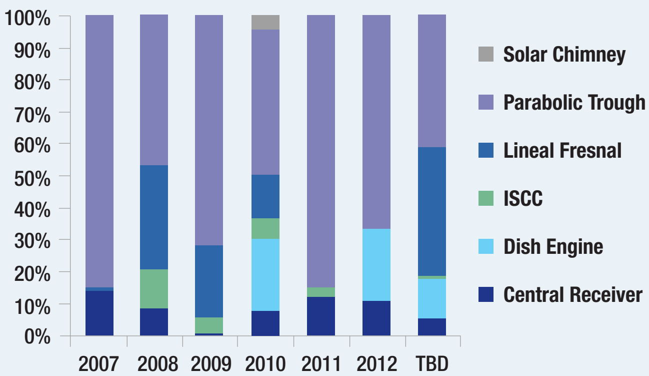
Source: Estela

Concentrating Solar Power by Technology

Current Installed CSP Technology



Announced CSP Facilities by Technology



- Abengoa's 11 MW central receiver system is the first large-scale commercial facility to come online in 17 years
- Acciona's 64 MW Nevada Solar One plant is the first parabolic trough plant to come online since 1991
- No current facilities have additional storage capabilities

- Solar Millenium has announced 1,000 MW of parabolic trough planned for Inner Mongolia by 2020
- 3,000 MW of Fresnel is planned by Solar Power Group for North Africa with the Libyan Center for Solar Research

Source: Emerging Energy Research

Installed Solar Trough Plants in the United States

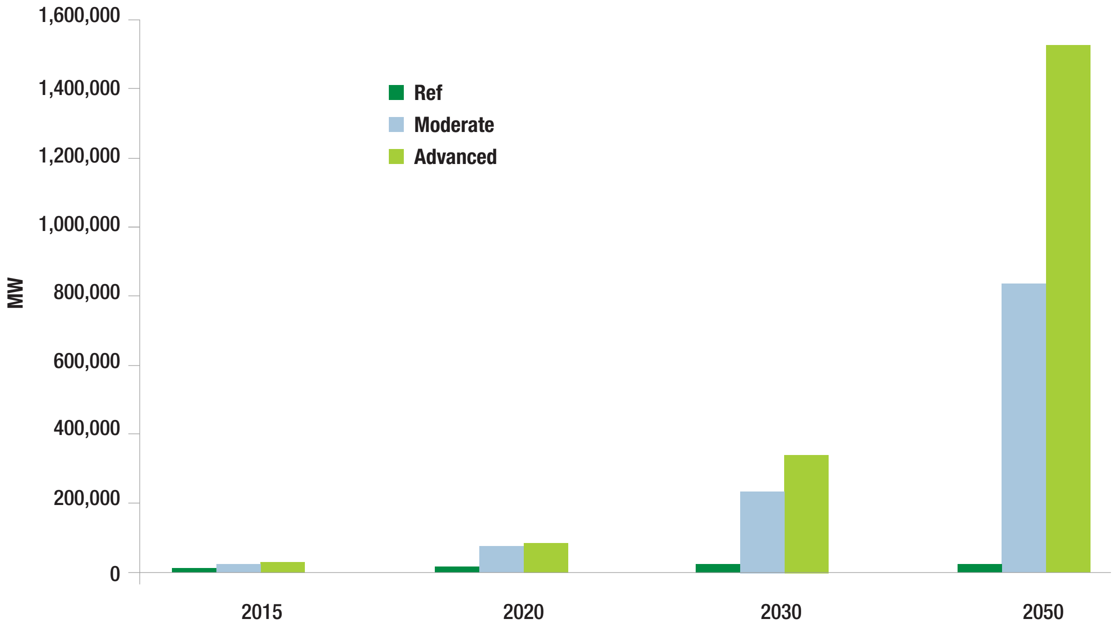
Plant Name	Location	First Year of Operation	Net Output (MW)	Solar Field Outlet (°C)	Solar Field Area (m ²)	Solar Turbine Effic. (%)	Power Cycle	Dispatchability Provided by
Nevada Solar One	Boulder City, NV	2007*	64	390	357,200	37.6	100 bar, reheat	None
APS Saquaro	Tuscan, AZ	2006	1	300	10,340	20.7	ORC	None
SEGS IX	Harper Lake, CA	1991	80	390	483,960	37.6	100 bar, reheat	HTF heater
SEGS VIII	Harper Lake, CA	1990	80	390	464,340	37.6	100 bar, reheat	HTF heater
SEGS VI	Kramer Junction, CA	1989	30	390	188,000	37.5	100 bar, reheat	Gas boiler
SEGS V	Kramer Junction, CA	1989	30	349	194,280	37.5	40 bar steam,	Gas boiler
SEGS III	Kramer Junction, CA	1987	30	349	250,500	30.6	40 bar steam,	Gas boiler
SEGS IV	Kramer Junction, CA	1987	30	349	230,300	30.6	40 bar steam,	Gas boiler
SEGS II	Daggett, CA	1986	30	316	190,338	29.4	40 bar steam,	Gas boiler
SEGS I	Daggett, CA	1985	13.8	307	82,960	31.5	40 bar steam,	3-hrs TES

Source: US National Renewable Energy Laboratory

Growth

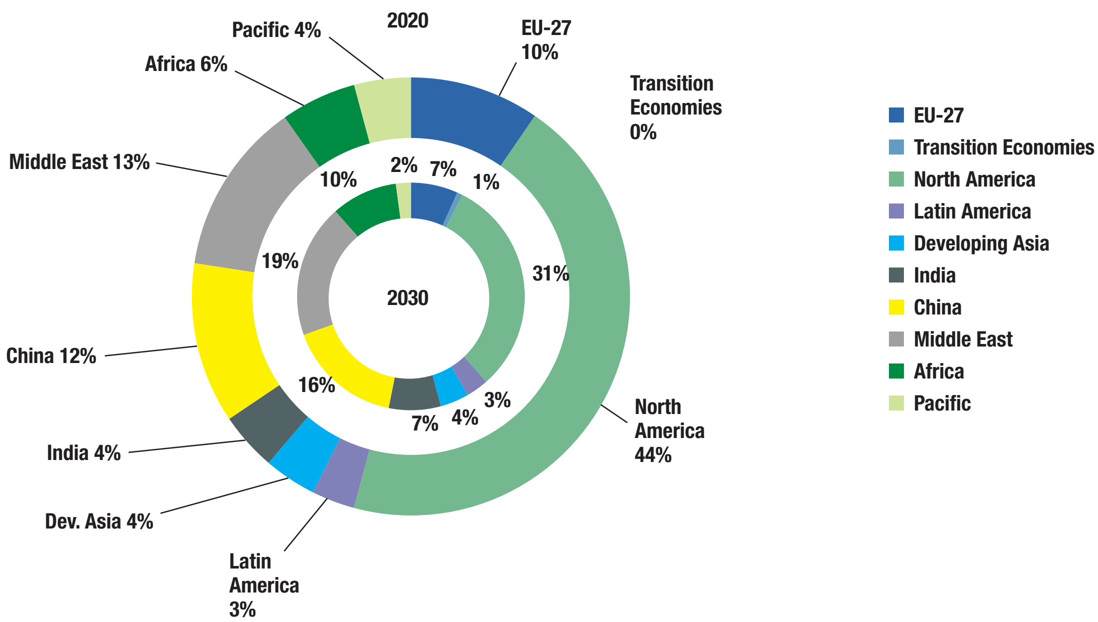
Looking further into the future, there are many varying estimates of the scale that concentrating solar technologies might achieve and exactly when it starts to form a significant part of global energy production.

The chart from the European Solar Electricity Association shows three scenarios of global growth for CSP, with the Moderate scenario installations of 69 GW and 231 GW by 2020 and 2030 respectively. The Reference scenario in this analysis **'takes into account existing policies and measures, but includes assumptions such as continuing electricity and gas market reform, the liberalisation of cross-border energy trade and recent policies aimed at combating pollution'.** The Moderate scenario 'takes into account all policy measures to support renewable energy either under way or planned around the world. It also assumes that the targets set by many countries for either renewables or concentrated solar power are successfully implemented'. The Advanced scenario **'examines how much this industry could grow in a best case 'concentrated solar power vision'.**



Source: ESTELA

The same report also provides forecasts for the geographic split for this Moderate scenario, with the chart below showing North America, the Middle East and China together accounting for some 69% of the installed capacity by 2020.

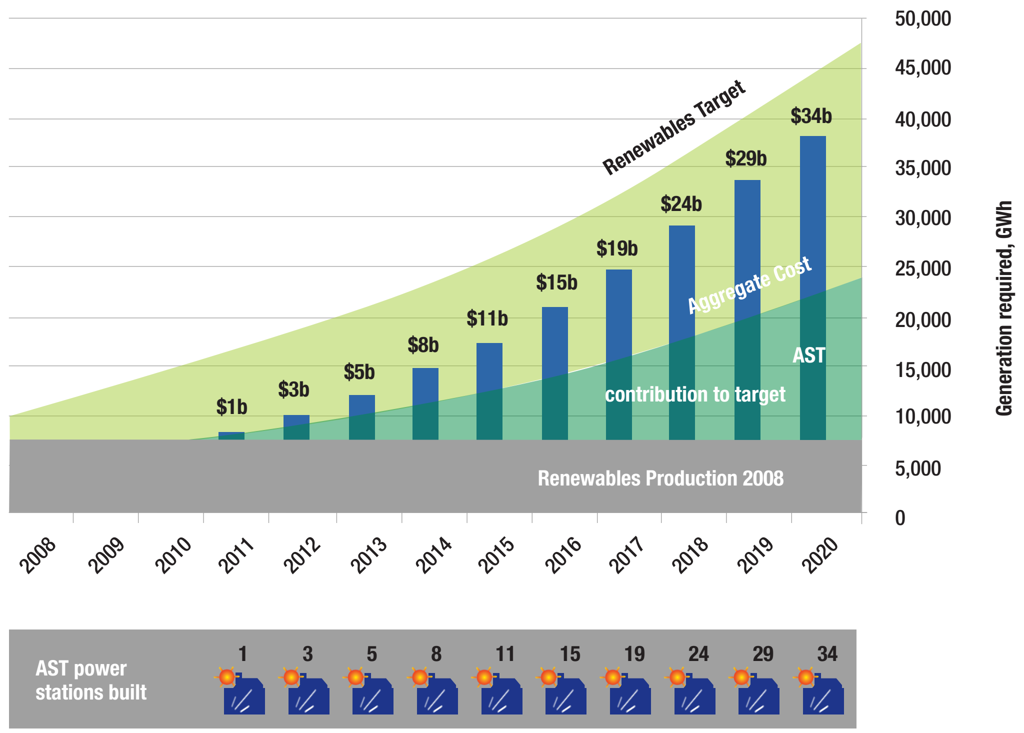


An estimate for solar power in Australia was produced by Worley Parsons in 2008. As shown in the chart below, Worley Parson's has estimated that by 2020, there will be 34 Advanced Solar Thermal (AST) plants each with a capacity of 250MW operating in Australia to give a total of 9GW. The report assumes that the technology used for these plants is solar troughs. The plants will have cost a total of A$34 billion and could fulfil 50% of the 20% Renewable Energy Target promised by the Federal Government.

McKinsey & Co published a report in June 2008 titled The Economics of Solar Power which considered the likely growth and the competitiveness of both concentrating and distributed solar technologies.

In this report it states:

The technology that currently seems most attractive for utilities is concentrated solar thermal power, because it involves centralized electricity generation……and is today's low-cost solar champion. Its long-term cost prospects, though, are less favourable than those of some emerging photovoltaic technologies, so choosing it now is in effect a strategic bet on how quickly relative costs and local subsidy environments will change.

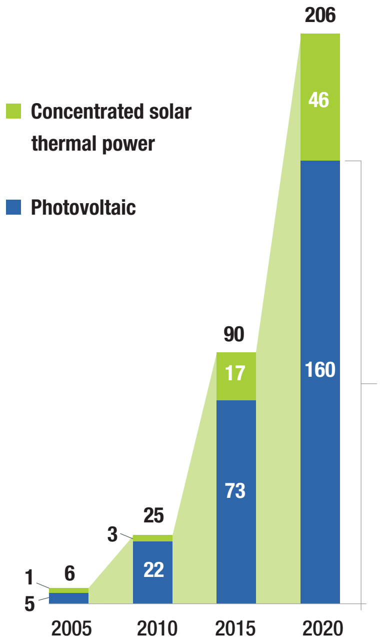


Source: Worley Parsons

The bulk of this McKinsey report considers distributed flat-plate PV panels, due to their current dominance over concentrating solar in terms of production and installed capacity. It does however provide some interesting statistics on the growth of both the PV panel market and of CSP. The chart beside shows the forecast growth of the global PV market with a forecast installed capacity of 46 GW by 2020.

Finally, market growth and investment trends have been sourced from CleanEdge. The table below comes from a report that reviewed the potential for the large scale roll out of utility scale solar in the United States an estimates some 16 GW will be installed by 2020.

The Global Solar Market Cumulative Installed Capacity (GW) in 2020



Source: McKinsey & Co

U.S. Concentrated Solar Power Installations, Generation (Current and Projected)

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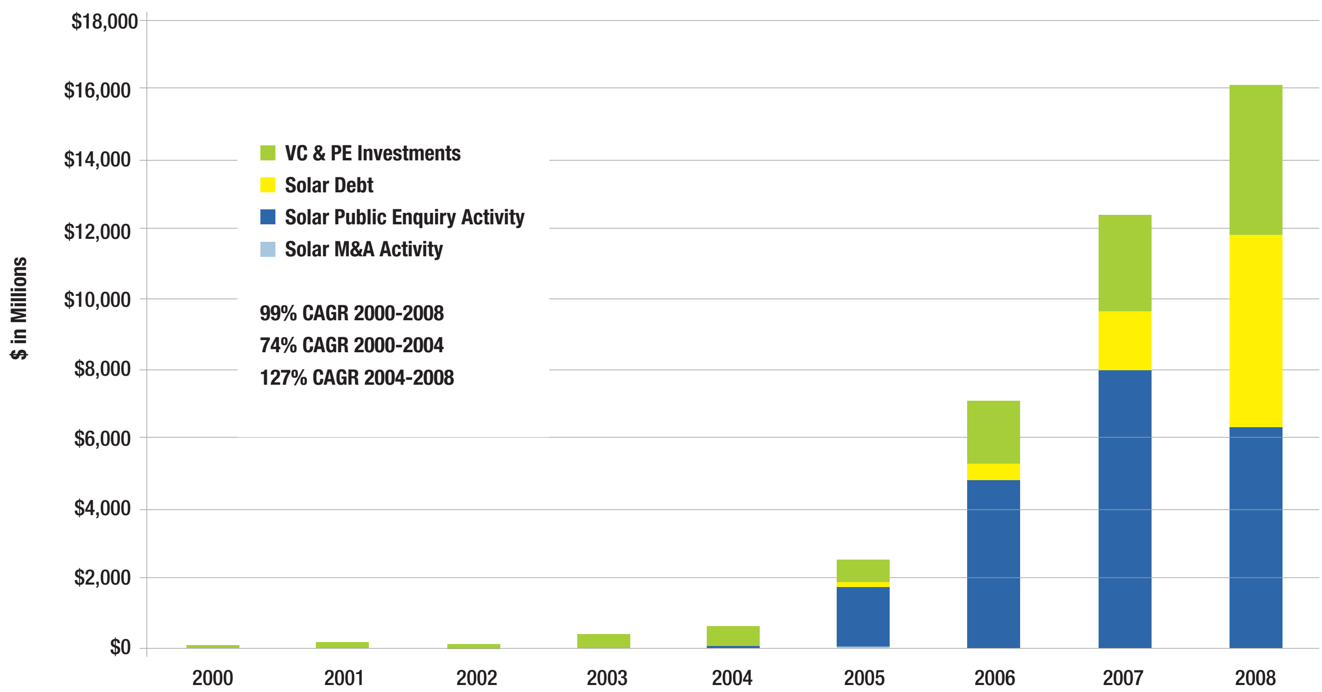
2007	64	419	921,800	0.02%
2010	168	783	1,722,600	0.04%
2015	1,194	4,030	8,866,994	0.20%
2020	3,467	16,471	36,235,965	0.79%
2025	6,613	42,832	94,230,906	1.94%

Source: CleanEdge

The Bloomberg New Energy Finance data that is presented in the two charts below shows the investments in solar companies between 2000 and 2008. The first chart shows this by investment source and the second by technology and region. From this latter chart it can be seen that there was virtually no investment in any region in CSP until 2008, when there were reasonable investments starting to be seen. Some of the investment into the 'Project Developer' category will also include developers of CSP projects.

Global Capital Investment in Solar Energy



Source: Bloomberg New Energy Finance

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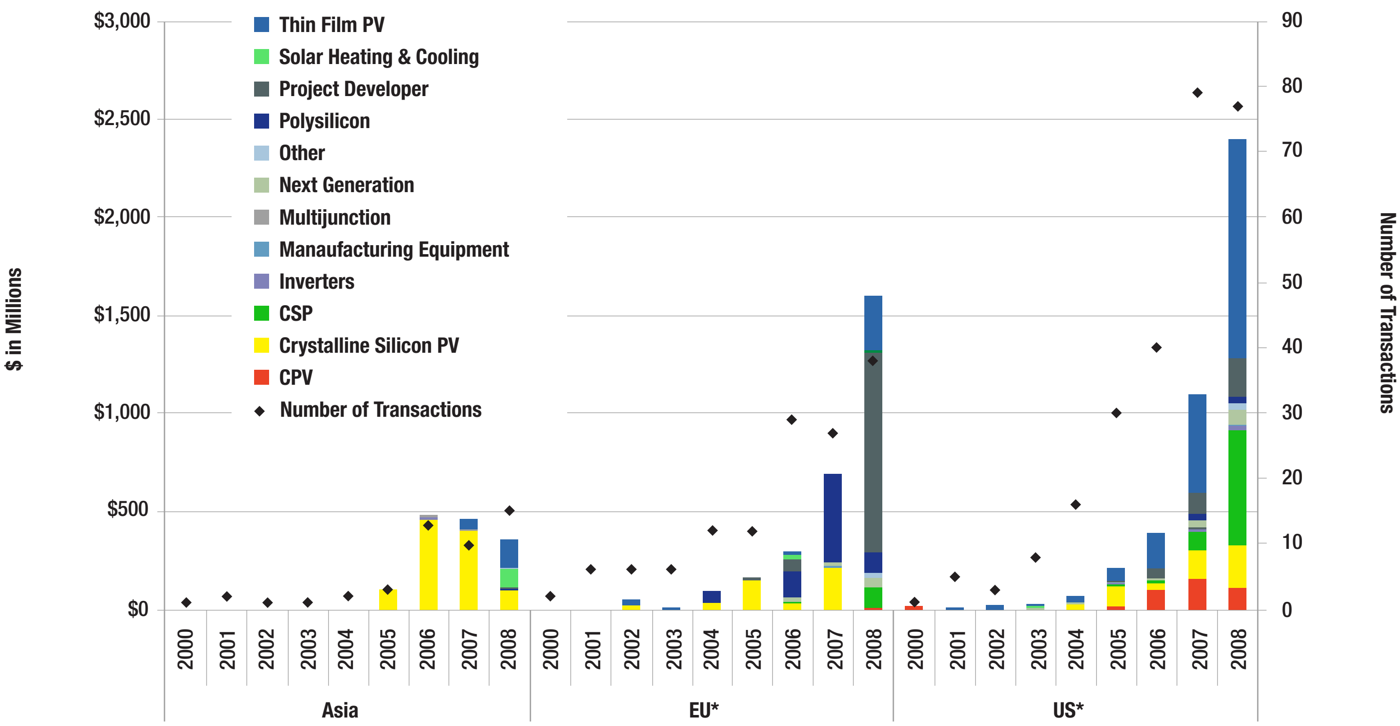


Source: Bloomberg New Energy Finance

*EU includes Israel, Morocco and South Africa
**US includes Australia and Canada

4. Australian Market

Concentrating Solar Power in Australia

Concentrating solar power in Australia has received some high profile coverage over the last five years.

This has included:

- EnviroMission's proposed 'mile high' solar chimney in Mildura;
- in 2007, David Mills of Solar Heat & Power taking his Linear Fresnel technology from New South Wales to form Ausra in California, where he secured the funding that he had been unable to find in Australia;
- Solar Systems being awarded $75m in 2006 from the Federal Government under the Low Emissions Technology Development Fund and $50m from the Victorian State Government to build its Solar Tower plant in Mildura, and the subsequent failure of the company in 2009 and the sale of its assets to Sylex Systems;
- Wizard Power announcing its success in securing a federal Government grant for its 'Big Dish' trial project in Whyalla;
- Acquasol Infrastructure Limited making announcements on its proposed gas/solar hybrid power station and desalination project in Port Augusta; and
- commentary on how solar thermal could help reduce the emissions of coal fired generators by providing pre-heating for the steam cycle.

However, with all of this publicity and prospective projects, there have been few hard assets constructed other than the following:

- the first stage of Solar Heat & Power's 1 MW demonstration plant at the Liddell Power Station in NSW was commissioned in 2004 and extended to 3 MW in 2008;
- the Australian National University in Canberra has built two of its 'Big Dishes';
- Wizard Power is using improved version of these dishes for its four dish 0.5 MW demonstration plant that is due for completion in late 2010; and
- there have also been some remote area installations using technologies provided by both Solar Systems and Green and Gold.

Despite this lack of progress, Australia has significant potential for widespread deployment of CSP facilities. The Worley Parson's estimates presented in Section 4 demonstrated confidence in the emergence of this sector within Australia.

The primary reason behind the potential growth is that the solar resources in Australia are extremely good. Parts of the interior, in northern South Australia and western New South Wales, have solar resources that are as good as anywhere in the world. Leading international technology companies such as Ausra and Man Solar Millennium have seen this potential and have active local operations seeking to develop large scale projects. There is a view that once prices fall to competitive levels, the only remaining hurdle will be how to economically get the power from the deserts to the cities. This latter point however presents a significant issue for the long term future of the industry in Australia.

Whilst the Solar Flagships program discussed below has focussed attention on dedicated solar facilities, there are several companies seeking to develop hybrid solar/fossil fuel power plants. This option enables projects to get up without such significant levels of financial support and would enable any company involved in these hybrid projects to then be better prepared when unsubsidised dedicated solar power plants become viable.

Policy Environment

The policy environment is clearly very important to driving any growth in the solar industry until such time as the technologies are viable on an unsupported basis. The global growth has been entirely driven by favourable regulatory regimes that either provide feed-in-tariffs or requiring local power utilities to lower their emissions profile for each MWh generated or purchased.

A policy tool that has been extremely successful in Germany, Spain and California has been the introduction of gross feed-in tariffs. Whilst some Australian States have introduced feed-in tariffs they are generally based on the net export of power from the house and are limited in size to only cover rooftop systems. By adopting a system that provided additional guaranteed revenue from a feed-in tariff for large scale generators based on gross output, the stimulus for technology uptake is likely to be provided.

The 20% by 2020 Renewable Energy Target (RET) will have a huge impact on the short term growth prospects of the renewable energy industry in general over the next five years. In the longer term this will then be replaced by some sort of price on carbon, regardless of whether it takes the form of a trading scheme or a tax.

However, neither of these schemes will particularly drive any large solar projects. The cheapest readily available form of additional renewable energy is wind power and it is likely to remain so for several more years. These legislative incentives will therefore just drive investment into the higher returns generated by wind power and provide no momentum for solar.

Since its introduction in 2009, the RET has had some unintended consequences. A part of the scheme that provided additional incentives for household PV and solar hot water systems by granting additional Renewable Energy Credits (RECs) and allowing the credits to be claimed upon installation had the effect of bringing down the REC price of to below $30. Most larger developers are claiming that a price of $50/REC is required to achieve sufficient levels of viability for projects to proceed. In late February 2010, the residential and large scale components of the RET were proposed to be separated from 1 January 2011 and this should help stabilise the REC price at a higher level.

Recognising that the RET will largely just drive wind farm development, the Federal Government introduced the Solar Flagships program in May 2009, with the original aim of using $1.5 billion to help make 1,000 MW over four solar projects viable and attractive to investors and developers. After a very negative reaction from the industry regarding the adequacy of this funding, the Boston Consulting Group was commissioned to review the scheme. In December 2009, the program was recast into two rounds with the Round 1 aiming to fund two projects, one using a thermal technology and the second using a photovoltaic technology, that would jointly deliver at last 300 MW with a target of 400 MW. The technologies have to be 'commercially proven' by having units of at least 30MW that have been operating for at least 12 months. There is also a constraint placed on paying for hybrid plants, although it may be possible to integrate a solar project that is awarded a grant with a neighbouring coal or gas fired power plant without contravening the guidelines.

Round 2 is scheduled to be held after the first two projects are operational. The aim of separating the program in this manner was to give a chance to technologies that are not yet proven to be eligible in the second round. However, many in the industry believe that it is quite possible that this second round will never take place.

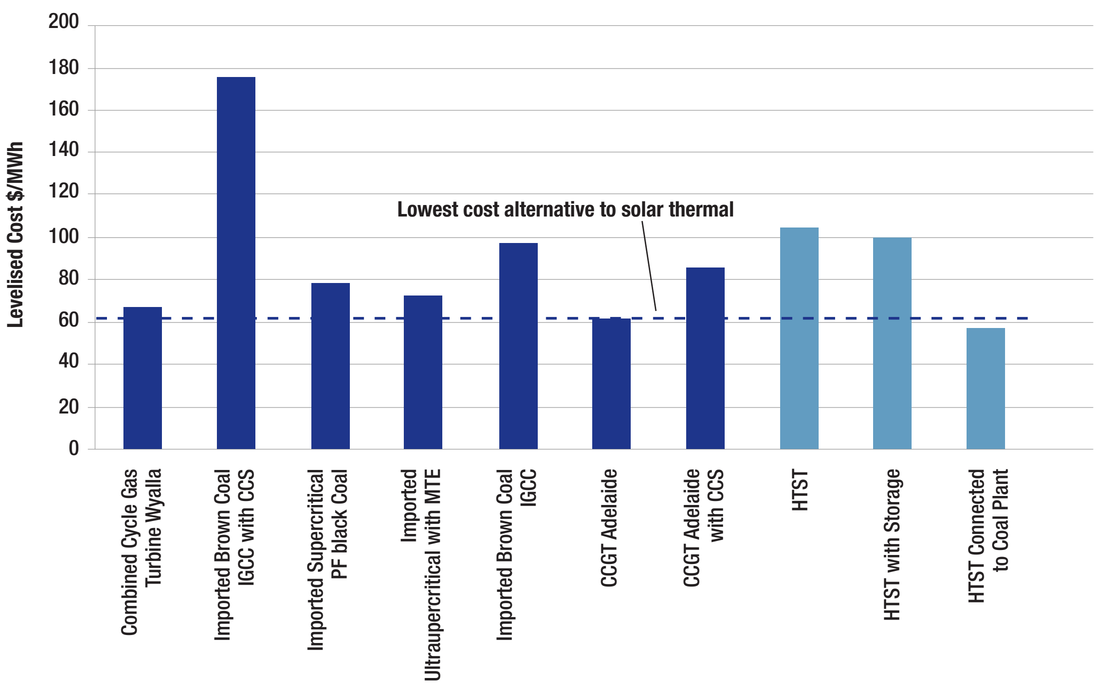
Despite the limitations placed on the Solar Flagships program, there were 52 submissions made by the deadline of 15 February 2010. It seems highly likely that not very many of these submissions will meet all of the key criteria in the program guidelines. In particular, the requirement for proven technology in an emerging environment constrains the projects to only a handful of proponents. A shortlist of submissions is expected shortly with final announcements to be made by the end of 2010.

Comparative Power Prices

The economics of CSP do not currently justify any unsubsidised investment in Australia.

In a study undertaken by the Wyld Group for the Victorian and New South Wales Governments in 2007, the specifics of technology pricing for South Australia in 2020 was considered. In the chart below HTST stands for High Temperature Solar Thermal and it shows that a stand alone CSP plant would be unable to compete on cost with a combined cycle gas turbine plant. It also shows however that the cheapest option might be a coal/solar hybrid facility.

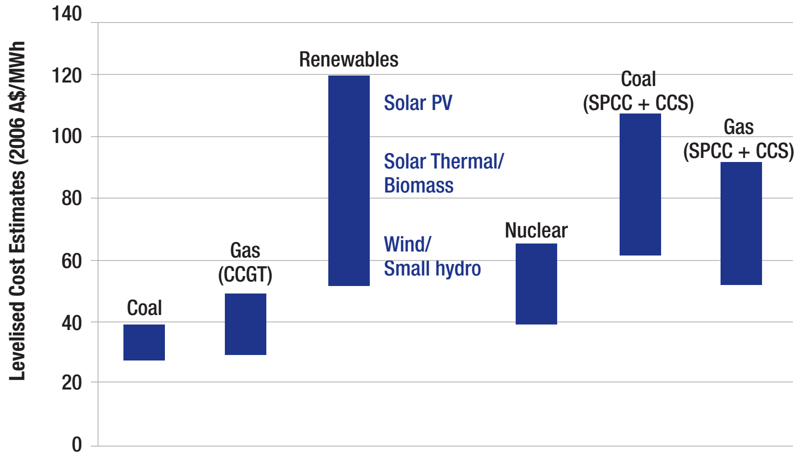
Levilised energy cost of new plant in Port Augusta, South Australia, 2020



Source: Wyld Group

Another estimate was undertaken by the Australian Energy Regulator in its State of the Energy Market 2009 report. The chart below from this report shows estimates of what it may cost toimplement Carbon Capture and Storage (CCS) and how that compares to other existing technologies. Solar thermal appears to provide a viable current option when CCS is considered, although, again, wind generation is an even cheaper source.

Lifecycle Economic Costs of Electricity Generation

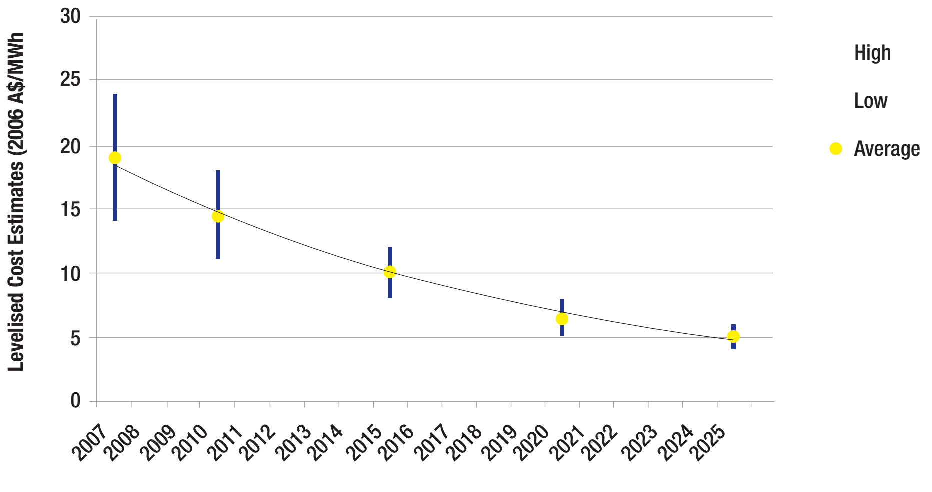


CCGT, combined cycle gas turbine: CCS, carbon capture and storage (costs are indicative only); PV, photovoltaic; SPCC, supercritical pulverised coal combustion (in which steam is created at very high temperatures and pressures

Source: Australian Energy Regulator

A further report by Clean Edge in 2008 estimated that the 2007 average cost for concentrating solar power was just under US$200/MWh and that this would fall to US$50/MWh by 2025.

CSP Price Ranges 2007-2025 (Cents/kWh)



Source: Clean Edge 2008

Location Factors

To develop the optimum concentrating solar power project in Australia requires a consideration of a number of specific factors that will determine the project location.

These factors include:

Climatic Factors
- High solar insolation
- Low probability of high-wind events

Infrastructure Factors - Access to HV transmission
- Access to gas infrastructure (for hybrid plants)

Other Factors - Flat, cheap land
- Proximity to load centres

Some of these factors are considered below.

Climatic Factors

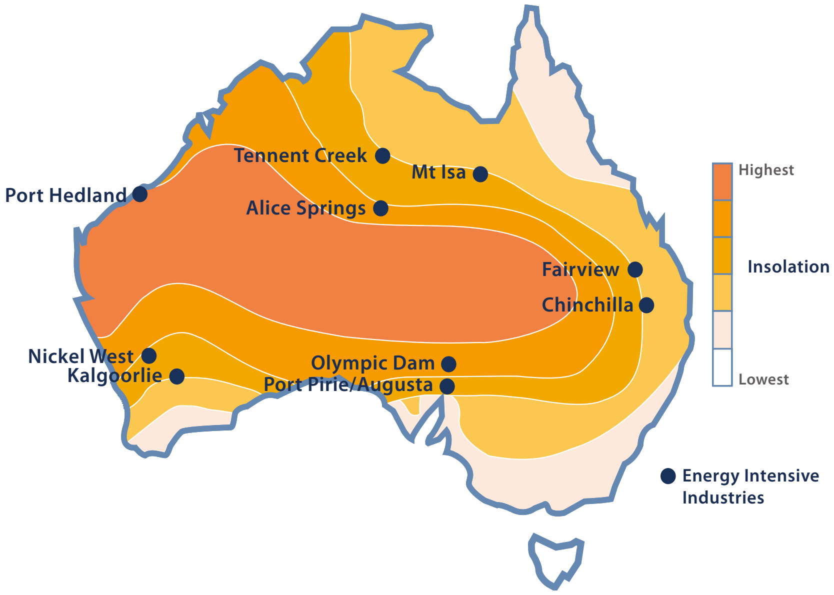
Not surprisingly, there are plenty of areas within Australia that have high levels of average daily sunshine hours. By considering everywhere with an average of greater than 7 hours of sunlight per day, means that it is only southern Victoria and Tasmania that are immediately excluded. In addition to sunlight hours, a consideration of direct normal radiation is critical. Direct normal radiation can be affected by air moisture and by cloud cover, so it is often inland dry desert regions that display the best direct normal radiation.

Other climatic factors also influence the choice of site such as tropical areas being susceptible to the high winds of cyclones that would make CSP installations too expensive. Sub-tropical areas have frequent cloud cover which reduces the solar radiation. These factors therefore exclude northern and coastal Queensland as well as any parts of the Northern Territory and Western Australia that are in cyclone territory.

Summer rainfall is also a factor that would count against a site as summer is the time of peak electricity demand and higher pool prices. It would therefore not make sense to build at a site where production decreased during the period of peak demand.

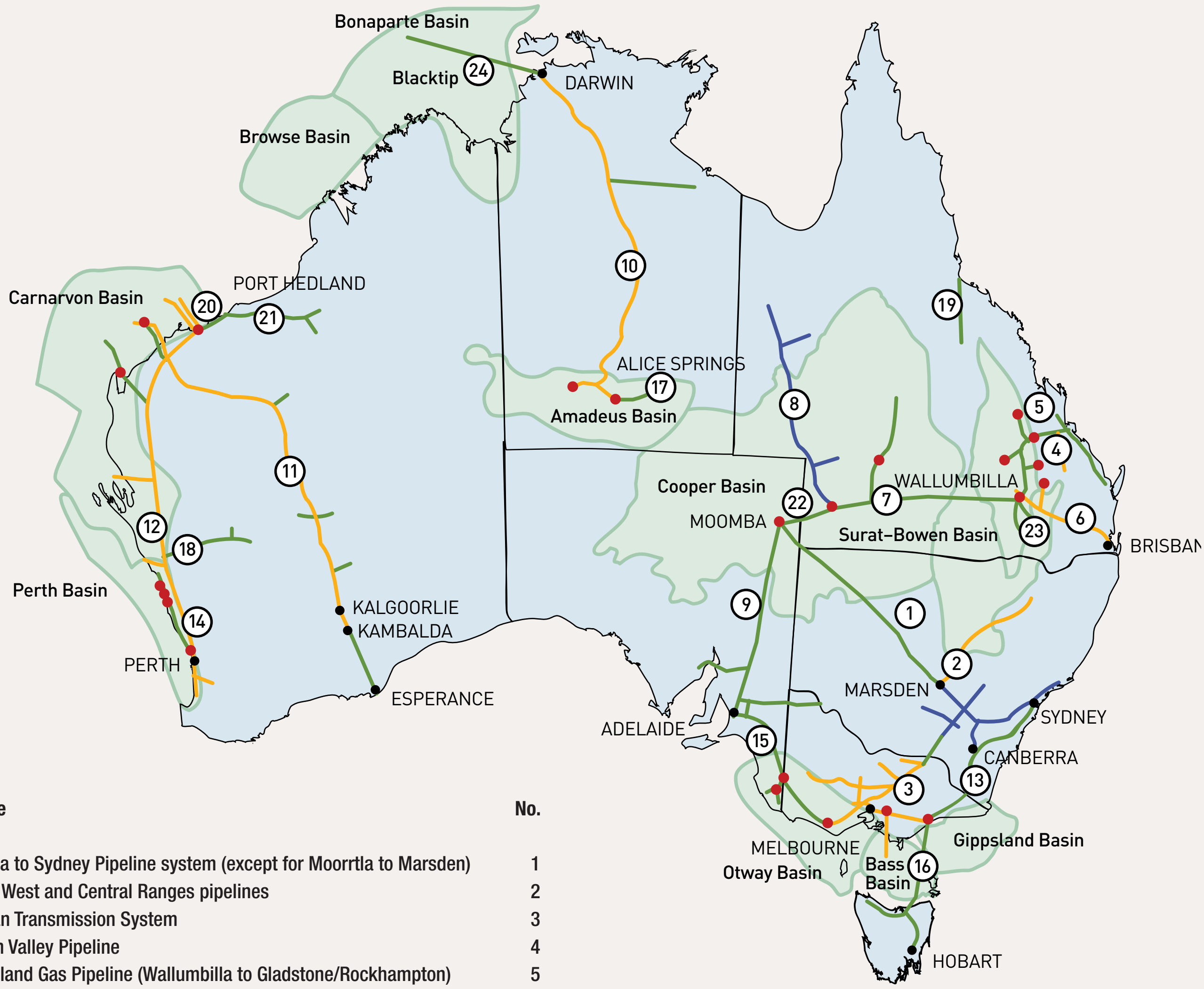
Using these climatic drivers alone would lead to a site location in northern South Australia or western New South Wales.

Solar Insolation Map of Australia

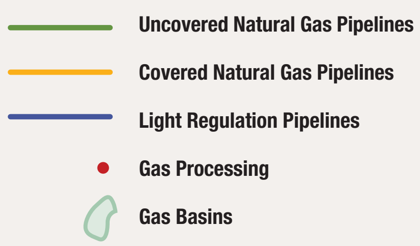


Source: Drawn for ANZSES using data from the Australian Solar Radiation Data Handbook reproduced by the WWF

Major Gas Transmission Pipelines



Pipeline	No.
Moomba to Sydney Pipeline system (except for Moorrtla to Marsden)	1
Central West and Central Ranges pipelines	2
Victorian Transmission System	3
Dawson Valley Pipeline	4
Queensland Gas Pipeline (Wallumbilla to Gladstone/Rockhampton)	5
Roma to Brisbane Pipeline	6
South West Queensland Pipeline (Ballera to Wallumbilla)	7
Carpentaria Pipeline (Ballera to Mount Isa)	8
Moomba to Adelaide Pipeline system	9
Amadeus Basin to Darwin Pipeline	10
Goldfields Gas Pipeline	11
Dampier to Sunbury Natural Gas Pipeline	12
Eastern Gas Pipeline (Longford to Horsley Park)	13
Parmelia Pipeline	14
SEA Gas Pipeline	15
Tasmanian Gas Pipeline	16
Palm Valley to Alice Springs Pipeline	17
Midwest Pipeline	18
North Queensland Gas Pipeline	19
Pilbara Pipeline	20
Telfer Pipeline	21
QSN link	22
Berwyndale to Wallumbilla Pipeline	23
Bonaparte Pipeline	24



Source: Australian Energy Regulator

If a hybrid gas/solar plant is being considered then clearly easy access to a gas transmission pipeline is essential. This then further limits the areas to strips along the southern part of the Moomba Adelaide Pipeline, along the Adelaide to Mildura Pipeline, areas in central New South Wales and, if the climatic factors are acceptable, areas in central Queensland.

Infrastructure Factors

Locations close to power transmission lines require the least cost to connect into the existing system. This is an advantage of solar power in that there is flexibility of locations to be able to reduce this connection cost. Compare this to the optimum wind sites in coastal areas that are often a long way from powerlines. By also locating at the 'end' of the powerlines that historically transport power out to these regions, power can instead be fed back the other way and so potentially reduce the need for future capacity upgrades. This criterion provides sites in northern South Australia, through the Riverland, into central New South Wales and north passed Roma.

There may also be potential to site concentrating solar power infrastructure in the easements that run below the power transmission lines.

Transmission Networks in the Electricity Market

Source: Australian Energy Regulator

Stakeholder Feedback

As part of this study, a number of interviews were undertaken with industry participants to find any common themes and constraints that are being experienced across the industry.

The stakeholders were asked to respond to the following questions:

1. How much capacity do you predict will be installed in Australia by 2015 and by 2020?
2. What Government incentives do you predict will be implemented to drive this growth?
3. What technologies do you see making up the majority of this installed capacity?
4. Which global suppliers do you think have the best chance of long term success?
5. Are there any Australian technologies that will achieve scale? If so, which ones?
6. What energy storage technologies do you predict will be used as part of this roll out?

Samples of the responses are provided in the table below.

Questions	Responses
1. How much capacity do you predict will be installed in Australia by 2015 and by 2020?	2015: 400-800MW 2020 : 1500-3000 MW
2. What Government incentives do you predict will be implemented to drive this growth?	Solar Flagships program will drive a significant amount of capacity, as well as the changes to the Renewable Energy Target. A Feed-in-Tariff for larger facilities would drive strong growth but seems unlikely at present. Dispatch priority for renewable energy in the NEM, possibly as an amendment to the RET. Acknowledgment of embedded PV as "firm peak generation capacity".
3. What technologies do you see making up the majority of this installed capacity?	Technologies capable of integrating with current and new fossil fuel thermal installations in hybrid plants will have the first mover advantage. For stand-alone power projects it will be the technologies that have the greatest capability for performance improvement, such as Linear Fresnel and the larger dish technologies for remote communities. Distributed installation of multiple units ranging in size from 1 MW to 10 MW. Key technical concept is to install power plants at strategically selected locations with the main purpose to feed electricity into the existing network at points where the network is currently at risk of insufficient supply capacity.
4. Which global suppliers do you think have the best chance of long term success?	So much consolidation is occurring right now that it is difficult to predict. Those technology companies with the backing of major global utilities will have far greater reach and consequent chance of success. Developers that are not tied to a specific manufacturer or technology.
5. Are there any Australian technologies that will achieve scale? If so, which ones?	Does Linear Fresnel still count as Australian? Maybe Origin Energy's Sliver technology
6. What energy storage technologies do you predict will be used as part of this roll out?	Perhaps 4-5 hours storage may be desirable for extended summer demands, but I believe it will be in a form yet to be developed. Maybe hydro pump storage but not necessarily directly linked to solar projects, more as general network balancing technology.

5. Industry Forecast

In Lord Nicholas Stern's publication, Meeting the Climate Challenge: Using Public Funds to Leverage Private Investment in Developing Countries, it was detailed that to be effective, policies must:

- be Transparent, Long-term and exhibit Certainty through consistent, secure and predictable, payment mechanisms ("TLC");
- introduce incentives that decrease over time as technologies move towards market competitiveness;
- eliminate non-economic barriers (grid access, administrative obstacles, lack of information, social acceptance);
- provide fair and open access to distribution channels (e.g. transmission grid); and
- be enforceable.

In developing Australian solar policies that will drive industry development, these principles are equally as applicable. In particular, the first point regarding policies being Transparent, Long-term and exhibiting Certainty (TLC) is critical for there to be any long term investments in this emerging sector in Australia.

To date the solar policy environment has been subject to change with the Low Emissions Technology Development Fund in 2006 failing to deliver anything of significance and the recent changes to the Solar Flagships program delaying two of the four projects for several years. To build long term operating assets, developers will need this certainty, and as yet the Australian policy environment is not able to provide this.

Australia appears to be the ideal location for CSP projects. It has plentiful solar resources and lots of cheap flat land. The tyranny of distance and the lack of available water provide some barriers to development, but nothing that is insurmountable. The only thing holding the country from starting to build a significant CSP industry is the lack of incentives in the form of feed-in-tariffs or mandated solar supply into the grid. The capital subsidies have been welcomed by the industry, but are generally seen as too low. It may be that some of the richer states are able to 'top up' the promised Federal money to bring the projects within their borders.

Despite all the promise, the short term picture for CSP in Australia does not appear to be one of rapid growth has been seen in other parts of the world. The industry sees that several hundred megawatts will be constructed over the next five years, primarily driven by the Solar Flagships program. By 2020, the industry sees that the costs for CSP will have reduced at the same time as the fossil fuel generated power will be hit with higher carbon tariffs, and that the Australian CSP industry will be growing very quickly.

Which of the technologies will succeed is debatable within the industry. In the longer term, it is seen that those technologies which have the greatest improvements still to make and those that use greater levels of concentration, using dishes and towers, will be the eventual winners. In the meantime the linear concentrators such as parabolic troughs and compact linear Fresnel systems will probably provide many of the installations due to their current lower risk profiles. When the cross-over happens will depend on the rate of efficiency improvements for each of the technologies and when the greater returns generated by the higher concentrators outweigh the greater risks inherent in the higher temperatures.

It still appears that the future for Concentrating Solar Power in Australia is bright. The brightness is currently at the end of a tunnel that may span several years. Commercial sized flat plate solar installations of 1-10 MW may fill the gap along with one or two Solar Flagships supported projects. We may also see several hybrid projects completed with a small (20-40 MW) solar applicationattached to a larger gas or coal fired plant.

The real growth in the industry in Australia, however, is still over five years away. However, once the growth point is reached there are likely to be significant numbers of large installations built over the period 2015 to 2030. Those companies that have gained experience before this growth occurs will be in a very strong position when it arrives.

Appendix 1 – Australian CleanTech Profile

Australian CleanTech is a research and broking firm that provides advice to cleantech companies, financial institutions and governments at all levels. Through its work it provides a bridge between investors and the investment and regulatory requirements of cleantech projects. With extensive experience in both cleantech technology assessment and investment analysis, Australian CleanTech provides unique services that will facilitate and deliver successful Australian clean technology projects.

Research Database

Australian CleanTech has developed and maintains a database of global cleantech companies. The database contains company profiles of more than 1400 companies, over 350 of which are based in Australia. Each company is assessed on the basis of their technical, regulatory and commercial risk profiles.

ACT Australian Cleantech Index

Australian CleanTech publishes the ACT Australian Cleantech Index provides a measure of the performance of the Australian listed stocks in the cleantech sector. With over 75 companies following under the coverage of the index and with a combined market capitalisation of over $10Bn, the index presents for the first time a picture of the Australian cleantech industry's growth in a single measure.

Sydney and Adelaide Cleantech Networks

Australian CleanTech facilitates both the Sydney and Adelaide Cleantech Networks that provide opportunities for those involved with the cleantech sector to meet, learn and collaborate.

Investor Services

Project sourcing, technical assessment, investment management, delivering exit strategies, lobbying.

Project Services

Development of growth strategies, sourcing funding, industry and technology research, strategic, project delivery, Intellectual Property protection strategies, securing and retaining the right people, securing Government grants, power, water and environmental credit purchase agreement negotiation, commercialising strategies, international expansion.

Government Services

policy development, policy impact analysis, economic development, facilitation of Industry Clusters, information dissemination

Recent Projects

Australian CleanTech has worked the following recent projects:

Growth Strategy

Australian CleanTech undertook a strategic review of the growth strategy of United Utilities and in particular developed scenarios for entry into other sectors and identified specific target acquisitions and projects.

Acquisition Searches

Australian CleanTech has performed acquisition searches and analysis for a private equity company and other corporations seeking to acquire cleantech companies. In particular there has been a focus water companies and technologies.

Tender Management

Australian CleanTech worked for United Utilities Australia leading its tender preparation for a wastewater treatment and recycling project in Victoria. Government Advice – Australian CleanTech has provided advice to state and local Governments on investment attraction and future skills and training requirements in the cleantech sector.

Current projects include:

- Advising DFEEST on future workforce skills and assisting the department to undertake a strategic review of TAFE courses to build in the flexibility to prepare for future technology scenarios.
- Working for DTED and Flinders University on the preparation of a South Australian Cleantech Sector Capability and Capacity Study which will involve a survey of all South Australian cleantech companies.

Solar Technology and Opportunity Review

For an oil and gas company seeking to invest in large scale solar projects.

Coal Bed Methane Review

For a large French energy company seeking to invest in Australia.

Cleantech Projects

Australian CleanTech is providing consulting services to companies seeking commercialisation, expansion and project finance. In addition, Australian CleanTech has provided the services including strategic consulting, corporate structuring, grant submission preparation, power and environmental credit purchase agreement facilitation, funding documentation preparation, financial modeling and introductions to potential investors. Clients include:

- A 180MW solar thermal and natural gas fired power station that includes a scalable desalination plant and brine capture and harvesting. The advisory role will be ongoing with a board position;
- A multiple wind farm development that utilises an in novative vertically integrated business model involving community financing and participation. The advisory role will be ongoing with a board position;
- Technology companies involved with biofuels, energy efficiency, geothermal energy, water treatment, desalination and nanotechnologies.

Events

Australian CleanTech has conceived and launched Australia's first cleantech network, the Adelaide Cleantech Network that will bring together cleantech companies seeking seed, expansion or exit capital with equity and debt financiers wanting to invest in this emerging sector. The Sydney Cleantech Network was launched in September 2009 in partnership with the ASX, Macquarie Group, KPMG, Clayton Utz and New Energy Finance.

Environmental Water

Australian CleanTech conceived and is currently developing a collaboration of both commercial and non-profit organisations that will enable individuals and companies to invest in environmental water to be able to claim to be 'Water Neutral'.

CleanFutures

Australian CleanTech conceived and is developing a joint venture to commercialise a number of nanotechnologies that is has secured from NanoVentures Australia. The technologies include a biosensor used for the real time detection of phosphate and nitrates in environmental waters, a water treatment technology and nano-composite materials.

John O’Brien

BA(Oxon), MSc, MBA, GAICD, CPEng MIE Aust

John is the founder and Managing Director of Australian CleanTech and has advised numerous organizations on their options with respect to securing or making cleantech investments. He has also launched the ACT Australian CleanTech Index that tracks the performance of Australia’s listed Cleantech companies, is facilitating the Sydney and Adelaide Cleantech Networks, is on the board of three unlisted cleantech start-ups, edited the book, Opportunities Beyond Carbon, is a regular media commentator and is a member of the South Australian Premier’s Climate Change Council.

John previously worked for Origin Energy on growth, strategy and M&A projects in addition to being the founding secretary of the company’s Operational Risk Committee. He specialized in reviewing and filtering clean energy and water industry opportunities. Through the combination and interaction of these sectors he became interested in the emerging cleantech sector and in 2004 started developing the plans for a cleantech business.

He has engineering degrees from the University of Oxford and Trinity College, Dublin and an MBA from the University of Adelaide. He has completed the AICD’s Company Directors Course, is a chartered engineer with the Institute of Engineers Australia and is a member of the Australian Water Association and Responsible Investment Association of Australia.

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