REALISING THE POTENTIAL OF CONCENTRATING SOLAR POWER IN AUSTRALIA

Summary for Stakeholders

PREPARED BY IT POWER (AUSTRALIA) PTY LTD
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Realising the Potential of Concentrating Solar Power in Australia – Summary for Stakeholders

Realising the Potential of Concentrating Solar Power in Australia – Summary for Stakeholders is available as a separate document but also forms part of the full detailed report: Realising the Potential of Concentrating Solar Power in Australia.

The Australian Solar Institute (ASI) has commissioned this study to facilitate discussion on the potential for Concentrating Solar Power (CSP) in Australia.

Study undertaken and report prepared by IT Power (Australia) Pty Ltd, part of the IT Power group, a specialist engineering consultancy focussing on renewable energy, energy efficiency and climate change. IT Power has offices in Australia, China, India, Kenya,, Morocco, Portugal, UK and USA.

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Report at a Glance

Major changes in the world's established energy supply systems are being driven by growing energy demand, energy security concerns, rising greenhouse gas emissions, local environmental issues, increasing oil prices, and international competition to lead in the emerging clean energy technologies. Australia shares these global concerns. To address them all at least cost and risk, while providing energy for intra-day peaks and longer-term demands, a portfolio of energy options is needed. Concentrating Solar Power (CSP) is one of those options. However, a significant cost-revenue gap for CSP projects is deterring private investment. Concerted action is needed to close that gap and retain CSP as a strong energy option for Australia's future.

CSP is proven and available

Global installed capacity of CSP is growing rapidly and is predicted to reach 2 GW in 2013, led by Spain and the US. Concentrating solar thermal (CST) plants dominate, typically using standard steam turbines and often integrating thermal energy storage.

CSP can contribute significantly to Australia's energy needs

Australia has just over 50 GW in electricity generation capacity from all sources. This study finds that, it would be technically feasible to add up to 15 GW of CSP capacity, with only modest grid extensions. Hybrid systems within existing fossil-fuel plants, and smaller plants for off-grid mines and towns, are important near term applications for CSP systems. Future 'nation-building' grid extensions would unlock more of Australia's world-leading solar resource, which vastly exceeds all predictable energy demand.

CSP offers particular benefits

As part of a future energy portfolio, CSP systems would deliver:

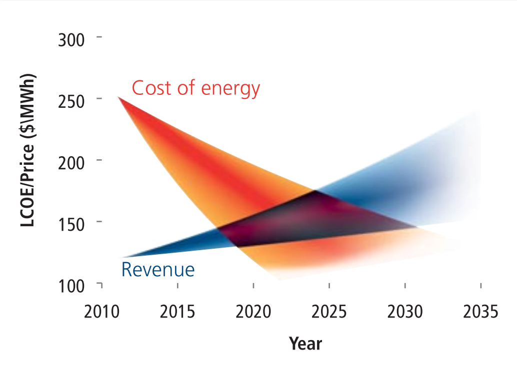
- **Dispatchable energy supply:** Systems that can dispatch electricity in the range of baseload to peaking power are an essential complement to variable renewable sources. CSP with storage has that capability.
- **Lower emission conventional power plants:** CSP can be efficiently integrated into existing and new coal and gas power plants to reduce emissions and extend plant life for a least-cost transition to a low-emission energy future.
- **Emission reduction:** 10 GW of capacity would reduce Australia's emissions by roughly 30 Mt CO_2 per year, about 15% of current electricity sector emissions.
- **Clean energy sector growth:** Only a few countries are currently investing in CSP. With CSP exploiting its world-leading solar resources, Australia can claim a significant place in the global clean energy supply chain. Delaying action will see that opportunity missed.
- **Community-supported generation:** CSP need not compete for valuable land or water and is low-impact. Every 100 MW system would create around 500 job years during construction and 20 jobs during operation, mostly in regional areas.
- **Potential for future solar fuels:** Emerging technology will convert solar energy to liquid fuels, supplied at scale to both domestic and export markets.

However, the cost-revenue gap is currently too great

The CSP cost-revenue equation varies enormously with system configuration and location. Instantaneous CSP generation correlates well with peak electricity prices. With thermal storage, the energy value of CSP systems is even higher, up to double the wholesale market average. Even so, CSP projects are not yet commercially attractive in Australia. For utility-scale systems, the baseline 'levelised cost of energy' (LCOE) is around $250 per MWh, while maximum revenue streams in main grid-connected markets currently total around $120 per MWh (including renewable certificates). The gap is smaller for the relatively small off-grid mining and remote towns sector.

The gap will close, with the help of Australian action

Consistent with overseas research, this study finds that the cost-revenue gap for CSP in Australia is likely to close over the next 6 to 18 years as plant costs fall through global deployment and technology improvement and available revenue rises. However, these projections depend on continued global investment in CSP. At this early stage of the global industry, Australia has the opportunity to contribute significantly to momentum in reducing costs and risk. Completing 250 MW of Solar Flagships and other deployments and maintaining a sector annual growth in line with recent global rates would lead to an Australian CSP capacity of around 2 GW by 2020.



Concerted Australian action needed

1: Bridge the reducing cost-revenue gap

Whilst continuing to focus on lowering cost, the CSP sector should work with governments and regulators to increase the reward for clean energy systems that better correlate generation to real-time demand.

Rather than subsidising CSP specifically, technology-neutral measures should target the dispatchable characteristics that Australia needs. Early deployment where the cost-revenue gap and other challenges are smaller will help maximise CSP opportunities and bridge the gap. The CSP industry must continue to focus on demonstrating lowering costs from deployment learning and technology improvement.

2: Build confidence in CSP's offer

The CSP sector should better communicate CSP's value proposition to key stakeholders including AEMO, AEMC, electricity retailers and financiers.

Government, consumer, energy industry and investor support for CSP will remain ephemeral until there is a base of understanding and confidence. The CSP sector must explain CSP's potential benefits, demonstrate them in practice, and respond to concerns.

3: Establish CSP-solar precincts

The CSP sector should work with governments, regulators and service providers to pre-approve and provide connections for CSP systems in selected areas of high solar resource.

CSP precincts would reduce planning, approvals and grid connection costs, helping to reduce early-stage project risk. They would also spread the costs of solar data collection, environmental impact assessments and community consultation across projects.

4: Foster CSP research, development and demonstration

The CSP sector should leverage continued public and industry investment in research, development and demonstration, with more emphasis on meeting Australian needs.

Building CSP in Australia requires growth in skills and capabilities that are lacking; targeting deployment of systems below 50 MW (overlooked by the global industry); incorporating energy storage; improving efficiency; hybridisation with fossil fuel plants; and using advanced cooling technologies (reflecting our water constraints).

If these actions are pursued successfully, the CSP sector would be large enough to deliver economies of scale within immediate investment and policy horizons.

Outlining CSP's future in Australia

Major change in the world's established energy supply systems is being driven by growing energy demand, energy security concerns, rising greenhouse gas emissions, local environmental issues, increasing oil prices, and international competition to lead in the emerging clean energy technologies.

Australia shares these global concerns. We have local pollution issues associated with energy generation. Although gas production is rising, Australia's domestic oil production is declining just as demand is growing and international prices continue to rise. Electricity demand, while slowing due to energy-efficiency and other demand-side measures, is predicted to grow at 0.9 to 1.5% annually.[1]

There is also a continuing lack of diversity in an energy mix dominated by fossil fuels. Although these have given Australia comparatively low energy costs, that advantage is being eroded. As fossil-fuel prices rise, countries that offer the best clean technologies may gain a new competitive advantage.

Nonetheless, Australia's most explicit driver is the aim to reduce net greenhouse gas emissions to 80% below 2000 levels by 2050. Given the high proportion of emissions from the power sector, and the challenges of reducing greenhouse emissions in the transport sector, meeting this target will require extensive clean electricity generation to be in place by 2050.

Concentrating Solar Power (CSP)[2] technologies are one of the future options being deployed with rising confidence and rapidity around the globe, led by Spain and the US.

Meeting Australia's energy needs

Decisions about Australia's energy future taken through to 2020 will lock in significant parts of our energy mix for decades. Most electricity used in Australia in 2050 will be generated from plants that do not yet exist. Over $200 billion in new generation investment is projected, over half being in renewables. Australia's transmission and distribution networks also require significant investment.

A portfolio approach is likely to offer the least cost and lowest risk pathway to meeting Australia's energy needs and emission targets. Wind and solar photovoltaic (PV) generation are the international success stories to date. However, they convert wind and solar energy only when they are available, and so require spinning reserve and fast-start power plants to manage their variability.

A significant part of our future clean electricity mix must be dispatchable on demand. Apart from concentrating solar power (CSP)[3] , clean energy technologies that are often suggested to provide that dispatchable power include geothermal and fossil-fuel generation with carbon capture and storage. All have risks that match their potential. CSP should be kept as an available option.

CSP's role in meeting those needs

CSP systems offer large-scale clean energy generation that can be configured to provide energy for intra-day peaks and longer-term demands. Australia has previously invested in a handful of small demonstration projects and at the time of writing, is working to finalise a major "Flagship" CSP project. Together with the overseas experience, they point to the potential for CSP making a significant contribution to Australia's future energy needs.

However, private investment in commercial projects remains limited. Though it is closing, the cost-benefit gap is still significant. Benefits to both the energy sector and the broader community are not recognised in the limited equations of project finance. Two of the most important benefits – preparing to meet Australia's long term greenhouse gas emissions reduction challenge, and securing for Australia a valued part of the global renewable energy supply chain – have greatest value if early action is taken. Targeted effort is needed to ensure the commercial case becomes positive as quickly as possible. Part of that effort must be to raise awareness of CSP technologies among Australian policymakers, energy consumers and financiers, and to build confidence in their potential.

1 Australian Government, Draft Energy White Paper 2011, p 38.

2 The term Concentrating Solar Power is often used synonymously around the world with Concentrating Solar Thermal Power (CST). In this study, the term is used in a more general sense to include both CST and Concentrating Photovoltaic (CPV) systems. The scope of the study was limited to systems designed for utility scale power generation and did not specifically include solar fuels or industrial heat.

3 CSP systems can also be variable but CST variants with built in thermal storage offer dispatchable characteristics.

As a step towards that awareness, the Australian Solar Institute has commissioned a detailed study on the current realities, potential and challenges for a CSP industry. This summary report for stakeholders presents the core findings of the study, and its views on constructive actions ahead. It offers a snapshot of:

a] CSP technology and its international adoption and growth,

b] Its potential applications and markets in Australia,

c] At the project level in those markets, the available revenues and the costs of attaining them,

d] The resulting commercial equation for CSP projects,

e] Available public and sector benefits that aren't being captured at project level, and

f] Options to accelerate CSP's development in Australia and so capture those benefits.

Table 1: CSP technologies currently in use

TROUGH

> The most widely deployed CSP technology, with 1,400 MW_e (CST) installed as at 2011.

> Parabolic mirror tracks sun east to west, and focuses energy onto a linear 'evacuated tube' receiver.

> Mature technology with systems operating for over 25 years.

LINEAR FRESNEL

> Long rows of flat or slightly curved mirrors, moving independently on one axis.

> Energy reflected up to fixed linear receivers mounted on towers well above the mirrors.

> Medium maturity, 38 MW_e (CST) installed as at 2011.

DISH

> Paraboloidal shape with two-axis tracking focuses sunlight to a point receiver.

> The highest optical efficiency of all CSP types, because full aperture directed toward the sun avoids the 'cosine loss effect'.

> Low maturity, 6 MW_e (CPV & CST) installed as at 2011.

TOWER

> An array of heliostats (large mirrors with two-axis tracking) concentrate sunlight onto a fixed receiver at the top of a tower.

> Large single receiver facilitates complex conversion processes such as direct heating of molten salt.

> Medium maturity, 60 MW_e (CST) installed as at 2011.

FRESNEL LENS

> Flat plastic lenses made as a series of concentric steps.

> Point focus used with high efficiency PV cells.

> Mounted in arrays to track the sun in two axes.

> Medium maturity, 15 MW_e (CPV) installed as at 2011.

Available CSP technologies

CSP has proven itself as a technically sound electricity generation option. Since the sector was reinvigorated in 2005, global installed capacity has grown by c.40% annually and will reach 2 GW in 2013.

Concentrating solar power systems

The defining characteristic of CSP systems is that solar radiation is concentrated by mirrors or lenses onto a single point or linear receiver. The receiver can convert the concentrated sunlight directly into electricity (with photovoltaics or receiver-mounted engines) or use a heat transfer fluid to transfer the energy to a central power system. The more common concentrated solar thermal (CST) plants typically use standard steam turbines, and often integrate thermal energy storage.

The five CSP technologies that are being used globally are set out in Table 1 on the previous page: trough, linear Fresnel, dish, tower and Fresnel lens. Systems that use two-axis tracking to concentrate sunlight onto a single point receiver – the tower and dish – are more efficient than the linear focus systems. When constructed as CST plants, they can operate at higher temperatures, and so generate power more efficiently.[4] However they are also more complex to construct.

Conversion and storage systems

Thermal storage works to make CST a more flexible and valuable electricity generation technology than variable renewable energy options. CSP systems can use a range of approaches to convert solar energy to electrical energy, though most rely on steam turbines. Manufacturers now offer customised CSP steam turbines that convert around 40% of steam thermal energy to AC electricity, at full load. Other conversion systems include photovoltaics (for CPV), Stirling engines, Brayton cycles and Organic Rankine Cycles. All need cooling. Water-cooled plants require similar water quantities to fossil fuel plants: 2 to 3 kilolitres per MWh. Air-cooling cuts water use by around 95%, but with a decrease in electricity production.

Opportunities for hybridisation with fossil fuel arise from CST systems, since both CST and fossil-fuelled plants convert heat to electricity. Options include feeding CST-generated steam to existing power stations, or adding gas-fired backup to CST plants.

CST's main advantage though comes from its use of thermal storage to provide 'dispatchable' clean energy. Storing heat energy is cheaper than storing electrical energy. CST plants add a thermal storage unit between the heat receivers and the turbines. This means that heat energy beyond or below the turbine's operating range can be stored and not wasted, and also allows the turbines to run at optimal loads for longer periods. Most importantly, thermal energy can also be converted into electricity and dispatched when the demand or price for that electricity is highest.

The thermal storage technology that is most advanced is the two-tank molten salt system: see Figure 1. For a trough based system, these cycle molten Nitrate salt[5] between a 'cold' (energy depleted) tank at 300°C and a 'hot' (energy charged) tank at nearly 400°C. At the end of 2011, 62% of installed CST systems in Spain used molten salt energy storage.

4 The efficiency of heat engines is measured in part by the relative loss of heat in the heat transfer fluid as it passes through the steam turbine or other heat engine: Carnot's theorem.

5 The salt composition is 60% $NaNO_3$ + 40% KNO_3.

Figure 1: **Two tank molten salt, thermal energy storage at Andasol 3, Spain.**

International growth in CSP capacity

Though CSP technology is being adopted internationally, the rate of its continued expansion depends on policy decisions in key countries. With supportive policies in place since 2005, global installed CSP capacity[6] will reach at least 2 GW_e by 2013. Countries believing it will be a major contributor to a future clean energy mix have offered CSP-specific feed-in tariffs, renewable portfolio obligations and direct project support. This support comes after a decade-long hiatus: after tax incentives that stimulated growth in the US in the 1980s and '90s ended, the deployment of utility-scale CSP plant stalled. The recent CSP adoption has been led by Spain, and increasingly by the south-western states of the US.

Though continued expansion of CSP is expected, it is not yet secure. Spain is winding back its industry support due to fiscal constraints. Future US federal programs, designed to complement state-based initiatives, are by no means certain. On the positive side, several Middle Eastern and North African countries have just begun low-level CSP activity. India is taking the first steps on its Jawaharlal Nehru National Solar Mission, which aims to install 20 GW_e of CSP and PV capacity by 2022. China could play a major role but has yet to demonstrate its intentions in a concrete way.

6 Installed capacity (in GW_e) is a somewhat misleading metric, since systems with storage and a higher capacity factor produce more energy per year and have a larger system area per GW_e of installed capacity. Capacity referred to here is an equivalent capacity normalised to have the same average capacity factor as plants existing at end 2011.

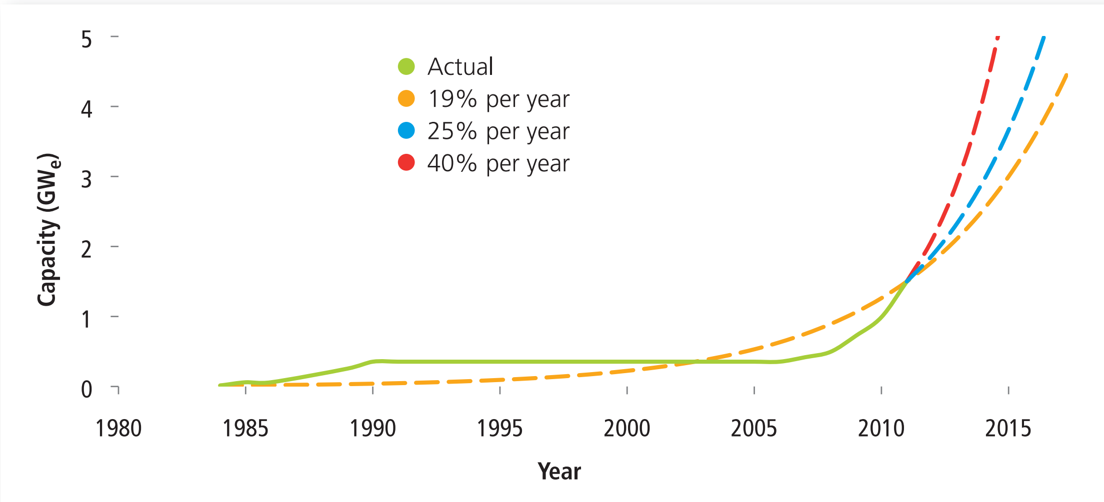
At the end of 2011, 62% of installed CSP systems in Spain used molten salt energy storage.

Installed capacity has grown at approximately 19% per year since 1984, and at about 40% per year since 2005. For the next decade, a range of industry studies estimate growth at between 25% and 40% annually. There are three scenarios that can be considered:

- Complete stagnation of the global CSP industry as competing technologies win on cost.
- Piecemeal growth spurts in various countries that allow the industry to maintain its existing 19% p.a. long term average growth rate.
- Strong growth of around 30% to 40% pa which is consistent with the track record of wind and PV and has been achieved by the CSP sector in recent years.

While complete stagnation of the CSP industry is possible, the need and demand for dispatchable clean energy makes this unlikely. If there is a concerted global effort to address greenhouse gas emissions and improve future energy security, the strong growth scenario is clearly possible. However, the current global situation suggests growth of 25% per year is more likely, at the low end of industry studies yet still substantial: see Figure 2. See the section 'Cost of delivering CSP energy' below for the likely implications of this growth.

Figure 2: Global installed capacity of CSP plants to end of 2011.



Australian markets for CSP

Despite being limited to areas of both high solar resource and grid connectivity, CSP could provide up to 15 GW in the near-to-mid-term, about 30% of Australia's total current electricity generation capacity, with significant benefits to the energy sector.

Market segments and location

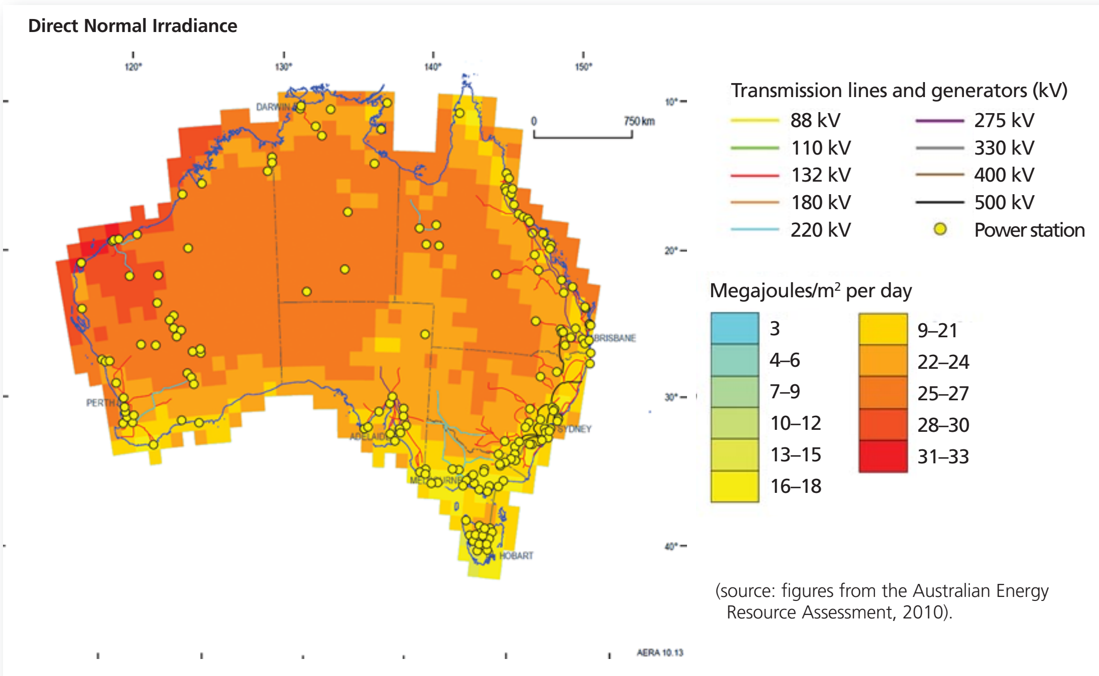
Both off-grid and grid-connected market segments can be considered for CSP. Demand for off-grid CSP applications comes from remote towns, mines or other industrial plants. Australia's growing electricity demand and mandatory renewable energy targets mean that there is a use for any electricity produced as long as the output profile is suitable to the customer. Whether that delivery is commercially viable is discussed below.

Australia's existing transmission and distribution networks are not ideally configured for CSP. Where the solar resource is best, there is either no grid to access, or the suitable grid capacity is limited: see Figure 3. It is not just a question of location. Australia's networks have been designed to transmit electricity one way: from large central generators, located near coal, gas or hydro resources, to their customers. In many potential locations, CSP-generated electricity would need to flow the other way, over relatively long distances. The local capacity of the network will also constrain the potential size of the CSP system seeking to connect to it.

Nonetheless, sufficient areas of high standard solar resource are accessible for CSP to make a significant contribution to Australia's energy needs. Three location-based market segments should be considered:

- large-scale plants connected to the high-capacity transmission network[7];
- medium-scale plants connected to lower-capacity distribution network; and
- off-grid systems.

Figure 3: Map of Australian transmission networks overlaid with the distribution of Direct Normal Insolation



7 The electricity network (grid) is made up of a backbone of high capacity, very high voltage, "Transmission" lines of > 66kV from which radiates a network of lower capacity sub 66kV distribution lines.

The technical potential for these market segments in Australia has been assessed, based on network limitations in areas of sufficient annual solar radiation and is summarised in Table 2 below. In total, there is about 14 to 15 GW of technical potential for CSP in Australia that could in principle be installed in a straightforward manner with modest grid extension. For CSP to meet more of Australia's future electricity demand than this, grid extensions of a 'nation-building' nature would be required.

In each of these location-based segments, CSP plants could be configured with or without thermal storage. This means that the energy potential ranges, between 25,000 and 60,000 GWh per year (equivalent to 8 to 20% of current annual electricity demand). Systems could be configured to offer combinations of:

- Immediate generation when solar is available (no thermal storage).
- Energy on-demand using storage or co-firing.
- Continuous generation at lower power level using storage or co-firing.

Table 2: Technical potential of different market segments

Market segment	Technical potential	Notes
Large-Scale grid-connected		
Hybridisation with existing fossil fuel plants or industry (CST only)	2 GW_e	Assumes 25% of appropriate coal-fired power station's steam needs are delivered by CSP.
Stand-alone 50–150 MW systems (grid-connected)	3 to 4 GW_e	Requires grid connection point capable of receiving significant new energy injections.
Stand-alone< 1 GW clusters (modest grid extensions)	8 GW_e	Likely requires high-capacity plants with thermal storage whose economics cover cost of grid extension
Stand-alone > 1GW clusters (nation-building grid extensions)	Limited by market demand	Available high solar resource land area vastly exceeds all conceivable demand if accessed with dedicated major grid extensions
Medium Scale grid-connected		
Grid-connected (1–20 MW systems)	0.6 GW_e	Particular systems (large solar field, large storage, smaller capacity, high capacity factor) suited to distribution networks with capacity constraints.
Mini-grid-connected (1–10 MW systems)	0.12 GW_e	Would need thermal storage and dispatchability to have an advantage.
Off-grid		
Mining (systems < 10 MW)	0.1 GW_e	> 50 remote mine sites may be suitable for small-scale CSP, but short mine life and risk avoidance by mine owners/operators limit uptake.
Remote Towns (1–10 MW systems)	< 0.005 GW_e	Relatively small-scale demonstration systems.
Remote Towns (CPV systems < 1 MW)	< 0.005 GW_e	Could be suitable to test equipment and integration strategies.
Total	**~ 14 to 15 GW_e**	

CSP's potential advantages

If CSP systems proved themselves viable to meet the needs of these market segments, they would deliver strong advantages to Australia's energy sector:

- **Dispatchable energy supply:** Systems that can dispatch electricity in the range of baseload to peaking power are an essential complement to variable renewable sources. CSP with storage has that capability.
- **Lower emission conventional power plants:** CSP can be efficiently integrated into existing and new coal and gas power plants to reduce emissions and extend plant life for a least-cost transition to a low-emission energy future.
- **Emission reduction:** 10 GW of capacity would reduce Australia's emissions by roughly 30 Mt CO_2 per year, or over 15% of electricity sector emissions.
- **Clean energy sector growth:** Only a few countries are currently investing in CSP. With CSP exploiting its world-leading solar resources, Australia can claim a significant place in the global clean energy supply chain. Delaying action will see that opportunity missed.
- **Community-supported generation:** CSP need not compete for productive land or valuable water, is low-pollution and low-impact. Every 100 MW system would create around 500 job years during construction and 20 jobs during operation, mostly in regional areas.
- **Potential for future solar fuels:** Emerging technology will convert solar energy to liquid fuels, supplied at scale to both domestic and export markets.

However, as with all technologies, CSP's place in the generation mix will be determined by project economics. These are explored over the following three sections.

To date Australia has only deployed some small CSP systems, largely of a demonstration or experimental nature. Some examples of these are listed in Table 3.

Systems that can dispatch electricity in the range of baseload to peaking power are an essential complement to variable renewable sources.

Table 3: Early demonstration and experimental CSP installations in Australia

LIDDELL POWER STATION (CST)

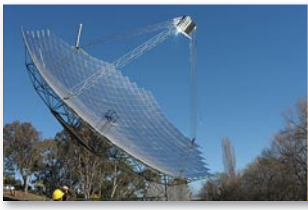
Liddell Power Station in the Hunter Valley, NSW, hosts a 1,300m² array of Linear Fresnel reflectors installed by Ausra (now Areva) Solar. Work is nearing completion on an additional 18,490m², 9.3 MW_{th} Linear Fresnel array provided by Novatec Solar. The arrays pre-heat feedwater for the coal-fired station.

ALICE SPRINGS AIRPORT (CPV)

As part of the Alice Springs Solar City project, a 235 kW CPV plant has been constructed at Alice Springs Airport. The system uses SolFocus SF-11100 tracking arrays which are based on panels of 'micro dishes' assembled behind a glass cover. The system was commissioned in early 2011.

SOLAR SYSTEMS INSTALLATIONS (CPV)

Solar Systems Pty Ltd first added a CPV power station to a diesel mini-grid in 2001. Four more CPV stations (total 1.25 MW), now fitted with Spectrolab III-V PV cells, were installed in Hermannsburg (2005), Yuendumu (2006), Lajamanu (2007) and Windorah (2008), with support funds from the Australian Government's remote power program.



AUSTRALIAN NATIONAL UNIVERSITY DISHES (CST)

Following on from a 14-(small)-dish system at White Cliffs, a 400m² SG3 dish was completed in 1994, then the world's largest. A 500m² aperture design, optimised for mass production for large-scale plants, was built in 2009.

CSIRO NATIONAL SOLAR ENERGY CENTRE (CST)

CSIRO has a major presence in CST R&D. The Newcastle site houses two Tower systems, a 500 kW_{th} system and a recently commissioned system with a 30m high tower and a 4000m² field of 450 heliostats. Key areas of ongoing investigation include solar reforming of natural gas, steam generating systems and solar-driven Brayton cycle systems.

GRAPHITE ENERGY STORAGE (CST)

The Australian Government's Advanced Electricity Storage Technologies program included a demonstration of graphite-based thermal energy storage by Lloyd Energy / Graphite Energy. The tower systems with their receiver-mounted thermal energy stores are visible from the town of Lake Cargelligo. The systems a drive a steam turbine of approximately 3 MW.

KOGAN CREEK FLAGSHIP AND SOLAR BOOST (CST)

The successful Solar Flagship Round 1 CST proposal is the 250 MW_e Solar Dawn system at Kogan Creek, yet to be finalised. It is sited next to the 44 MW_e Solar Boost CST project funded by the Australian Government's Renewable Energy Demonstration Program, which is under construction. Both use Areva Linear Fresnel technology. When complete, these systems will together account for most of Australia's CSP capacity.

Available revenue for a CSP asset

The major source of revenue for CSP assets is the sale of electricity into Australia's wholesale electricity markets. Renewable generation that offers dispatchability could secure revenue well beyond average wholesale market prices – perhaps double the per-unit- revenues of base-load fossil-fuel plants. Additional network income may contribute a little extra under current settings, with renewable energy certificates (RECs / LGCs) adding a further $30-40 per MWh.

The income available to a CSP system, whether under a negotiated power purchase agreement (PPA) or not, reflects the following income streams that represent the system's underlying value:

- Income set by pool prices in wholesale electricity markets, and
- Additional income for network benefits such as:
  - avoided line losses/marginal loss factors
  - ancillary services such as the ability to compensate for supply variations from other sources, and
  - avoided grid augmentation expenses.
- Renewable Large-scale Generation Certificates (LGCs)
- Capacity Credits in the Western Australia South West Interconnected System (SWIS), and
- Direct sale via contract to off-grid and mini-grid customers.

Pool prices in wholesale electricity markets

Extensive modelling using the NREL System Advisor Model (SAM) has been used together with historical price data to test the hypothetical revenue that CSP plants could produce in Australian wholesale electricity markets. The results confirm the additional value that dispatchability offers a CSP plant. Table 4 sets out the results from two relevant scenarios:

a] generation of electricity and sale whenever solar is available; and

b] storage of the energy and subsequent sale at a time of day that maximises the revenue value accrued.[8]

All regions show that immediate dispatch solar has a higher value than the pool average, and that store and dispatch produces a higher value still. This analysis was repeated for different technologies and different sites within a state and found to be virtually independent of both issues. However, there is quite a large variation (+/- 30%) from year to year. While the average wholesale price of energy in the NEM for 2005–2010 was $43.4 per MWh, modelling suggests dispatchable energy from CSP storage would have averaged $87.0 per MWh.

Table 4: Sale price of energy from a CSP system, averaged over 2005–2010, with and without storage.[9]

State	Market average price $ / MWh	Immediate dispatch average sale price	Ratio immediate / market average sale price	Dispatch from storage average sale price $ / MWh	Ratio Storage / market average
VIC	$39.2	$58.9	1.50	$74.6	1.90
SA	$49.5	$89.7	1.81	$136.9	2.77
QLD	$36.9	$50.0	1.35	$77.2	2.09
NSW	$41.3	$54.7	1.32	$80.7	1.95
WA	$50.1	$58.1	1.16	$65.8	1.31
AVERAGE	**$43.4**	**$62.3**	**1.43**	**$87.0**	**2.01**

8 Dispatch start times were varied separately for summer and winter to seek a simplified approach to maximising value. Plant power block size was increased relative to the solar field size and an optimum storage size of approximately 6 hours was indicated by the model.

9 All NEM regions except Tasmania are compared in Table 4 along with results for the Western Australian South West Interconnected System (SWIS), which also operates a competitive energy market, the Short Term Energy Market (STEM).

This analysis neglects the potential effect that a large amount of solar capacity could have on the pool prices if it were installed. The addition of very large amounts of CSP generation would tend to reduce the premium for immediate-dispatch and storage; conversely, a large proportion of other variable renewable generation in the network may actually increase the price premium available to a CSP plant with dispatchable capability.

Additional network value and income

While there is clarity on the wholesale energy prices available through the NEM, an operating CSP system offers the network further values, some of which are only partly recognised by expected plant revenues at present.

Avoided line losses

The positioning of CSP systems in areas of high line losses may lead to their generated energy securing higher prices. As electricity moves through the transmission and distribution networks, some energy is lost as heat. Marginal Loss Factors (MLFs) measure the energy loss in the transmission network, and Distribution Loss Factors (DLFs) do so for the distribution network. Where energy is fed into the network at a location with a high loss factor (>1), it has a higher value. Electricity prices vary in direct proportion to the MLFs and DLFs. In 2010-11, MLFs ranged from 0.8 to 1.16, though usually within 5% of unity. DLFs also range generally within 5% of unity, but in 2010-11 ranged up to 1.251 (in Ergon Energy's network).

CSP systems are likely to be in rural or reasonably remote locations, where the loss factors are greater than 1, implying a higher value for their generated energy. However, as the loss factors are recalculated annually, the new CSP plant will itself reduce the local loss factor, and so the price paid to it. Some policy or contractual price adjustment may be needed to recognise the underlying benefit to the network.

Avoided network costs

To meet peak demand across the network, lines must have the capacity to carry electricity from generation to supply points, allowing for line losses throughout. Reliable generation at the end of near-capacity lines potentially reduces the network capacity needs throughout. Though this network benefit is recognised in the Code of Practice Demand Management for Electricity Distributors, anecdotal evidence suggests that there has been little financial recognition. There is no matching requirement for the transmission system.

Again, a policy or contractual price adjustment may be needed to recognise the underlying network benefit. The implied value would vary, depending on the CSP plant's capacity characteristics and the costs of network infrastructure. The benefit may fall between 1 and 5% of total energy value, with the likely onus on the CSP plant to demonstrate that benefit.

Capacity Value

The capacity value relates to the extent that the CSP plant can offset the need for investment in other dispatchable systems on the grid. To some extent, this capacity value is recognised in the NEM by the high wholesale prices for peaking power. In the WA SWIS, capacity value is recognised explicitly, with payments of around $180,000 per MW per year for available capacity. If a high-capacity CSP system could earn 90% of that rate it would equate to an extra $20 per MWh income. A CSP system that could retain a few hours of energy in storage would qualify for such payments[10]. A hybrid system with fuel-fired back up could also qualify.

10 Note that molten salt storage can retain energy for one to two weeks if it is not used. Molten salt tanks also have resistive electrical heaters fitted so they can be kept molten in the event of several weeks of zero input. These could provide a last resort way of meeting capacity obligations.

Ancillary services

'Ancillary services' are those provided by generators and others connected to the electricity network, that are needed to keep the network operating reliably within its specifications of voltage and frequency. The more variable the energy supply to the grid, the more that these services are needed. CSP systems, particularly those with appropriate energy storage, may offer the NEM a range of ancillary services. The services are recognised independently of the sale and purchase of energy, though their combined value amounts to only $1 per MWh at present. This may rise to significant levels if very large amounts of variable renewable generation are connected to the grid.

Income beyond the wholesale markets

Large-scale Renewable Energy Certificates

The Renewable Energy Target was expanded in 2009 to an additional 41,000 GWh per year of 'new renewable generation' by 2020. Large-scale generation certificates (LGCs) are earned for every MWh generated by accredited renewable energy power stations, and were trading at around $40 per MWh at the end of 2011. While there has been volatility in the REC/LGC spot prices and uncertainty in projected prices remains, LGC income is likely to remain material to project finance considerations.

Off-grid systems

For CSP systems with off-grid or mini-grid customers, there is no open market; Power Purchase Agreements (PPAs) are negotiated with each customer. The main fuel has been diesel, with natural gas used where available. The per-MWh cost of these fuels is highly variable, and depends on the size of the system and fuel transport costs as well as the base commodity price. A recent study[11] of the cost of large (30 MW_e) diesel and gas systems in the Pilbara and mid-west of Western Australia estimated generating costs of $285–$300 per MWh from diesel (priced at about 85c per litre) and $180–$190 per MWh for gas. CSP systems with acceptable output characteristics could negotiate PPAs of similar value.

While the average wholesale price of energy in the NEM for 2005–2010 was $43.4 per MWh, modelling suggests dispatchable energy from CSP storage would have averaged $87.0 per MWh.

11 Assessment of the potential for renewable energy projects and systems in the Pilbara, Evans and Peck 2011.

Cost of delivering CSP energy

Identifying the cost of delivering energy to grid or off-grid customers is a complex process. Capital costs depend on the configuration, size and location of a plant. In addition, given the relatively early stage of the CSP industry in Australia, reliable data is difficult to establish. The best comparative metric is the Levelised Cost of Energy (LCOE), which amortises the construction, operation and other costs across the plant's lifetime. A baseline LCOE of $252 per MWh represents the most conservative, least technical-risk CSP technology built at a 'most favourable' site in Australia. However, that baseline is strongly sensitive to capital cost variables (notably system size, storage, and relative power block size), the cost of capital, and the amount of energy generated annually.

A baseline cost and sensitivities

Capital cost estimates for Australia have been established from published data and confidential briefings from key technology providers. These have been converted to cost estimating coefficients[12] that allowed a range of configurations and system sizes to be examined. Table 5 gives three possible examples of system costs established in this way, for the particular case of 100 MW_e systems with differing capacity factors.

Table 5: Examples of specific CSP system costs for 100 MW_e central power block systems

	No storage (lowest capital cost)	2 hours storage (approx min LCOE)	5 hours storage (earns higher value)
Configuration	100 MW_e block, 350 MW_{th} field, 21% capacity factor at 2,400 kWh/m²/year	100 MW_e block, 395 MW_{th} field, 30% capacity factor at 2,400 kWh/m²/year	100 MW_e block, 526 MW_{th} field, 40% capacity factor at 2,400 kWh/m²/year
Specific installed cost (AUD 2012)	$4653 / kW_e	$5534 / kW_e	$7350 / kW_e

These costs include grid connection, but not grid extension costs nor the cost of construction finance. While adding two hours' storage increases the system's installation cost, it reduces its LCOE. This and other variables and sensitivities need further analysis and are discussed below.

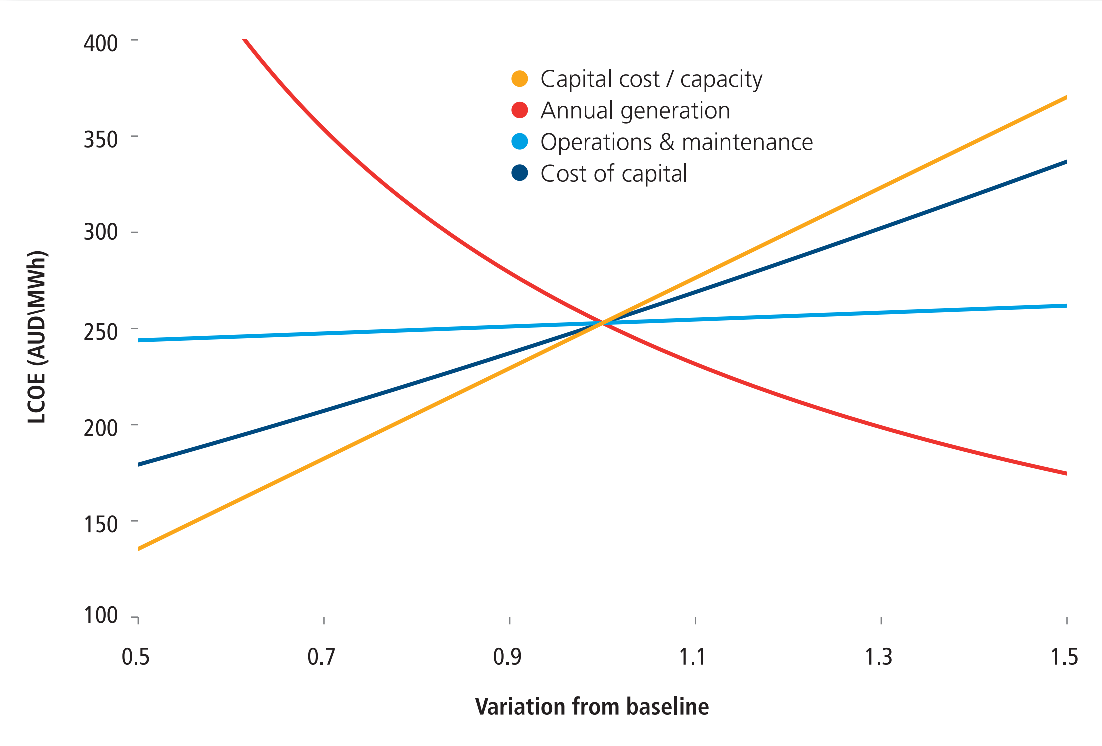
Capital cost estimates have been used, together with modelled annual generation for a 64 MW_e trough plant[13] with no storage, using solar data equivalent to a typical year in Longreach Queensland. With a capital cost of $308 million (or $4,817 per kW_e) and annual generation of 128,800 MWh, the LCOE is $252 per MWh. This baseline represents the most conservative, least technical risk technology built at a representative 'most favourable' site in Australia.

Around this baseline, the strong sensitivity to key parameters is shown in Figure 4. Annual energy generation, capital cost and weighted average cost of capital (WACC) all influence LCOE materially. Indices that track construction costs in regional Australia imply that initial capital costs could be 10 to 20% higher for remote regions. Early Australian 'first of a kind' projects may also cost 10–15% more again due to inexperience along the supply chain.

12 The costing calculations used are wherever possible based on the status and potential of CSP as a general combined technology class.

13 The characteristics of the actual Nevada Solar 1 plant in Las Vegas were used, with a known solar field capacity of 241 MWth. The financial parameters used were: loan fraction 60%, loan period 15 years, loan interest 7.78%, discount rate for equity 10.29%, depreciation period 20 years, project life 25 years, inflation 2.5%, O&M costs 1.8c / kWh, allowance for construction finance costs 6%.

Figure 4: Variation of costs and performance against an LCOE baseline for a 64 MW_e trough system at Longreach.

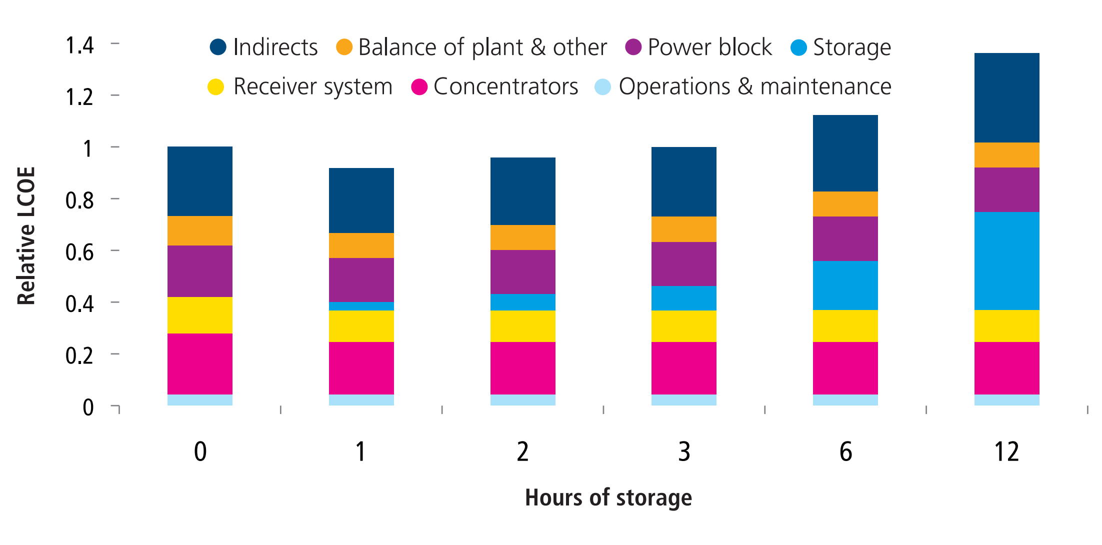


Effect of energy storage

CST with storage is now the most common CSP configuration installed globally. A small amount of storage (1 to 2 hours) improves plant performance and reduces the LCOE compared to the no-storage case. However, increasing storage beyond around 3 hours adds significant further capital cost without generating more energy, and so increases LCOE.[14] Figure 5 shows the modelled results for a CSP trough system. These have been normalised to a value of 1 for the no-storage case, so that the impact of storage on LCOE can be seen independent from the assumed site, size, technology and financial parameters.

14 This finding is consistent with overseas studies: www1.eere.energy.gov/solar/thermal_storage_rnd.html.

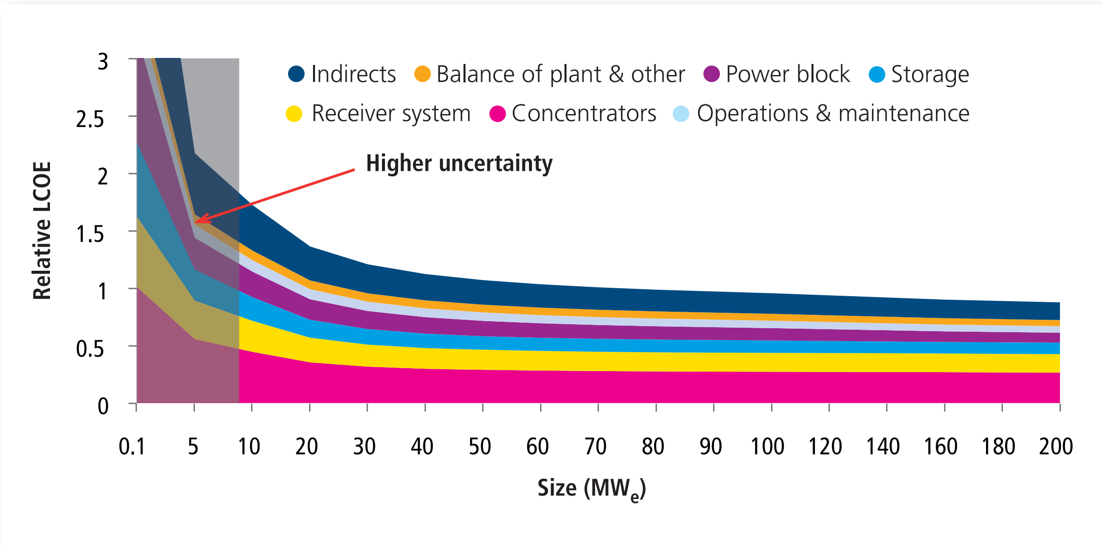
Figure 5: Impact of storage on LCOE for a 64 MW_e trough system, relative to a base case of no storage



Effect of system size

Whatever the ratios between solar field, storage and power block size, the overall system size has a significant impact on the LCOE. Calculating the optimal size and its benefits is a global challenge. The current consensus is that the minimum LCOE for stand-alone systems is reached at around 250 MW_e. Beyond that, greater energy losses[15] reduce the system's relative output and the LCOE starts to increase. Over about 60 MW_e the cost curve flattens considerably, as shown in Figure 6, with LCOE within ±15% relative to systems with a 100 MW_e central power block. The results follow the installed cost of the systems very closely[16]. The relative cost curves for systems without storage reveal a very similar size dependence.

Figure 6: Estimated LCOE dependence on system size (normalised to a 100 MW_e system with 5 hours storage).



15 Eg thermal losses from pipe networks or optical losses from distant heliostats.
16 Financial parameters such as cost of capital were assumed independent of size.

Two key factors drive these economies of scale:

a] many components are more cost effective at large size; and

b] CST turbine efficiency falls with reductions in turbine size, so that all subsystems on the thermal side of the power block must be increased to compensate.

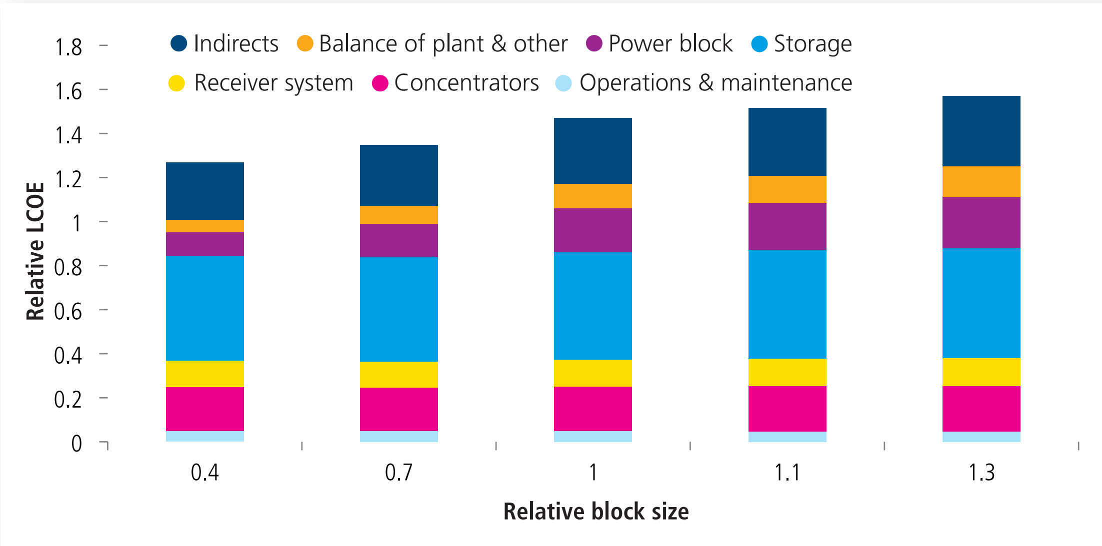
Where a CST system is added to an existing fossil-fuel plant, its LCOE would be virtually independent of size, since the power block would be set and have a fixed efficiency. Without the need for storage and power block costs, the LCOE would be about 30% lower than for a large stand-alone plant.

By comparison with central power block systems, CPV or Dish Stirling systems appear to be more cost effective below approximately 10 MW_e, but do not offer storage.

Effect of power block size relative to field and store

The ratio of power block size to input energy and thermal storage determines a system's best application. To supply baseload power, the system will have a relatively small power block: more thermal energy is being stored to be released uniformly. Increasing the relative size of the power block gears the plant to meet intermediate and peaking demand, and earn higher prices. However, this increases the plant's LCOE: see Figure 7.

Figure 7: Impact on LCOE of relative power block size[17] for a trough plant (fixed thermal store and collector area).



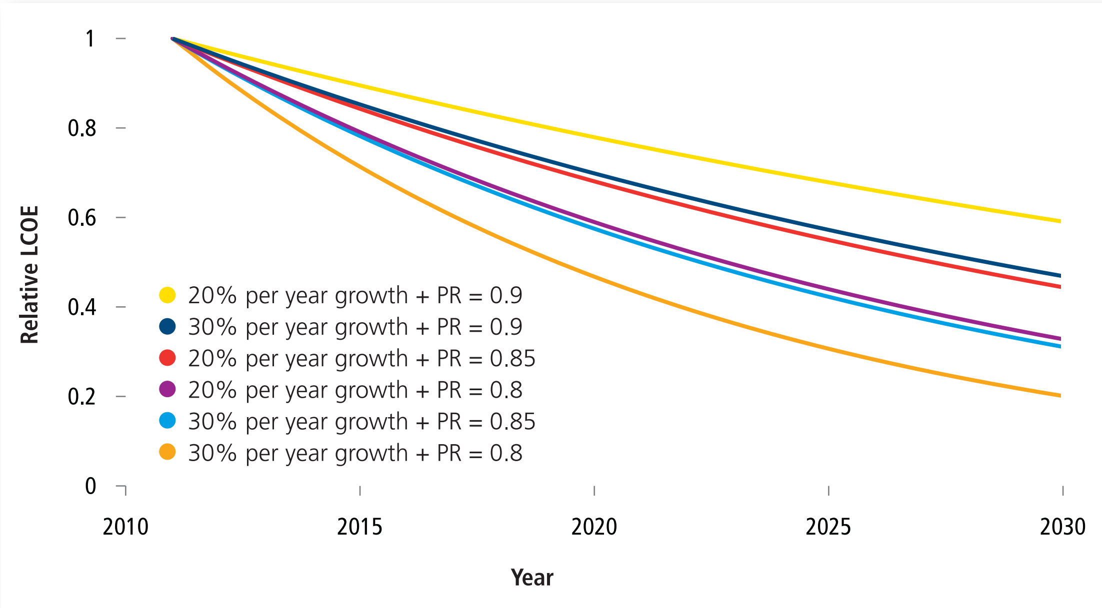
17 The block size of 1 corresponds to the 12 hour storage data point in Figure 5.

Projected cost reductions

Significant reductions in the CSP system costs could be occurring within just a few years, as long as deployment levels are maintained. Consistent with other technologies at a similar stage of development, the LCOE of a CSP system is expected to fall by at least 20% by 2020, with a 50% reduction being quite feasible.

Cost projections are made while acknowledging that the global CSP industry has not stabilised sufficiently since its 2005 restart to show clear data points. Available evidence from CSP and similar industries points to a cost reduction of 10–15% for every doubling in global capacity (a progress ratio of 0.9–0.85). Compound growth in capacity appears likely to continue at at least 19% per year (the historical rate since 1984, including the sector hiatus), and more likely somewhat higher. Figure 8 plots the progression over time of relative costs (either LCOE or capital costs[18]) under either 20% pa or 30% pa growth rates, and for cost progress ratios of 0.8, 0.85 and 0.9.

Figure 8: Relative cost reductions over time under different deployment growth rates and progress ratios



A system's cost of energy does not, however, correspond directly to its commercial viability. For example, smaller systems built for remote or end-of-grid markets may have a higher LCOE, but can earn higher revenues. These value analyses are pursued below.

18 Note that LCOE is strongly dependant on capital cost, but also depends on O&M costs and financing costs. To a first approximation LCOE and capital cost are assumed to reduce over time according to the same progress ratio.

The commercial equation for a CSP asset

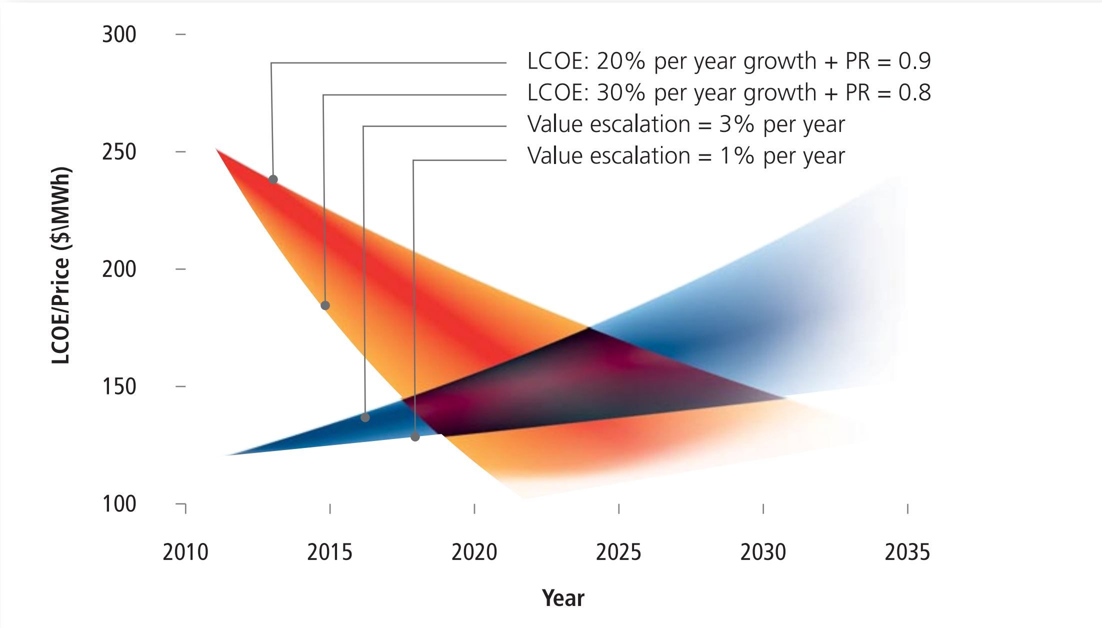
Under current market and policy conditions in Australia, CSP projects are not commercially attractive without subsidy. Private investors cannot monetise the broader public and sector-wide benefits that CSP generation may offer, so that project Net Present Value (NPV) does not meet their risk-reward benchmarks. There are other sector and project-specific challenges that hinder investor interest. But the cost-revenue gap, though closing, is the main issue.

The financial gap

The revenues available to a potential Australian CSP plant in 2011 fall far short of the cost of building and running it. The indicative baseline LCOE of $252 per MWh for a typical 64 MW_e trough CSP plant, compares to potential earnings of around $120 per MWh in today's grid-connected markets.

However, rising energy prices and falling CSP capital costs should close this gap between 2018 and 2030. On the revenue side, real energy values are likely to rise at between 1% and 3% per year through to 2030. Meanwhile, capital costs are expected to fall by 20% to 50% by 2020, depending on the eventual growth rate and progress ratio: see Figure 9. These projections are supported by international investigations[19], and suggest that private investment in CSP will increase significantly as the cost and revenue lines converge. They are however at odds with the very small projected cost reductions in the Draft Australian Energy Whitepaper[20], which in turn led to projected solar contributions of just 3% by 2050.

Figure 9: Possible progression of indicative CSP LCOE and market value in Australia (2011 real AUD) for 2 combinations of growth rate and progress ratio.



19 SunShot Vision Study, US Department of Energy 2012.
20 Draft Energy White Paper – strengthening the foundations for Australia's energy future. Commonwealth of Australia 2011.

While Figure 9 considers an indicative, medium-size CSP plant without thermal storage, the investment case for actual CSP projects varies enormously according to its configuration and market. The most significant variable for both revenues and cost is whether the proposed system includes thermal storage. Table 6 compares the LCOE with potential revenues in the key market segments, with and without storage.

Table 6: Estimated 2012 Australian LCOE[21] and market value of CSP systems for various market segments

	CSP with no storage			CSP with significant (5+ hours) storage		
	LCOE ($ / MWh)	Value ($ / MWh)	Gap ($ / MWh)	LCOE ($ / MWh)	Value ($ / MWh)	Gap ($ / MWh)
Large Systems on NEM	220 to 300	100 to 106	115+	250 to 360	125 to 138	110+
Small Systems on NEM	350 to 550	102 to 110	240+	370 to 500	132 to 148	220+
Large Systems on SWIS	250 to 300	98 to 102	150+	260 to 360	154 to 162	100+
Off-grid / mini grid	400 to 550	290 to 390	10+	500 to 650	340 to 450	50+

While LCOE significantly exceeds income in every case, the gap varies considerably. For example:

- A CSP plant in a remote, high solar resource area that targets off-grid or mini-grid customers has a smaller value gap to close. However, it is also the segment with the greatest uncertainty in both the cost and value estimates. There is also a high level of technical risk avoidance, and payback times less than a CSP plant lifetime are expected.
- The NPV implications of storage are not linear. A system with one or two hours of storage may be more attractive than the two extremes of no storage and high storage.
- CSP systems connected to large gas or coal power stations to become hybrid systems should also be considered. While LCOE drops to $150–170 per MWh, value falls to around $70 per MWh if the system essentially becomes a fuel saver for the existing plant, or could be up to $100 per MWh if the system offered extra output when solar was available.

Comparison with other renewable sectors

This study does not judge the relative merit of CSP investment against investment in other forms of renewable energy. It is suggested that all forms will be required to meet the twin challenges of energy security and emissions reduction. However, because the current cost gap for CSP is large and undermines confidence in the sector, it is reasonable to compare Figure 9 with the cost curves of other available technologies. The starting point is that wind and solar PV are more mature technologies than CSP, so that their cost curves are expected to slow and level out in coming decades. A recent key study[22] suggests that the LCOE of CSP with storage will match that of wind by 2025, and be half that of solar PV with batteries. Available CSP revenue would be more than wind, and similar to a PV system with batteries. Accordingly, though CSP is starting further behind, its commercial case will be as strong as any other form of renewable energy within the strategic horizon of this review.

21 Estimates reflect expected system size and configuration together with likely range of annual solar radiation for the market segment location.
22 AT Kearney 2010, Solar Thermal Electricity 2025, Report for ESTELA.

Challenges, confidence and risk

In addition to the pure financial equation detailed above, there are other considerations that influence the project developer and financiers' investment decision. Many of these are specific issues facing CSP market segments, as set out in Table 7 below.

Table 7: Specific issues facing CSP market segments

Market	CSP Value Proposition	Specific issues
Off-grid / mini grid	• Reliable power at price competitive with diesel. • Hedge against future fuel price fluctuations and supply chain risks.	• Customer expectations of very high overall system availability and capacity factor. • Short time horizons on investment decisions. • Split/perverse incentives around diesel fuel excise rebates. • Requires demonstration at 1 to 10 MW scale in grid connected areas to build confidence.
Stand-alone, grid-connected plants	• Grid-stabilising, load-firming, zero-carbon generation. • Enables penetration of renewable energy sources to > 20%. • High correlation with daytime peak loads. • Load-following using thermal energy storage. • Co-fire with gas, biomass etc to maximise reliability of supply.	• Very large capital costs of individual projects. • Lack of transmission infrastructure to optimal solar locations. • Benefits of avoided line loss and grid extension not adequately rewarded. • Building confidence with network service providers. • Hard to get long term PPAs.
CSP add ons to fossil-fired systems	• Lower emissions intensity for existing power plants. • Leverage existing infrastructure. • Prolong existing fleet lifetime. • High performance systems with lower project risk and capital cost.	• Building confidence of existing generators re CSP integration with core (traditional/fossil) operations. • Split/perverse incentives, e.g. free carbon permits reducing pressure to lower emissions.

The CSP sector must build confidence in its capability among key stakeholders, including government, network service providers, electricity retailers and financiers, for the projects are perceived to be high risk.

For any significant CSP system, the initial capital cost is large. Investors do not underwrite large capital projects unless they are familiar with the technology and confident in its financial returns. For an Australian investment community unfamiliar with CSP, these factors weigh against investment.

This higher risk profile has four consequences. Most obviously, CSP investments must offer higher rates of return than investments in more familiar energy systems. The time horizons for those returns are shortened to further minimise risk. Third, CSP projects can draw only from the smaller pools of funding that are available to riskier investments. Finally, those smaller pools manage their own portfolio risk, making a relatively large single investment from that smaller pool unlikely.

Public and sector benefits

The investment case for individual CSP projects currently does not take into account the national and sectoral benefits that CSP investment offers. Yet these benefits are significant, and the means to capture them should be explored. For the energy sector and its customers, they include network performance (explored above), energy security, and price security. For the broader public, the benefits include reduced emissions and related pollution, and regional employment and infrastructure. Many of these benefits are to an extent time-sensitive: the window for securing them will close if, for example, emission reduction action is delayed, or other countries secure the lead positions available in CSP development. Accordingly, the option value of CSP's potential in Australia will be eroded unless that option is retained.

Looking at Figure 9 above, the need for supportive market intervention becomes clearer. Purely commercial deployment will only occur when the cost and revenue lines are close to converging. However when public and sector benefits are added to the existing market returns on CSP investment, the net returns from the project look far more attractive. If these benefits can be captured, some of the corresponding value could be invested to accelerate CSP development, and so bring forward the point at which private investment will sustain the industry.

Potential benefits

The major capital investments associated with CSP plants are challenging but there are also flow-on economic benefits. The fraction of the expenditure that is likely to remain in the country is considerably higher than for many other electricity generation technologies. There are considerable levels of employment both direct and indirect, and much of this can be in the regional areas where plants are built.

Reducing emissions

Australia aims to reduce its greenhouse gas emissions by 80% (from 2000 levels) by 2050. To do so will logically require electricity-generation to be near emissions-free. Every available option needs to remain in play until the exact composition of a long-term least-cost portfolio is established.

The operational range of CSP systems with storage is from base-load to peak generation, making them complementary to other variable renewable electricity sources.

Clean energy sector development and R&D

Clean energy has become a major global economic driver, with more than US$246 billion invested in 2011, more than half the total spend on new power generation[23]. In some countries, notably including the US and Germany, clean energy jobs already dominate the energy sector. Although the renewable energy target, carbon pricing and the Solar Flagships Program provide some support, more initiatives are needed for Australia to claim a place in the global supply chain for clean energy. CSP provides a clear opportunity for it to do so, as its level of development is at an earlier stage than other clean energy sectors, and Australia has the solar resources and R&D capabilities to be a sector leader. The construction and operation of CSP plants in Australia would provide a focus for applied R&D, with the essential links between commercial players and research institutions.

23 Clean Energy Trends 2010, www.cleanedge.com

Energy security

Energy security is the adequate, reliable and competitive supply of energy for Australia's industrial and domestic needs. The recent Australian energy security assessment rates the level of security in the electricity sector to be moderate over the short, medium and the longer term to 2035. This assessment reflects Australia's multiple energy options and resources. CSP is one of those options. Once a CSP system is installed, it offers a long-term energy source with very low supply, price, environmental, trade and sovereign risk. While security issues around future transport fuels are less certain for Australia, and although out of scope of this study, it is noted that CSP has significant long-term potential to contribute in this area also, both as a clean energy source for the electric vehicles becoming available now, and through the creation of CSP-generated liquid fuels.

Regional employment and education

Employment created by CSP plants varies significantly depending on project location, system size and technology type. About 10 construction and manufacturing job-years are created per MW for plant in the 100 MW range. Continuing operation and maintenance jobs range from 0.2 jobs to 0.7 jobs per MW, with smaller plant having much higher employment.

It is likely that a CSP plant will be constructed in regional areas, giving those regions a greater share of employment, with the potential to gain from both local projects and exports. Local employment can be increased by leveraging the local project to increase the local manufacturing proportion of the project, and to integrate local parts of the CSP value chain into the international supply chain. This in turn provides opportunities for existing or new training institutions.

Option value of CSP

Public economics recognises the concept of 'option value', and it applies well to the nascent CSP sector in Australia. Option value can be thought of as a form of insurance value: how much should one spend now to retain access to a future asset, given uncertain future developments. Option value rises with the likely future value of the asset, and rises with the cost of its replacement if lost. Though it was not in the scope of this study to attempt to quantify the option value of CSP in monetary terms, a qualitative analysis suggests that it is substantial.

Australia's emerging CSP sector is an asset that has two quite distinct future values. The first is its potential to deliver the clean dispatchable energy that Australia needs. The other likely technologies– such as geothermal, and fossil-fuel generation with carbon capture and storage – carry significant technical risks and may prove more costly than proponents suggest. If they fail to deliver on expectations, it will take many years to build the CSP capacity that will be needed. CSP would be kept as an available option via some early deployment and establishment and maintenance of capability.

Doing so will also retain CSP's second option value as a significant place for Australia in the future clean energy supply chain. At the moment, Australia has the option of having a significant stake in a highly valuable global clean energy supply chain – a stake we do not hold for other technically-sound clean energy alternatives (such as wind or PV). As other countries invest more in the CSP sector, the value of Australia's potential share in that asset falls. Conversely, if insufficient countries invest, the value of the CSP sector relative to other options is eroded. Accordingly, the option value of our CSP asset cannot long be preserved.

Actions needed for CSP investment

With falling capital costs and rising energy prices, commercial viability for CSP projects will be attained between 2018 and 2030, as shown in Figure 9. Many of the significant benefits from including CSP in Australia's energy mix are maximised through early deployment. It is therefore in the interests of investors, the sector and the nation that CSP projects reach commercial viability as soon as practicable within that time range.

For this, the CSP industry must work with the energy sector and its regulating governments to systematically identify and address the barriers to investment delineated above. This will support the smooth, rational development of the sector, and help avoid the 'boom-bust' cycles that both renewable and fossil-fuel industries have experienced.

These barriers are real yet surmountable. Specific actions to increase investment, demand and product development are needed. These actions are discussed in turn below. If they are successful, the sector could track international growth rates to provide at least 2,000 MW of clean energy by 2020. This figure presents itself as a realistic medium-term target for overall CSP installations, toward which the sector could set clear milestones in meeting its challenges.

1: Bridge the reducing cost-revenue gap

Whilst continuing to focus on lowering cost the CSP sector should work with governments and regulators to increase the reward for clean energy systems that better correlate generation to real-time demand.

The benefits identified in this study would be maximised by early deployment.

Rather than simply subsidising CSP, technology-neutral market-based measures should target the dispatchable clean energy characteristics and strong correlation of generation to real time demand that CSP provides and Australia needs. Rewards linked to competitive market time of day pricing or equivalent firm capacity contributions should be considered. Towards this, energy sector agencies should build on this study and model future prices of both energy and ancillary services in the NEM, to calculate future CSP value under scenarios that include high penetration intermittent renewables.

The CSP industry must continue to focus on lowering cost through deployment learnings and technology improvement, particularly efficiency. Those cost reductions must also be clearly demonstrated to stakeholders. Major cost reductions will be achieved through capturing the lessons of early deployment. The CSP Industry should work pro-actively to leverage the lessons gained from publically funded early deployment to ensure they flow to the widest possible base within the constraints of competitive markets.

Public sector loan guarantees to mitigate construction risk have been used successfully in other countries, in parallel with other risk-mitigation measures. Facilitated finance, such as through the Clean Energy Finance Corporation, will only be defensible if revenue and capital depreciation settings are in place for both public or private loans to be repaid on their respective terms. Financial products such as infrastructure bonds, developed for large capital assets in the energy and infrastructure sectors to offer long-term low-risk returns, may be adapted to CSP projects to meet their large upfront capital cost.

Unless the gap is bridged, there will be no significant CSP deployment in Australia in the near term. Early deployment in market sectors where the cost revenue gap is smaller has the potential to optimise public sector investment. This includes off grid applications (where the competing cost is diesel generation) and hybrid applications with existing fossil fuel technologies. However these sectors do not offer a "silver bullet" and do not replace the need to address the main grid connected segment that ultimately offers greatest potential.

2: Build confidence in CSP's offer

The CSP sector should better communicate CSP's value proposition to key stakeholders including AEMO, AEMC, electricity retailers and financiers.

For those stakeholders who are unfamiliar with CSP's advantages and international progress, CSP's potential role in Australia may appear fanciful. Any actions taken to develop CSP in Australia can only be laid on a base of understanding and confidence. Without that base, the risk premiums that the sector currently faces will remain in place, and government, consumer, energy industry and investor support will remain ephemeral. The CSP sector must take every opportunity to explain CSP's potential benefits, demonstrate them in practice through successful ventures, and respond to the reasonable concerns of their stakeholders.

Specific actions could include:

- Working with AEMO and the transmission industry on the National Transmission Network Development Plan, factoring CSP availability into plans for grid extensions and upgrades (or the avoidance of them).
- Working with electricity distributors to raise awareness of CSP availability and benefits, and on plans for developing the distribution network to take advantage of those benefits.
- Ensuring that CSP's offer is fully represented in every government review of any part of energy generation, transmission, distribution and use in Australia, and in every public investment in the energy sector.
- Engaging more closely with financial sector asset owners and managers who have a demonstrated interest and understanding of long-term alternative asset classes.
- Better targeting information dissemination and education, leveraging Australia's membership in the IEA SolarPACES and PVPS programs for real international collaboration.
- Working with key customers and networks to establish best practice guidelines and standards for CSP system development, finance and operations.

Inviting stakeholders to visit operational CSP plants will add intensity to all of these engagement strategies.

3: Establish CSP-solar precincts

The CSP sector should work with governments, regulators and network service providers to pre-approve and provide connections for CSP systems in selected areas of high solar resource.

A precinct or solar park plan, developed with tri-level governments and energy sector partners, would have several benefits. For example:

- CSP projects would proceed to completion with a much reduced overhead in approvals and planning, helping to reduce early stage project risk.
- Planned and facilitated grid connection would reduce costs, which may then also be shared over multiple projects.
- The cost of solar data gathering, environmental impact assessments and community consultation would also be shared across projects, improving their value and levels of certainty for project development and financing.

4: Foster CSP research, development and demonstration

The CSP sector should leverage continued public and industry investment in research, development and demonstration, with more emphasis on meeting Australian needs.

Given that the benefits of early technology and market development will flow to future participants, there is a strong case for continued public sector support. Funding should be targeted at areas that offer the most traction for Australia's market conditions. These include:

- Systems optimised for below 50 MW_e (overlooked by the global industry, but with off grid / end of grid application in Australia)
- Hybridisation and enhancement of fossil fuel systems and exports
- Improved energy storage
- Advanced cooling systems to minimise or avoid groundwater and river water use, (reflecting our water constraints) and
- Improved efficiency of advanced energy conversion systems and receivers.

Other global R&D priorities should be considered for public co-investment where there is strong commercial involvement. In addition to these research and development priorities, program design and project selection should foster the skills and capabilities that the Australian CSP sector needs.

Supporting actions

The key pathway actions would be further supported by activities that include:

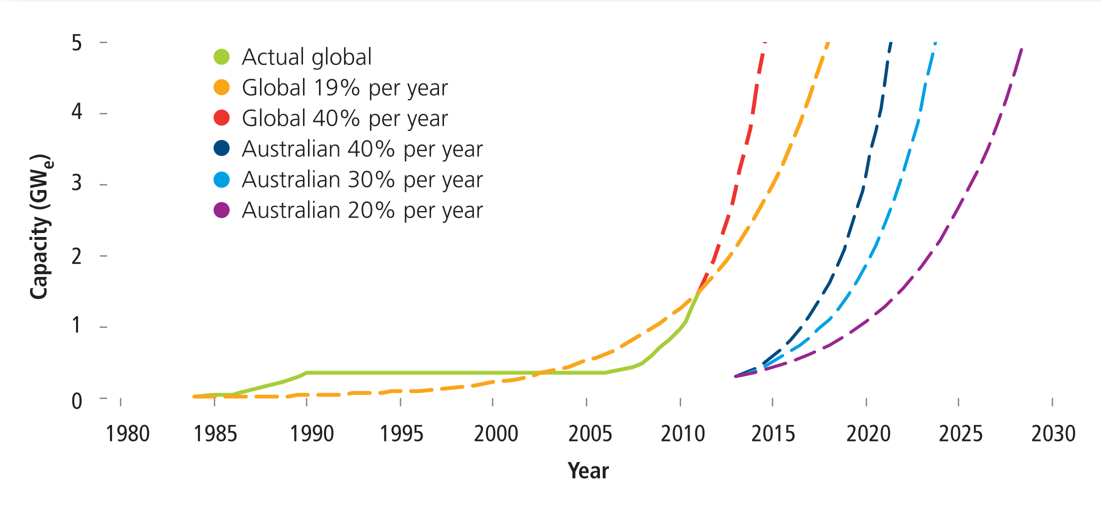
- Further extending Bureau of Meteorology direct beam solar radiation data collection, both to extra sites and to higher frequencies, to better support plant output prediction.
- Synthesising an improved set of data files for use with NREL's Solar Advisor Model, both Typical Meteorological Year and real historical years, to allow this excellent publically available tool to be used to best effect by researchers and commercial organisations.
- Modelling the likely effects of climate change over the coming two decades on solar radiation levels and CSP system performance, to help reduce risk in project planning.
- Studying the potential for concentrating-solar-driven fuels production as a possible major future driver for CST in Australia.
- More detailed study of the relative economics and potential for new combined gas / CSP systems.

CSP's future contribution

If these actions are pursued successfully, the CSP sector would be large enough to deliver economies of scale within immediate investment and policy horizons. A contribution of 2,000 MW by 2020 is readily achievable, which would see CSP play a significant role in Australia's low emission solution, and Australia be a significant part of the global CSP industry.

The growth of CSP technology globally has started to form the familiar S-curve that traces the early stages, fast development and eventual maturity of technology adoption. The medium-case growth projection for Australia, the light-blue 30% line in Figure 10, reaches 2 GW of capacity by 2020. Looking at CSP's market segments in Australia, this figure is quite reasonable. It could realistically be structured as c.100 MW in off-grid or mini-grid systems, c.500 MW in solar add-ons to fossil-fuel systems, c.300 MW in 10-50 MW systems connected to energy distribution networks, and c.1,000 MW in larger units connected to transmission networks: see Table 2 above. Investment in Australia would reach approximately $5.5 billion by 2020, assuming the retention of $1.4 billion in project commitments made to the end of 2011.

Figure 10: Global and Australian CSP development trajectories and projections



These projections form the basis for a series of development goals for the Australian CSP industry: see Figure 11 below. The 2013 goal will be reached assuming present-committed demonstration projects are successfully deployed. If the 2020 target is reached, Australia would be well on its 30% growth track to 10 GW of capacity by 2030. Beyond that is the aspiration for CSP to be a significant contributor to the essential decarbonisation of Australia's energy supply by 2050, and make up 30-50% of Australia's electricity mix.

Figure 11: Aspirations for an Australian CSP Industry[24]

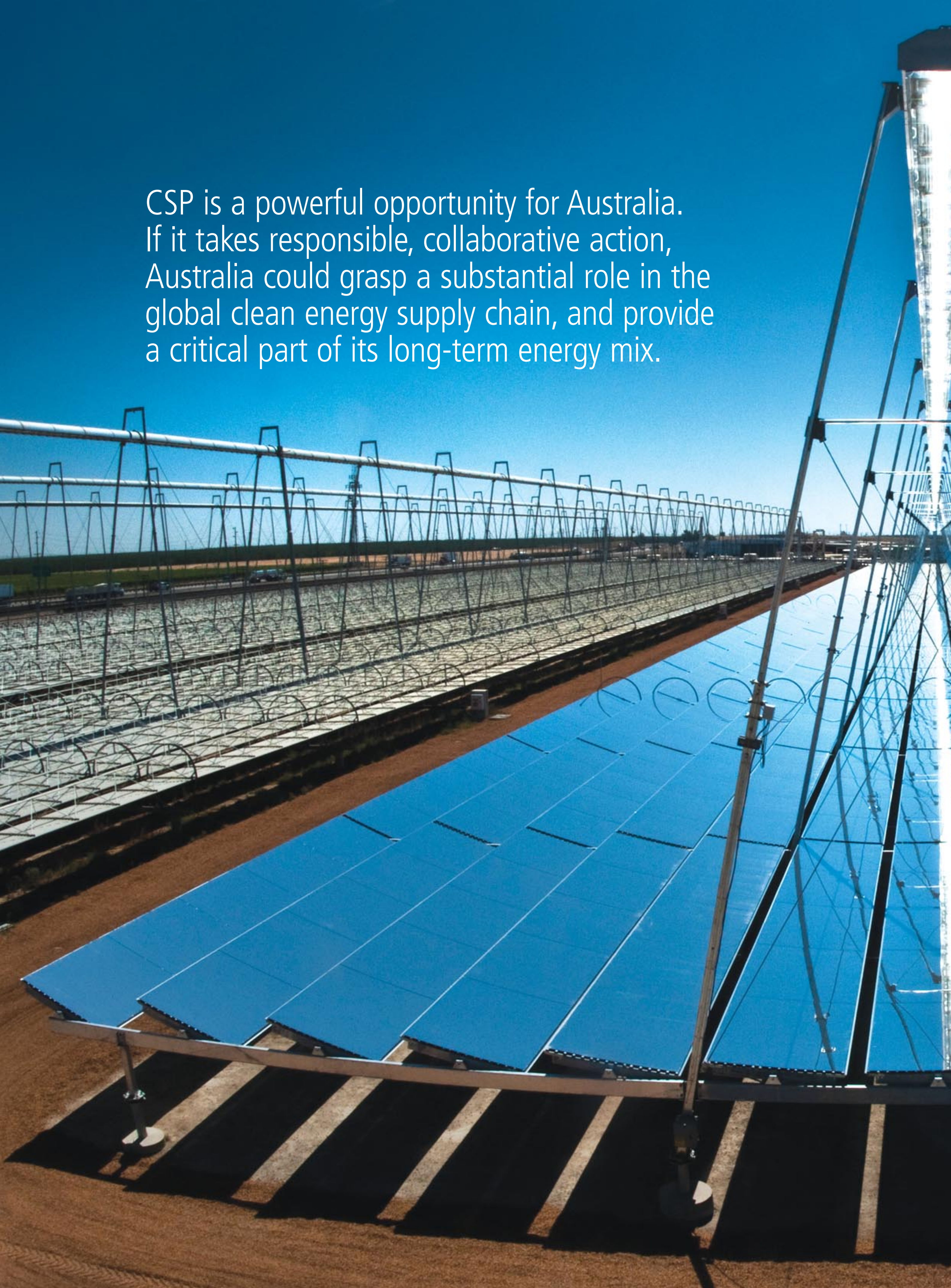
Cumulative capacity	Timing	Fraction of national demand	Notes
100s GW	2050 +		Significant source of export income via solar derived fuels and or HVDC links to Asia
100 GW	2050	30–50%	CSP provides between 30–50% of Australia's electricity in a mature 100% clean energy scenario
10 GW	2030	5–10%	CSP provides significant contributions in all market segments. Established Australian supply chain
2 GW	2020	1%	First fully commercial projects in the most prospective market segments
0.3 GW	2013	0.2%	First assisted demonstration systems at various scales

In the foreseeable future, CST-driven chemical processes already under development could deliver clean transport fuels and may allow the export of CSP-generated fuel. Alternatively, high-voltage DC transmission lines have been forecast to connect North Africa to Europe and Mexico to the US, and have also been proposed to connect Australia to Indonesia and beyond. This is a vision of very large commercial potential for the industry that, while remaining in the background of more immediate goals, will continue to offer inspiration for our young and future scientists, investors and policy makers.

As with all developed economies, Australia is gearing itself to meet the joint challenges of rising energy demand and greenhouse gas emissions. To meet these diverse needs at least cost and risk, a portfolio of energy options is needed. On its current development projections, concentrating solar power should be one of those options. However, that development is not assured. The current cost-revenue gap for Australian CSP projects is deterring private investment, while overseas support cannot be guaranteed. CSP is a powerful opportunity for Australia. If it takes responsible, collaborative action, Australia could grasp a substantial role in the global clean energy supply chain, and provide a critical part of its long-term energy mix.

24 Adapted from LEK Consulting's Advanced Biofuels Study – Strategic Directions for Australia, Summary Report, 14 October 2011 prepared for the Department of Resources, Energy and Tourism.

CSP is a powerful opportunity for Australia. If it takes responsible, collaborative action, Australia could grasp a substantial role in the global clean energy supply chain, and provide a critical part of its long-term energy mix.



Glossary

AC	Alternating Current
AEMO	Australian Energy Market Operator
AEMC	Australian Energy Market Commission
ANU	Australian National University
ASI	Australian Solar Institute
AUD	Australian dollar
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSP	Concentrating Solar Power
CST	Concentrating Solar Thermal
CPV	Concentrating Photovoltaic
°C	Degrees Celsius
DC	Direct Current
DLF	Distribution Loss Factor
GW	Gigawatt
GW_e	Gigawatt electrical
GWh	Gigawatt-hour
HTF	Heat Transfer Fluid
HVDC	High Voltage DC
IEA	International Energy Agency
kW	Kilowatt
kW_e	Kilowatt electrical
kWh	Kilowatt-hour
kW_{th}	Kilowatt thermal
LCOE	Levelised Cost of Energy
LGC	Large Scale Generation Certificates, created under the Renewable Energy Target scheme
m^2	Square metres
MLF	Marginal Loss Factor
MW	Megawatt
MW_e	Megawatt electrical
MWh	Megawatt-hour
MW_{th}	Megawatt thermal
NEM	National Electricity Market
NPV	Net Present Value
NREL	National Renewable Energy Laboratory (US)
O&M	Operation and Maintenance
PPA	Power Purchase Agreement
PV	Photovoltaic
PVPS	Photovoltaic Power Systems Program (IEA)
R&D	Research and Development
SAM	System Advisor Model (NREL)
SolarPACES	Solar Power and Chemical Energy Systems Program (IEA)
STEM	Short Term Electricity Market (WA)
SWIS	South West Interconnected System (WA)

Photography acknowledgements

Table 1: Trough – R Dunn,
Linear Fresnel – CS Energy and AREVA Solar,
Dish – K Lovegrove,
Tower – Torresol Energy,
Fresnel lens – Amonix.

Figure 1: image Ferrostaal.

Table 3: Liddell Power Station – CS Energy and AREVA Solar,
Alice Springs Airport – K Lovegrove,
Solar Systems installations – K Lovegrove,
Australian National University (ANU) dishes – ANU,
CSIRO tower – CSIRO,
Graphite Energy storage – K Lovegrove,
Kogan Creek Flagship and solar boost – CS Energy and AREVA Solar.

Page 33: Image courtesy of CS Energy and AREVA Solar.

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