Solar Power Plant Pre-feasibility Study

2 September 2008

ActewAGL and ACT Government

Parsons Brinckerhoff Australia Pty Limited ABN 80 078 004 798

Level 4, Northbank Plaza
69 Ann Street
Brisbane QLD 4000
GPO Box 2907
Brisbane QLD 4001
Australia
Telephone +61 7 3854 6200
Facsimile +61 7 3854 6500
Email brisbane@pb.com.au

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Author: Peter Cameron, Glenn Crompton ....

Signed: ....

Reviewer: Joseph Devries ....

Signed: ....

Approved by: Paul Gleeson ....

Signed: ....

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Glossary

ACT	Australian Capital Territory
ActewAGL	ActewAGL is the ACT based multi utility offering electricity, natural gas, water and waste water services in the area. It is the largest supplier of energy in the ACT
ACF	Annual capacity factor (actual energy production in MWh/a as a fraction of nameplate energy production)
AETS	Australian Emissions Trading Scheme
CCGT	Combined Cycle Gas Turbine
CER	Certified Emission Reduction
CDM	Clean Development Mechanism
CPV	Concentrating photovoltaic (PV)
CST	Concentrating solar thermal
DA	Development approval
DCF	Discounted cash flow
DNSP	Distribution Network Service Provider
EUA	European Union Allocation (of “carbon credits”)
GWh	Gigawatt hours
GWh/a	Gigawatt hours per annum of electricity production (10^9 watt hours)
ha	hectares (land area)
HRSG	Heat Recovery Steam Generator
kWh	kilowatt hours
kV	Kilovolt
MRET	Mandatory Renewable Energy Target
IRR	Internal Rate of Return
MW	Megawatts (capacity)
MW (e)	Megawatts (electric)
MWh/a	Megawatt hours per annum
NEMMCO	National Electricity Market Management Company
NGAP	National Green Energy Accreditation Program
NPV	Net Present Value
O&M	Operating and maintenance (cost)
PB	Parsons Brinckerhoff
REC	Renewable Energy Certificate
PV	Photovoltaic

SEGS	Solar Energy Generating Systems
WACC	Weighted Average Cost of Capital

Executive summary

This Solar Power Plant Pre-feasibility Study was undertaken for ActewAGL and the ACT Government (the joint parties) by PB. Its purpose was to investigate solar power generation technologies, identify an appropriate solar technology for the ACT, and establish the economic viability of a solar power facility.

Technology for producing electricity from solar energy is technically proven for both PV and solar thermal technologies. 354 MW solar thermal plants, using trough technology, have been operating in the USA since the 1980s and new plants of this type (between 50 MW and 70 MW) are now coming into service in the USA and Europe. Other solar thermal technologies that are not yet in commercial use are power towers, paraboidal dishes and Fresnel systems. Large multi-megawatt PV plants, to approximately 50 MW, are now in operation. Solar technology is expensive, and significant financial assistance from government is available to the developers and operators of new plants. There is significant local community and market support for solar power generation.

This study identifies a 22 MW project that uses solar thermal trough technology, similar to new overseas plants, as the best option for the ACT. This technology has been chosen because of its substantial operational record (more than 20 years), lower cost compared to other solar technologies, and use in new commercial plants in the USA and Europe. The plant will produce enough electricity for approximately 10,000 Canberra homes and the project cost, before government assistance, is estimated at $141 million (including land and infrastructure). A site of 120 ha will be required and if engineering, planning and environmental work commenced immediately, it is envisaged that a plant could be commissioned by 2012.

An alternative option is a large PV cell-based plant. To produce the same amount of electricity (that is, to service 10,000 homes), 75 ha of land would be required and the plant would have an electrical capacity of 57 MW. This would be one of the largest PV plants in the world but the risks would be lower than the solar thermal plant, reflecting the more mature status of PV technology, its predictable performance and cost. However, the total project cost of $424 million is high.

It is recommended that this pre-feasibility study be followed by a feasibility study that includes engineering studies, ongoing commercial evaluation, financial modelling and environmental and planning studies.

A staged study, extending over eighteen months, could be conducted and lead directly into procurement and construction. However, trough technology is not cost effective for a staged development at the size of the proposed ACT plant. Even though the solar field is modular, the balance of the plant is not suitable for staged development without incurring significant additional costs.

A financial evaluation of the solar thermal project, assuming 100% equity funding, a 9.5% Weighted Average Cost of Capital (WACC) and a 20-year project life was undertaken, Key results were:

- a levelised electricity cost of $106/MWh for a net project cost of $47 million. This is for a plant cost of $2,500/kW, which is forecast for the technology in Australa, and allows grant funding of 50% of the project capital cost;

- the relatively high cost of generation is due to the high capital cost of plant itself, the high proportion of infrastructure and land (38% of project cost) and the relatively low productivity (measured by the 42% capacity factor).

- larger plant size would significantly improve the economics by spreading the infrastructure costs over a larger productive plant and capturing economies of scale of the production plant itself. For example, doubling the plant to 44 MW would lower electricity cost by about 25%;

- 57% grant funding was required to reduce the levelised electricity cost to $95/MWh which is the expected Power Purchase Agreement (PPA) electricity selling price;

- higher solar radiation levels such as at Mildura would lower levelised electricity cost by about $50/MWh, or 17% (before rebates); and

Government grants and subsidies have been fundamental to the facilitation of the growth of solar energy generation around the world. The requirement for government support also applies to this project. This project would appear to fit well with current Australian and ACT Government policies (such as the move toward zero/low carbon emissions and renewable generation) and it supports ActewAGL regulatory requirements for renewable energy.

The Sun is a reliable but intermittent and diffuse source of energy. There is strong daily and seasonal variation and availability, and it may be limited by cloud cover. To extend power generation beyond periods of sunlight and to allow a steady supply of heat, two approaches to solar thermal plant energy storage were proposed:

- storage of heat at the plant and use of this heat when direct sunlight is not available. This would give an extra four to six hours operation without the Sun shining; and

- use of natural gas as an auxiliary fuel to supply heat as an alternative. If this is supplied by the waste heat from a cogeneration plant, an additional 47 MW could be generated by a gas turbine. The use of gas auxiliary fuel does not affect the eligibility of solar generation as renewable or green energy under the current regulatory arrangements, but may have some impact on community perceptions.

The solar thermal plant would occupy a significant area and unless it is well-shielded, it is likely to be a prominent visual feature. It would combine the physical features of the large solar field with a small thermal power station, possibly with a gas boiler or small gas turbine for back-up. While the solar technology itself is considered to be relatively benign, it is likely to require consideration environmental issues, that are similar to those raised by a small gas-fired power station with the additional issues raised by the large land area and visual amenity.

Formal evaluations of potential sites for the solar facility will occur only if the project is found to be viable and progresses to a more detailed study, at which time such sites would undergo a rigorous environmental and planning assessment.

1. Introduction

1.1 Background

PB was appointed to undertake a pre-feasibility study for a proposed solar electricity generating plant in the ACT. The study investigated solar power technology options that were appropriate for a large scale solar power facility for Canberra, and the economic viability of such a solar power facility.

The scope for this study is set out in the ActewAGL Request for Tender (ActewAGL)[1] and PB's response, 'Solar Farm Feasibility Study', April, 2008 (PB)[2].

1.2 Solar energy use for electric power generation

In Australia, 92% of electric power generation is provided by coal or gas, the balance is from renewable sources. There is over 40,500 MW of installed capacity of generating plant but only 71 MW (including off-grid systems) is solar.

Most of today's electrical energy is generated by plant with a low cost of production and high reliability. However, concerns about the longer term sustainability of fossil fuel-based generation, particularly related to climate change and largely unaccounted future environmental costs, are driving the energy industry toward sustainable, low carbon emitting, renewable energy sources. Community expectation for this change is high and government policies are also driving the energy industry in this direction.

Solar energy is an unlimited energy resource, set to become increasingly important in the longer term, for providing electricity and heat energy on a large scale. It is an energy resource that could be used in large, centralised power generation plants; smaller distributed heat and power plants; or scaled down, at the individual consumer level. Solar energy technology is technically proven and draws on an inexhaustible primary energy resource. Carbon emissions and greenhouse gas impacts are very low.

This pre-feasibility study examines solar energy options for electricity generation in the ACT. While it can be argued that wind and biomass are examples of indirect solar energy, for the purposes of this study only those technologies that use the radiant energy from the Sun are considered. There are two alternatives—solar PV and solar thermal energy technologies.

Solar PV technology collects and converts solar radiation directly into electricity. Solar thermal generation systems collect solar energy as heat to raise steam for use in an otherwise conventional thermal electricity generating plant (steam turbine). Low grade solar heat is used for water heating and, less commonly for air/space heating, solar ponds and solar chimneys. However, it is high temperature solar systems that are most prospective for large scale power generation. These require solar radiation to be concentrated to achieve temperatures high enough to be thermodynamically useful and are also known as Concentrating Solar Thermal (CST) systems. CST is best suited to relatively large generation plants as distinct from smaller household rooftop PV systems.

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[1] ActewAGL, *Request for Proposals, Solar Farm Feasibility Study*, closing date 11 April, 2008.

[2] Parsons Brinckerhoff, *Solar Farm Feasibility Study. A Proposal for Services*, April, 2008.

1.3 Approach to this study

This pre-feasibility study examines solar electricity generation technologies, undertakes a brief analysis of those that could reasonably be considered suitable for commercial power generation in the ACT, and identifies a preferred technology for further evaluation. The review and selection of a preferred technology includes:

- an assessment of the technology;
- consideration of the status of the technology and commercial experience;
- consideration of the solar resource in the ACT;
- costs; and
- risks.

The levelised unit cost of electricity and NPV were the key financial measures used to rank the technologies and projects. Levelised unit cost is derived by taking the present value of the capital and O&M costs, and dividing it by the present value of the electrical energy (kWh) generated over the lifetime of the project. No taxation expenses, debt interest costs (excluding interest during construction), depreciation or revenue streams are included in this calculation.

The report is structured as follows:

- introduction to solar energy and its use for electricity generation;
- key study assumptions;
- review of the available solar power generation technologies, cost and performance;
- the solar energy resource;
- identification of a preferred technology for an ACT solar farm;
- location, interconnection with the electricity network, services and infrastructure issues;
- environment and planning;
- project structure;
- electricity sales including green energy;
- government policy and government assistance;
- project evaluation;
- risk assessment; and
- conclusion and recommendations.

2. Key study assumptions

2.1 General

This pre-feasibility study includes a contingency for costs and performance of ± 30%.

While some potential sites have been identified and a broad assessment has been made, no planning or environmental studies have been undertaken, nor have possible stakeholders been consulted beyond the extent necessary to carry out this study. This study considers technology issues and high level costs, and identifies key issues and pathways for further examination of this project.

2.2 Project size

The ACT solar generation project is sized for 80 GWh/a. This is approximately equal to the amount of electricity consumed by 10,000 Canberra homes where the average annual household usage is approximately 8.3 MWh/a[3]. The option of a staged development to this output size and expansion beyond it are also considered.

This represents about 2.5% of ActewAGL sales in the ACT, 39% of renewable energy and about 94% of the Mandatory Renewable Energy Target (MRET) liability in 2007/8.

2.3 Project location

Nominally, the project is to be located in the ACT, using the existing infrastructure, such as power transmission, gas, water and other services, as much as is reasonable.

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[3] Advice from ActewAGL.

2.4 Assumptions and financial modelling

The financial evaluation used discounted cash flow (DCF) to calculate a levelised cost of generation and a net present value (NPV) analysis to assist in the selection of the preferred solar generation technology. Key project assumptions on which the study was based are identified in Table 2-1.

Table 2-1: Evaluation assumptions

Parameter	Value	Notes
Currency	A$	Unless otherwise noted
Project life	20 years	Typical for a project of this nature
Inflation	2.5%	Estimate of long-term CPI. (Source: ActewAGL)
Power price (selling)	$95/MWh	Bundled PPA price, including RECs (Source: Market data (June, 2008))
Escalation	CPI	Escalate both costs and revenue at full CPI
Construction period and capital drawdown	3 years	40% drawdown of capital in Project Year 1 30% drawdown in Years 2 and 3.
Taxation rate	30%	(Source: ActewAGL)
WACC	9.5%	Assumes all equity funding. Estimate, based on a range of 9% to 10%. (Source: ActewAGL)

3. Solar generation technology options

3.1 General

The solar energy electricity technologies considered for the project, solar PV and solar thermal, are presented in this section. A brief description of the technologies and their commercial status follows.

3.2 Solar photovoltaic (PV) options

PV generation technology is commercially proven and large multi-megawatt generation plants have been operating since the 1990s. Costs associated with the technology are high, but the technology is well-known and reliable. The largest plants are based on fixed solar panels inclined at latitude angle. In Australia, this has proven to be the most economic way of building PV power stations. More recent developments use PV collectors that track the Sun to allow collection of a greater amount of energy and concentrating photovoltaic (CPV systems that focus the collected solar energy into a smaller area.

PV panels silently convert sunlight to electrical energy. They generate direct current (DC) that is converted to alternating current (AC) to be used by the electricity grid. Regardless of the PV configuration, inverter hardware is required to change the direct current PV output to useable AC power for the grid. PV may be connected to the distribution network at the domestic level of 240V or at higher voltage, depending on the size and location of the generating plant.

A detailed assessment of PV for the ACT has been carried out and this is presented as Appendix A and summarised below.

Note that PV systems are rated for capacity in watts (or kW or MW) with the designation 'peak' (e.g. kW(p), MW(p)). This refers to the practice of rating the PV cells at internationally recognised standard conditions that include temperature and wavelength of sunlight. Typically, these conditions will produce a higher output than may be achieved in practice. However, because of the natural variation in sunlight and other environmental conditions, this approach provides a rational and industry-accepted basis for specification. Other energy systems also use standard reference conditions for performance specification.

3.2.1 Fixed flat panel PV

The simplest configuration for a PV system is a fixed position flat panel module. Generally for 'all round' performance, the module is inclined at the site’s latitude angle. A fixed flat panel system has no moving parts and offers the solution with the least ongoing cost of the PV options. Its output will however be less per module than the PV systems that track the Sun.

3.2.2 Tracking flat panel PV

A tracking array can move on one or two axes in order to expose the PV module surface to follow the Sun and capture the greatest amount of solar radiation possible.

Compared to a fixed system, a tracking system will provide a greater electrical output per module. It will also have both a higher capital and operating/maintenance cost due to the more complex mounting system. While the greatest possible output is desired, this must be evaluated over the life of the project against these higher ongoing costs.

3.2.3 Concentrating photovoltaic (CPV)

In order to reduce the net cost of the expensive PV cells, mirrors or lenses can be used to focus energy onto a smaller area of PV material. Due to the high solar concentration, this system generates waste heat that must be dissipated. If a use for this relatively low grade heat can be found, such as water heating, the overall system efficiency would be increased[4].

3.2.4 Comparison of PV options

A comparison of the PV options at 80 GWh/a production is presented in Table 3-1. This shows fixed flat panel PV as the lowest price option with a levelised electricity cost of $697/MWh. It represents the lowest risk of the PV options because of the relative simplicity of the installation and the long experience with these systems in Australia and overseas.

CPV is marginally more expensive in this assessment, but with higher risks because of the relatively less mature technology and greater complexity. However, though less mature, there is a high potential that costs can be driven down at a greater rate than flat panel systems and it may prove to be more cost competitive in the longer term. Simple one-axis tracking systems are less attractive because the additional energy production from the solar panels does not justify the additional complexity and cost of the tracking system.

Table 3-1: Comparison of PV options

Technology	Capacity (MW)	Energy (GWh/a)	ACF (%)	Plant capital cost ($/kWp)	Project capital ($ m)	Annual O&M ($m/a)	NPV ($ m)	Levelised electricity cost ($/MWh)	Land area (ha)
Fixed flat panel	56.5	80	16	6,704	424	1,893	-374	697	75
Tracking flat panel	47.6	80	19	9,158	482	3,098	-434	808	84
CPV	45.0	80	20	8,525	427	2,925	-386	720	56

3.3 Solar thermal options

Solar thermal energy systems use the Sun to supply heat, such as for solar water heating, and in higher temperature systems that produce sufficient energy to drive machines for power generation. The latter is the subject of this study. There are a number of solar thermal technologies that are considered for power generation. These are:

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[4] The Australian company, Solar Systems offers CPV systems that are much cheaper than those indicated by the studies by PB. PB costs and performance are based on the latest commercially available costs and performance estimates. The PB cost for CPV is $8,525/kW (p). Public information suggests an even lower cost of about $2,700/kW (p) for the proposed, larger, northern Victoria plant.

This study focuses on technologies rather than suppliers and it would be expected that the cost-effective performance of all PV, including Solar Systems CPV, would be evaluated as part of future follow-on studies. Currently there is insufficient information available to PB to undertake such an evaluation.

- lower temperature applications such as solar ponds and solar chimneys; and
- concentrating solar thermal power (CST..

3.3.1 Lower temperature solar thermal systems

Solar ponds

A solar pond is a reservoir of salty water that stores solar heat and uses this heat for power generation or other applications. Solar ponds up to 5 MW(e) have been developed and operated in Israel, but are not currently developed for large scale commercial power generation.

Solar chimney

In a solar chimney, an upward flow of air is induced by heating the air at the base of a tall chimney. The airflow up the chimney drives a turbine which generates electricity. Following an initial 51 kW prototype with a 200 m chimney in Spain, a larger 250 MW plant with a 1,000 m chimney was proposed for southern NSW. Development of this proposal has not proceeded and this technology is not proven for commercial operation.

Neither of these lower temperature solar thermal applications is sufficiently developed for consideration for the ACT project.

3.3.2 Concentrating solar thermal (CST) power systems

CST systems concentrate and collect solar energy. The concentrated solar energy generates high temperature heat for use in an otherwise conventional thermal electricity generation plant.

There are three main components of a CST generating plant:

- the solar concentrator which is a reflection or diffraction system that collects and concentrates the energy from the Sun;
- the solar energy receiver that absorbs the concentrated solar energy and converts it to useable heat to run the generation plant, and
- electricity generating plant that uses the heat collected from the sun to produce electricity.

CST systems that are under development are those based on a central receiver, parabolic trough, paraboidal dish and Fresnel systems.

Since the 1980s, 354 MW of generating capacity in nine solar trough-based CST plants, collectively owned and operated by Solar Energy Generating Systems (SEGS) SEGS, have been in operation in the USA, but until recent times, there have been no new commercial plants built. Technically, trough solar thermal technology has had some successes but costs are high in comparison with current wholesale power costs. These systems are now evolving due to renewed interest in low carbon generation, increased fuel costs and new financial support mechanisms which have encouraged developments. Three 50 MW trough plants were under construction in Spain in 2007, a further 18 similar-sized plants are planned in Spain and the USA, and the World Bank is actively pursuing CST/gas combined cycle plants in at least three countries - Egypt, Mexico and Morocco.

One advantage of solar thermal systems is that during times of prolonged lack of solar energy input, an alternative heat source can be used to provide reliability of electrical output.

Parabolic trough

In a parabolic trough system, the solar field consists of parallel rows of large reflective parabolic troughs that focus solar energy onto a central receiver tube where it is absorbed. The troughs rotate on one axis to follow the Sun throughout the day. A working fluid, usually oil, is circulated through the receiver and heated to temperatures of around 400°C (typically). The absorbed heat is used to generate steam for use in a conventional steam turbine generator. Some other trough developments generate steam directly.

Of the main solar thermal technologies, troughs have by far the most commercial experience and now appear to be favoured by commercial developers. Notwithstanding, research and development continues to play a role. Improvements in mirror curvature and alignment, more sophisticated Sun tracking, additional mirrors behind the receiver to collect scattered light, updated cleaning techniques and loss minimisation will all improve newer plants. Researchers expect this second generation of troughs will drive the cost down further. The largest trough system announced for development recently is through an alliance between Arizona Public Service Co. and Abengoa Solar. This 280 MW plant is scheduled to go online in 2011.

Power tower

In recent years, tower systems have been attracting significant research and development investment, and this type of solar thermal technology continues to develop. With a receiver located in a central tower where the solar radiation can be concentrated up to 600 times, these systems can achieve temperatures of around 1,000°C, or about 2.5 times that of troughs. These higher temperatures have the potential to lead to significant improvements in energy conversion efficiency.

The three main components of a power tower system are heliostats (reflectors), receiver(s) and the tower(s).

A heliostat is a device that tracks the movement of the Sun—in this case it is a highly reflective mirror. The receiver absorbs the radiation and transfers it to a working fluid. The hot fluid is used to generate steam for use in a steam turbine, but can also be used as a thermal storage medium to allow a more controlled release of the captured energy. The tower must be positioned at an appropriate height to ensure minimal blocking and shading of heliostats occurs.

Tower technology has been seen to have higher costs, but the associated higher temperatures have produced higher efficiency generation. In 2003, Sargent and Lundy[5] suggested that in the medium to long term this might become the lowest-cost form of solar power.

Operational from 1982 to 1986, Solar One was a pilot solar thermal project that put power towers ‘on the map’ for many. Jointly designed by several utilities and government departments in the US, Solar One was built in the Mojave Desert east of Barstow, California. In the mid-1990s, additional heliostats and thermal storage were added and it was renamed Solar Two. The updated configuration operated effectively until 1999. The

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[5] Sargent and Lundy, Assessment *of Parabolic Trough and Power Tower Solar Technology Cost and Performance*, 2003.

success of the Solar One and Two projects led to the construction of the 15 MW Solar Tres power tower in Spain.

This project makes use of systems tested in the original plant and incorporates technical advances made since the Solar projects were commissioned. These include higher reflectivity glass, more heliostats with updated controls, advanced pump design, greater storage using heat transfer material and improved efficiency in the thermodynamic generation cycle.

The tower configuration lacks the track record of trough systems, and therefore represents a higher risk option than troughs. Some proposed tower developments use a large heliostat field and several towers. Heliostats can be orientated to reflect toward the most appropriate of several towers depending on the time of day and orientation to achieve maximum solar input to the system.

Research and development predictions in solar towers indicate a production cost similar to troughs by 2020. However, while towers carry great promise, they also carry higher risk due to the lack of longer term track record.

Fresnel system

The Fresnel solar energy collection system currently under development at Liddell Power Station, and being further developed by Dr Mills and his team in the USA, represents a variant of the more conventional solar trough or dish concentrators by using the Fresnel lens concept. Originally, Fresnel systems were developed as cheaper and lighter optical systems and were initially used in lighthouses. The Fresnel solar collector is based on a development of this concept - where a number of discrete mirrors approximate a large parabolic trough collector, and are used with a large linear solar receiver. This linear receiver has important engineering advantages - it is fixed, it does not have the mechanical complexity of the moveable receivers used on solar troughs and dishes and it does not require flexible connections between the receiver and the piping systems that carry heated fluids or steam to the centralised boiler or engine.

While this will probably have lower energy conversion efficiency, and may not have the high optical accuracy of dish and trough systems, it has the potential for lower capital and operating costs and could produce energy cheaper than other solar thermal systems.

The Liddell system has not progressed beyond the initial demonstration phase and it is understood that the developer of the technology in Australia is focusing on larger developments in higher solar radiation areas in the USA.

Paraboidal dish

A dish system is a two axis tracking mirror system that focuses sunlight onto a single point. Typically, higher temperatures than a trough are achievable. Dish systems were initially developed as steam generating solar thermal systems in Australia and the USA, and more recently, have been applied to Stirling engines, other cycles and CPV.

The potential benefits of dish technology include the promise of lower capital costs and high temperatures that could provide higher energy conversion efficiencies. The combination of both is expected to lead to lower dispatched electricity cost.

The high temperature performance of dishes makes them suitable for chemical engineering applications and the possibility of energy systems based chemical reaction engineering.[6]

3.3.3 Comparison of solar thermal options

Table 3-2 shows the major solar thermal projects internationally, and illustrates the domination of trough technology in the new, nominally commercial projects. These are mostly located in Spain and the USA, where there is significant government financial support for solar technology in the form of high tariffs, and a good solar resource near suitable infrastructure. Recent studies, including an Australian study by Wyld Group[7], drawing on USA and European experience, and a study by Sargent and Lundy[5], identifies trough technology as technically proven, and there is significant potential to drive down current costs with further technology development. This is the basis for predictions of lower costs for solar thermal power in the future.

Table 3-2: Major solar thermal projects and programs

Name	Location	Capacity (MW)	Technology	Developer	Capital cost ($/kW)
SEGS	California	354	Trough	FPL Energy	-
Nevada Solar One	Nevada	64	Trough	Acconia Solar	4,549
PS 10	Spain	11	Tower	Abengoa	2,500
Andasol 1	Spain	50	Trough	Solar Millennium	9,300
Liddell	Australia	38	Fresnel	SHP/Ausra	800
Cloncurry	Australia	10	Tower	Lloyd Energy Systems	3,100
Solar Tres	Spain	15	Tower	SENER	5,888
SHAMS	Abu Dhabi	100	Trough	Masdar	5,000
Mojave Solar Park	California	553	Trough	Solel	n/a
Solana	Arizona	280	Trough	Abengoa	n/a
Barstow	California	59	Trough	Solar MW Energy	n/a

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[6] Dish technology developed at ANU has been a world leader and has seen an ANU dish supplied to Israel. Further development is taking place under the Wizard Power banner. While a single dish has been in existence at ANU since the 1990s, this has operated intermittently as part of programs that included funding by ANUTech, Energy Research and Development Corporation and electricity industry funding. Notwithstanding, this dish technology has real potential for commercial development for power generation using steam and for high temperature chemical engineering systems.

[7] Wyld Group, *High Temperature Solar Thermal Roadmap*, 2008.

3.4 Energy storage, auxiliary fuel and the performance of solar generation

3.4.1 Role of energy storage

Solar generating plants collect the energy from the Sun for conversion to electricity. To allow generation at times when the Sun is not shining, the captured solar energy must be stored for later use or an alternative source of heat must be available for use. Typically, in the case of solar thermal plants, energy is stored as heat while with PV this requires the use of batteries. There is also research into energy storage in the form of hydrogen or compressed air. Alternative energy sources such as gas can be used at night or when the Sun is obscured by cloud.

Current practice with solar thermal plants is to use both heat storage and an alternative energy source, such as natural gas. Under the current regulatory arrangements in Australia, the use of natural gas as an auxiliary fuel is allowed provided that renewable electricity produced from solar energy is measured and reported separately. In this case, the solar energy sould be classified as renewable energy for the purposes of creating RECs.

3.4.2 Heat storage for solar thermal

Two broad approaches are taken to energy storage - storage as sensible heat and storage as latent heat.

Storage as sensible heat in molten salts and heat transfer fluids are the most common methods with the new trough and power tower plants. Other approaches are to store heat as sensible heat in water, ceramic, concrete and graphite and as latent heat in organic material. Considerable research and development continues with no clear advantage identified for any particular method. However, because of its use in current plants, storage of hot heat transfer fluids is proposed for this project.

Without energy storage, the capacity factor[8] of a solar generating plant is typically limited to between 16% and 20%.

3.4.3 Plant performance

Traditionally, the capacity of electrical generating plant is expressed as MW and describes the generating plant size. Energy production is related to capacity by the capacity factor[8] by the formula:

Energy produced over a period (MWh) = Capacity (MW) x capacity factor x time (hours).

This approach is used here, recognising that in the case of PV, the capacity of generators is based on its 'peak' value, which is capacity, reported at reference conditions, which could be 20% or more above the actual capacity of the plant at operating conditions.

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[8] Capacity factor is the ratio of actual energy production to nameplate energy production, assuming the plant is capable of operating 24 hours per day, 365 days per year.

For this reason, the comparisons in this study are based on annual energy of 80 GWh/a, and not capacity which is the more common basis for comparing fossil fuel and most other technologies.

Note also that the use of storage or auxiliary fuel allows a higher capacity factor for the solar generation plant. For example:

- a PV generation plant producing 80 GWh/a without energy storage would have 45 to 60 MW of installed capacity, depending upon the efficiency of energy conversion for an ACF between 16% and 20%; and
- solar thermal without storage would be about 45 MW (16% capacity factor). With storage, the capacity factor is higher and in the case of Andasol is 42%. This would reduce the installed capacity to 22 MW, for 80 GWh/a of electricity.

4. Solar energy resource

4.1 Nature and use of solar radiation

The Sun is a reliable source of energy that is received at the surface of the Earth as relatively diffuse energy, at a maximum flux of about 1 kW/m^2 in Australia. It has a variable daily cycle with seasonal variation and may be intermittent, influenced heavily by meteorological conditions (i.e. cloud). Solar energy, being radiant energy, cannot be stored directly.

The total amount of solar radiation or using the precise scientific term, solar insolation, received at a point on the Earth is made up of two components - direct and diffuse insolation.

Direct radiation

This is solar radiation received directly from the orb of the Sun. Direct solar radiation is of interest for solar concentrators used in CPV and solar thermal systems.

Diffuse radiation

This is solar radiation that has been scattered in passing through the Earth’s atmosphere and includes reflected solar radiation including solar radiation re-reflected from the Earth.

Global radiation

Comprises both the direct and diffuse components and is of interest for flat panel and tracking PV power generation systems.

The amount of solar radiation of all types received is influenced by the location of the receptor on the Earth’s surface and by its orientation. Fixed receptors oriented toward the Sun collect less solar energy than those that track the Sun.

It is important to note that concentrating systems use the direct beam component of global (total) solar radiation and as with many renewable energy solutions, weather conditions, such as cloud, haze and fog, play an integral role in system performance. Direct or normal beam radiation data is, in general, less readily available than other solar energy data.

The most common type of PV system in Australia is the flat panel collector or module, which is typically inclined at latitude angle. This usually is the best compromise between minimising cost and maximising annual energy collection. The same is true for a solar hot water collector. An alternative form of installation is Sun tracking where the solar collector panel is mounted in a mechanism that tracks the Sun. This can be on one or two axes. This results in greater energy collection for the same size solar collector but comes at a higher cost. The impact of tracking on energy collection is illustrated below in Figure 4-1.

Solar concentrating systems are usually Sun tracking.

4.2 Solar resource in Canberra

The solar energy resource data for Canberra is drawn from a number of sources, principally the Australian Solar Radiation Data Handbook (ANZSES[9]). The specific data of interest is Global (received on a plane inclined at latitude angle), Global (Sun tracking), Direct (Sun tracking plane) and Direct (single North-South axis). This data is presented in Appendix C and summarised in Figure 4-1, Figure 4-2 and Figure 4-3.

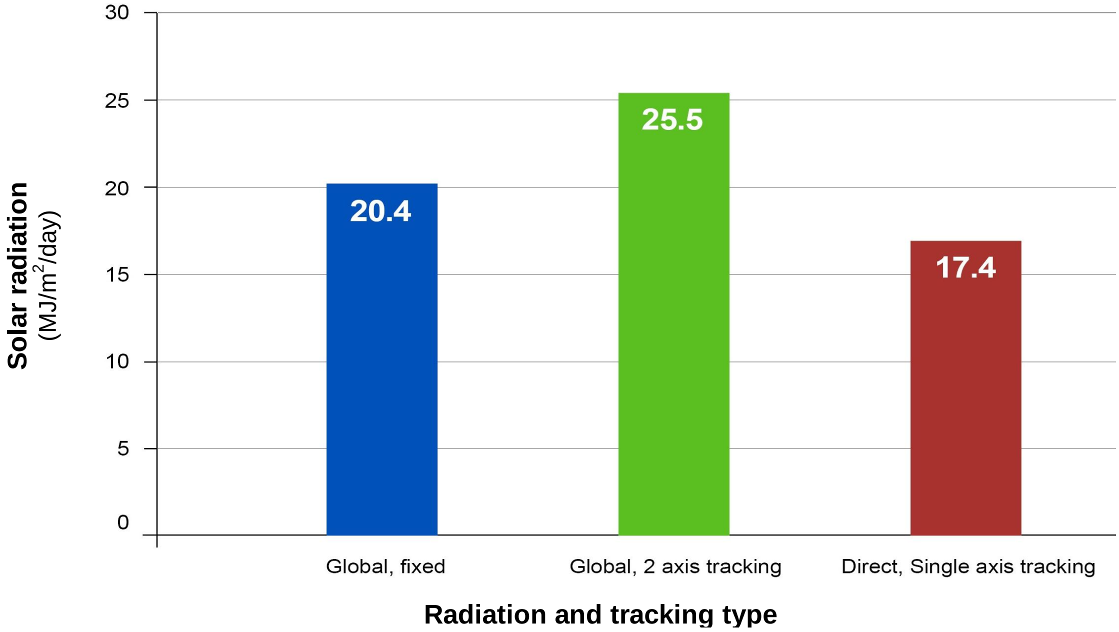

Figure 4-1: Solar radiation in Canberra

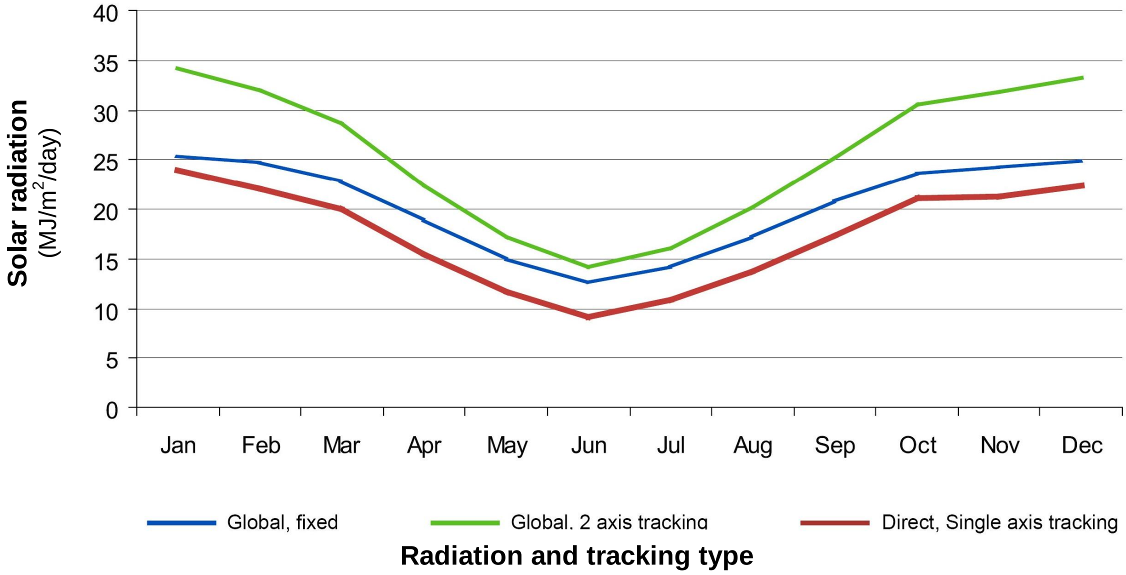

Figure 4-2: Monthly solar radiation in Canberra

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[9] ANZSES, Australian Solar Radiation Data Handbook, Edition 4, April, 2006.

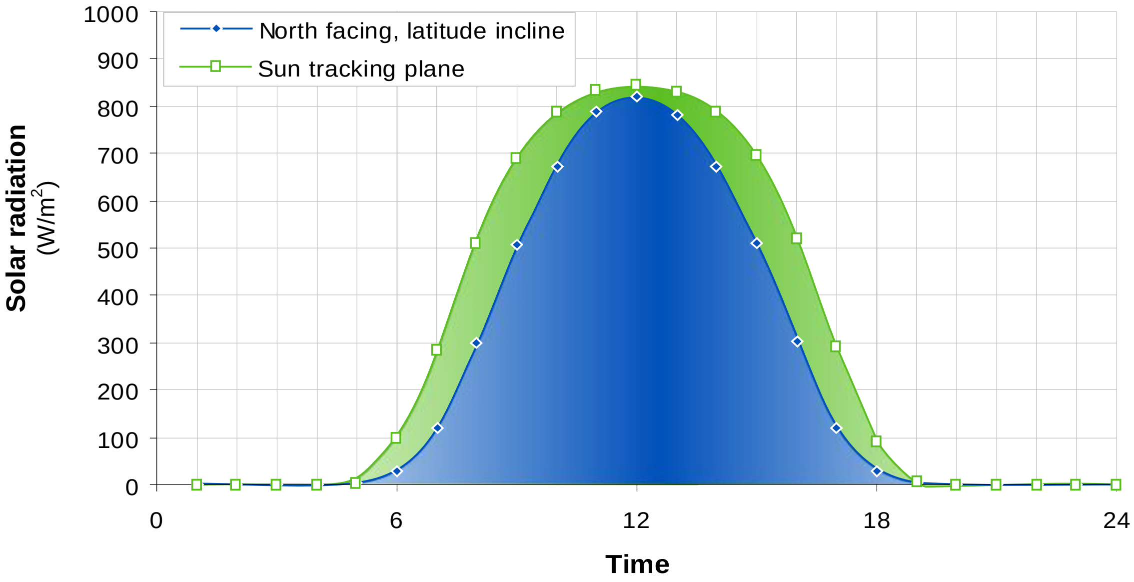

Figure 4-3: Hourly solar radiation in Canberra

4.3 Solar resource at other locations

The solar energy at available at other locations is illustrated in Figure 4-4.

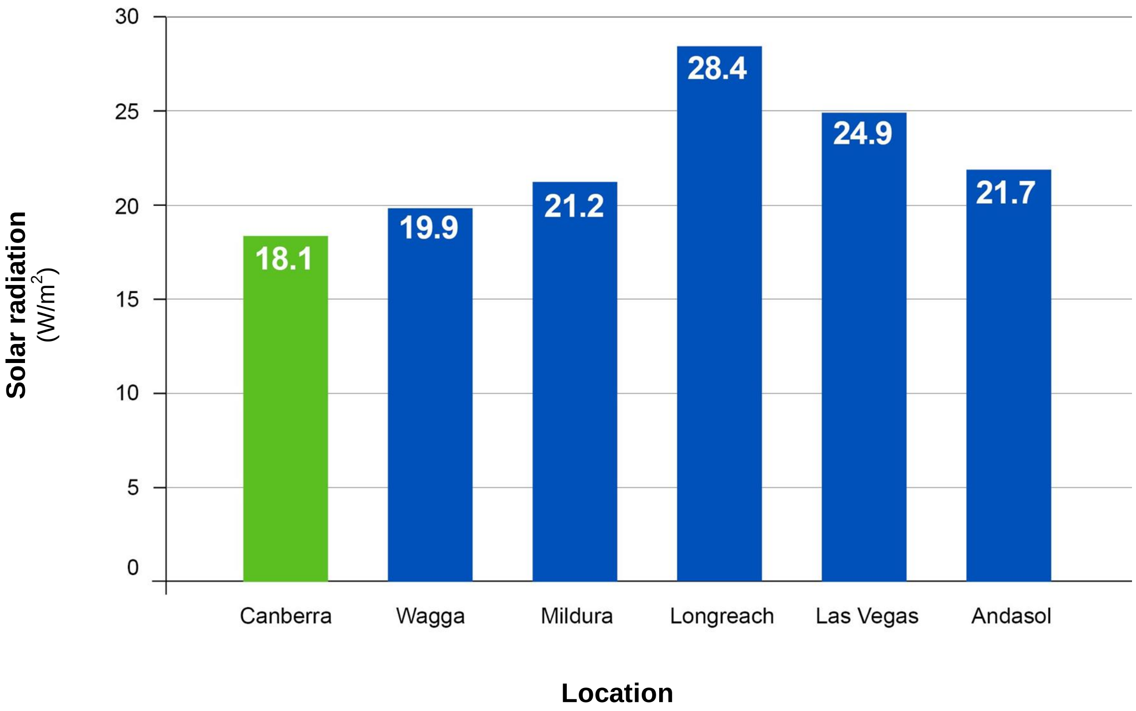

Figure 4-4: Solar radiation at other locations (annual)

Note. This Figure uses Sun tracking data which is the only data that is available for all the sites and which is higher than single axis tracking data that is used for trough plants. It is assumed that the ratio of single axis tracking data to Sun tracking is the same for all sites.

4.4 Reliability and measurement of solar radiation

While global solar radiation data is readily available and reliable for all locations, this is not true for direct radiation. In keeping with most places in Australia, there is limited data on direct solar radiation in Canberra, and the extent to which the available data has been verified is not clear. The success of a solar thermal project depends heavily on the quantity and quality of the resource data.

It is therefore recommended that site specific monitoring be carried out at one or more potential sites. There are few organisations with the capability to measure, record and verify direct solar radiation and to correlate it with existing stations. In Australia, such a capability is probably limited to organisations such as the Bureau of Meteorology, CSIRO and the ANU.

It is recommended that discussions be held with ANU and CSIRO with the objective of scoping and costing a monitoring and data verification program and correlating this with other direct radiation data from ANU and Canberra Airport. Until a program of work is scoped, it would be inappropriate to cost an associated measuring and verification program.

This work should extend to identifying the differences that exist between sites in the same region. For instance the existence of local conditions like fog, cloud or haze could significantly affect the available solar energy.

5. Solar generation plant at Canberra

5.1 Selection of appropriate technology

Parabolic trough technology is identified as the appropriate technology for the ACT. This is because of its more advanced commercial status compared with other CST technology, and the lower energy costs compared with the alternatives. There is also greater potential for this technology's costs to be driven down over time and performance improved as a result of the developments now under way.

The cost and performance of electricity from an ACT trough plant is based on the costs and performance of the Nevada Solar One plant. It is compared with other major trough plants and fixed panel PV in Table 5-1. Some features of the ACT plant, which are discussed in more detail later in this report are:

- use of energy storage to allow 42% capacity factor operation;
- increased size of the solar collector field to accommodate the extra energy required for increased capacity factor operation (increase by 87%) and to compensate for the lower solar radiation in the ACT (increase by a further 38%); and
- lowering cost by 30% for technology developments for the next generation plant that the ACT plant could realise.

This shows the ACT trough plant to have the lowest levelised electricity cost, $254/MWh, compared with the costs of the overseas trough plants, $392/MWh and $435/MWh, and $697/MWh for PV.

Table 5-1: Solar power generation options for the ACT plant

Project	Capacity (MW)	ACF %	Capital cost		O&M cost ($ m/a)	NPV ($ m)	Levelised cost ($/MWh)
			($/kW)	($ m)			
ACT Solar Trough	22	42	4,600	141	1.95	-137	254
Nevada Solar One	39	23	4,549	219	2.9	-210	392
Andasol Trough	22	42	9,300	247	2.9	-234	435
Fixed Panel PV	57	16	6,704	424	1.9	-374	697

Note that the information given in this table is intended to allow comparison of technology options and does not include any capital cost grants from government or other assistance that could be expected for a project of this type. This assistance is addressed in Section 11.

Based on this analysis, the ACT trough plant is identified as the preferred technology for further analysis. It should be noted that while this does appear to be the lowest cost option, all solar technologies continue to develop rapidly and should be kept under review.

5.2 Overview of the ACT solar plant

It is envisaged that an ACT solar trough plant would be similar in appearance and operation to the parabolic trough plants at Andasol in Spain and the Nevada Solar One in USA. It would have an installed generating capacity of 22 MW, capable of producing 80 GWh/a. A view of the Nevada plant is presented in Figure 5-1 while Figure 5-2 is a process diagram of a trough plant.

Figure 5-1: Illustration of Nevada Solar One

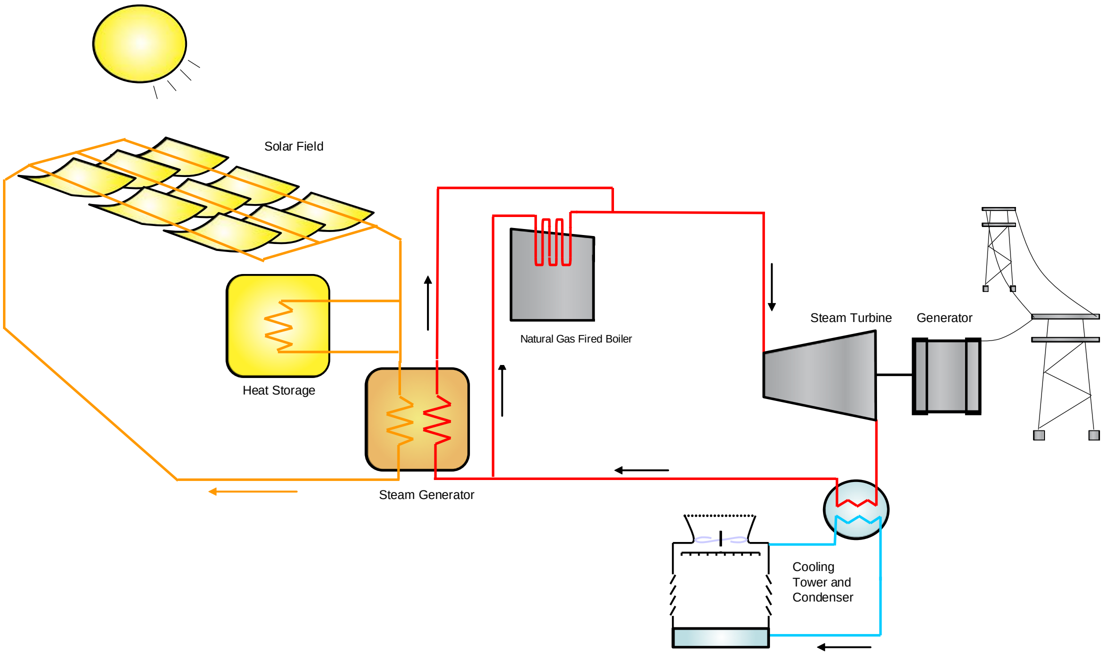

Figure 5-2: Process diagram of a trough plant

The plant would have the following key features:

- solar field comprising rows of trough reflectors for collecting the solar energy from the Sun. These trough collectors, illustrated in Figure 5-3, would consist of glass reflectors attached to a structure that, driven by small mechanical drives, allow the collectors to track the Sun.

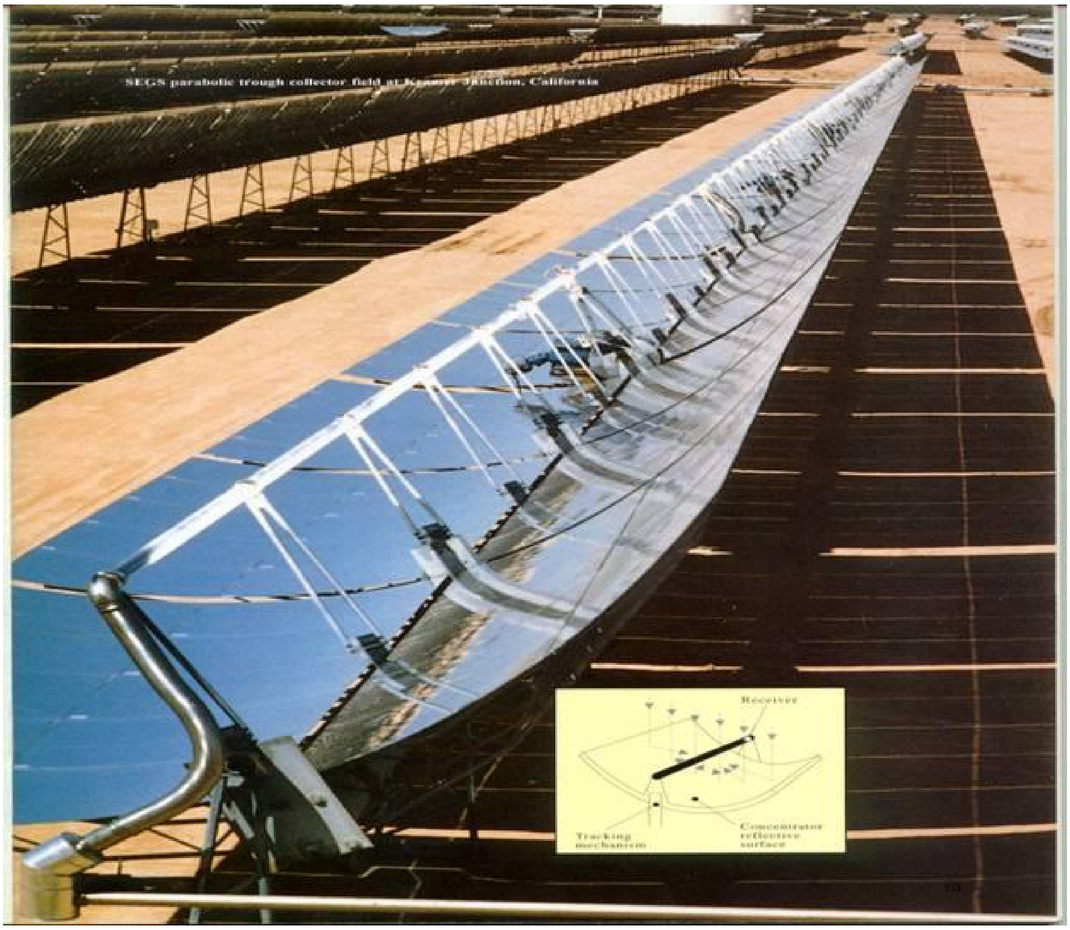

Figure 5-3: Trough collectors

- solar heat would be collected by a solar receiver that runs the length of each trough. Oil, specially designed as a heat carrier is pumped through these pipes;
- a central power block where the heat from the solar field would be converted to superheated steam which would power a conventional 22 MW turbo alternator for power generation. The steam generator would be a heat exchanger and have provision for drawing heat from either the solar field or from heat storage;
- heat would be stored by holding the heat transfer fluid or special molten salt in large, insulated tanks;
- electric power generation would be by a 22 MW (e) (nominal) conventional generator that will produce electricity at a nominal 11 kV;
- step-up transformer and switchyard facilities feeding into a short power transmission line, connecting to an ActewAGL substation;

- auxiliary gas-fired heater or gas turbine, with sufficient capacity to supply full-load steam to the 22 MW (e) steam turbine generator at times when there is insufficient solar heat available (such as during extended cloudy periods), or at times the heat storage is depleted or when additional generation is available. This could either operate as a boiler producing superheated steam or as a heater that heats the heat transfer fluid;
- condenser and wet or dry cooling tower for heat rejection as used with conventional thermal power station; and
- conventional auxiliaries, control systems, environmental management and amenities, typical for a small thermal power station.

5.3 Operation of the ACT solar plant

The solar power generating plant would generate electricity using solar energy when the Sun was shining directly on the reflectors and this was concentrated on the solar energy receiver. During cloudy weather or when the Sun was obscured even for a short period, it would stop collecting solar heat and draw on stored heat or use auxiliary fuel to supply the heat.

The reflectors can be turned over when out of service or when it is necessary to protect the glass surface of the reflectors or the glass receiver tubes from weather such as hail. This is illustrated in Figure 5-4.

Figure 5-4: Partially stowed trough reflector

Operation would be similar to a conventional gas-fired thermal plant but with the added necessity to operate the solar field and the energy storage. None of these tasks require unusual skill levels beyond that required for thermal power station operation.

Regular reflector cleaning has been found to be crucial to satisfactory, high efficiency operation of a CST plant. It is likely, depending on the site, that reflector cleaning would be required every one or two months. SEGS experience is that a mobile cleaning machine based on a truck chassis with water sprays on a continuous cycle is sufficient to maintain high efficiency operation and clean reflectors. Water of a high purity will be required for cleaning. The extent of treatment of this water will depend upon water availability and its quality. This could be recycled water. Reflector cleaning is illustrated in Figure 5-5.

Figure 5-5: Trough reflector cleaning at SEGS

The cost of labour and reflector cleaning is included in direct O&M costs.

5.4 Energy storage and auxiliary fuel

The solar plant without any energy storage could operate only when the Sun was shining. There could be no solar generation at night or during cloudy or foggy conditions and operation would be interrupted for short periods when the Sun was obscured by intermittent cloud. These short and long term interruptions could be addressed in a number of ways:

- use a form of heat storage for the heat carrier fluid, decoupling the generation from the operation from the solar field;
- provide an auxiliary fuel with a fired boiler or heater for use when solar energy is not available or is insufficient, such as at periods of low radiation; and
- make no provision to continue generation during interruptions, and configure the plant instrumentation and control systems to manage the loss of primary energy input.

Both energy storage and auxiliary fuel are proposed for the ACT plant. Energy storage in the form of an insulated tank for the hot oil transfer fluid would be used to allow full load operation of the plant during those periods when the Sun was interrupted for shorter periods (e.g. passing clouds) up to several hours. This would allow solar generation to be extended into the night. Longer non-solar operation can be achieved by using natural gas to provide an alternative heat input to the solar field.

5.5 Cogeneration and the additional energy

The performance of a solar thermal power plant is highly dependant on factors such as the time of day and cloud cover. A more consistent and reliable power supply can be achieved by augmenting solar thermal power with other energy sources such as natural gas-firing. Various operating philosophies may be considered for this type of hybrid solar thermal/gas-fired system, including:

- a gas-fired steam generator is fired to generate the shortfall in solar heat capacity (option 1); and
- steam generated by the solar thermal plant is integrated into a gas-fired combined cycle plant, which may be operated regardless of solar thermal operation (option 2).

Option 1

The two principle technologies available to provide gas fired steam augmentation are:

- natural gas boiler; and
- CCGT plant, i.e. gas turbine with HRSG.

Each of these technology options has its advantages and disadvantages. For instance, the main advantages of using a natural gas boiler over a combined cycle plant are:

- lower capital cost; and
- lower overall gas consumption.

The main advantage of using a combined cycle plant over a natural gas boiler is the greater efficiency of energy use.

Table 5-2 presents a high level summary of the output and efficiencies of the gas boiler and CCGT options. In each case, these generate enough steam for the 22 MW (e) steam turbine generators.

Table 5-2: Options for generating steam

Item	Natural gas boiler	CCGT with fired HRSG
Steam turbine plant net output (MW)	22	22
Gas turbine net output (MW)	N/A	24.77
Net plant output (MW)	22	46.77
Gas consumption (GJ/hr)	273	394
Net plant efficiency (%)	29	43

Note that the information presented for the CCGT output relates to a HRSG that is fitted with supplementary firing to boost steam production. This enables a smaller gas turbine to be provided while maintaining an equivalent steam production and also allows greater flexibility over the steam generated. Without supplementary firing of the HRSG, the steam produced from the gas turbine's waste heat alone would generate approximately 11,600 kW.

Alternatively, in order to generate a net 22 MW (e) from the steam produced through an unfired HRSG, a gas turbine of approximately 47 MW capacity would need to be installed.

Option 2

An integrated solar thermal and gas-fired project could operate a combined cycle gas plant as a base load plant, with the steam generated through the solar thermal plant injected into the steam turbine as available. This would enable a greater use of the gas-fired generation.

In this case there would not be an upper limit to the size of the combined cycle plant, but there would be a lower limit. The lower pressure steam turbine would need to be suitable for operation under conditions of both combined cycle generated steam, or combined cycle and solar generated steam. This would place limits on the minimum size of the combined cycle plant. It is anticipated that for a solar thermal plant of 22 MW (e), a minimum combined cycle plant of approximately 67 MW (45 MW gas turbine, 22 MW steam turbine) would be needed to support the additional solar thermal steam injection to the turbine.

A variation on this concept could be to install the combined cycle HRSG with supplementary firing. In this case, the HRSG could be fired when the solar thermal plant is out of service to make up lost output, with the supplementary firing being ramped out of service as the solar thermal plant begins generating steam. Under this scenario the total plant output, including the gas turbine, could be maintained at a relatively constant level, about 67 MW.

5.6 Cost

5.6.1 Capital cost

The forecast capital cost of a trough CST plant in the ACT, is based on USA and European experience, but using the Nevada Solar One as a model. The derivation of the cost is presented in Appendix B and includes:

- as a starting point, the cost of A$4,549/kW[10] based on USA plant US$262 million (refer Table 5-1);
- a total increase in collector area of 2.6 times, increasing the cost of the solar field by 75%. This is the result of two factors. Firstly, 87% additional solar collector area is required to allow the recovery of extra solar energy for the increased electricity production to 80 GWh/a, compared with the Nevada plant. Secondly, additional 38% of collector area is required to compensate for the lower solar radiation at in Canberra 18.1 MJ/m^2/day, compared with 24.9 MJ/m^2/day in Nevada;
- a Canberra plant built in 2010 could expect to benefit from lower costs as a result of development of the technology, as the current generation plants are further improved. Based on a study in the USA by Sargent and Lundy[5], it is estimated that a 30% cost reduction could be achieved.

Together, these change the net cost of the ACT plant to $4,600/kW. At this price, the cost of the solar plant (excluding water supply, roads, gas, network connection and land) is estimated to be $101 million.

A recent study for the Victorian and NSW Governments by Wyld Group[7] identified costs driven down to $2,500/kW in Australia, as a result of the ongoing technology development and is additional to the short term cost reduction already identified by Sargent and Lundy[5]. This gives a lower ACT plant cost of $55 million.

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[10] US$ = A$0.9

5.6.2 Operating and maintenance cost

The O&M cost is intended to cover the direct costs of plant operations and include:

- direct operating labour including operators on shift (2 per shift), supervisor, reflector cleaners (2) and maintenance staff (2);
- materials and consumables; and
- long term maintenance.

The estimated O&M cost is $1,950,000/a. This is an estimate based on the work of Sargent and Lundy[5] and includes Australian costs for the above labour, materials, consumables and services.

5.7 Development schedule

A development schedule for the project shows commissioning at the end of 2011 with commercial operation commencing at the beginning of 2012. This includes:

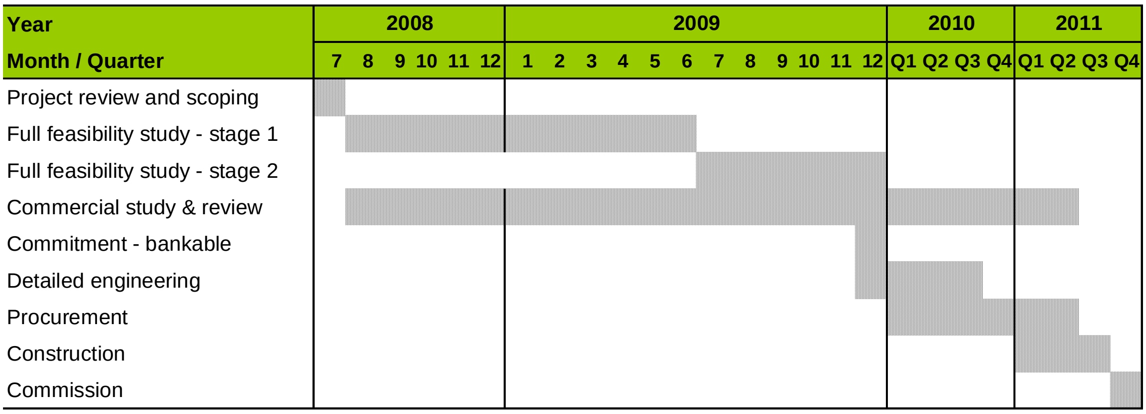
- an initial study to define the scope of work and cost of a full feasibility study that would take the project to the point where a firm commitment to proceed could be made. The study would take one month, with a budget cost of $20,000, depending on the scope of work, to be developed with the joint parties;
- a full engineering and commercial feasibility study would cover technology review and confirmation of technology selection, performance review, assessment of the solar resource, engineering, environmental studies leading to a full EIS and planning studies leading to an application for a Development Approval (DA). In parallel with this study, a full commercial evaluation would be undertaken. This could be done in two stages. Stage 1 leading to a concept design (+/- 15% contingency) and Stage 2 would be +/- 10% contingency.

  Stage 1 is forecast to take 11 months. Its scope would include a review of technology including consideration of other solar technologies. This would confirm the technology selection and identify two or three sites that would form the basis for progressing the study. This phase would include the commencement of initial public consultation and EIS to identify any major project impediments. The plant would be costed to +/- 15% with the outcome to include an advanced Concept Design.

  Stage 2 is forecast to take a further six months. This would confirm the technology, capital cost, O&M cost and performance estimates. It would complete a draft EIS and submit a Development Application. Costs to +/-10%.

  While the engineering, EIS and DA work is proceeding, a parallel commercial evaluation including a review of funding could be undertaken;
- at the end of this feasibility study, it is expected that tender documents could be written and tenders called for the detailed design, engineering, supply, construction and commissioning of the plant (18 months from start of Scoping Study); and
- while the feasibility study is proceeding, regular meetings (monthly) should be held with updates on project viability at 2 monthly intervals.

Following formal commitment, the project would then proceed to detailed engineering, procurement, construction and commissioning at the end of 2011. An indicative development schedule is presented in Figure 5-6.



Year	**2008**						**2009**												**2010**				**2011**			
Month / Quarter	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Project review and scoping	▨																									
Full feasibility study - stage 1		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨														
Full feasibility study - stage 2													▨	▨	▨	▨	▨	▨								
Commercial study & review		▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
Commitment - bankable																		▨								
Detailed engineering																		▨	▨	▨	▨					
Procurement																			▨	▨	▨	▨	▨	▨		
Construction																							▨	▨	▨	
Commission																										▨

Figure 5-6: Development schedule

5.8 Staged development option

The option of developing the solar generation plant in two stages was considered.

A PV project would be easily amenable to a staged development because of the modular nature of the PV panels and the balance of plant electronics.

Such an approach would not be a realistic option for a trough CST plant. While the solar thermal field would be suitable for a staged development, albeit with some complexity and additional cost, this would be a higher cost approach for most of the remainder of the plant. Particularly, this would apply to the power block comprising the steam generator, steam turbine, generator, transformers and electrical equipment.

A 22 MW steam plant is, compared with industry practice, relatively small and because of this, is relatively high cost. Staged development, in say three stages, would require the power block to be broken into two or three smaller parts which would impose significant cost penalties, on top of the normal cost penalty arising from construction work on the power plant while commissioning and operating an adjacent component plant. This could impose an additional 15% to 20% of capital cost. Given the relatively short construction period for the plant, this would not be justified in cost or engineering terms.

This staged development pathway for PV is illustrated below in Table 5-3.

Table 5-3: Development pathway

Development option	CST		PV	
	Size MW	Capital cost $m	Size MW	Capital cost $m
Incremental			19	175
			38	132
			57	132
Total				439
Single development	22	141	57	424

5.9 Size of the solar plant

The solar thermal plant would benefit from larger scale development, and it is expected that economies of scale, that would accrue from larger plant size, would significantly reduce unit capital (i.e. $/kW) and sent-out electricity cost, as is the case with modern thermal generating plant.

This was investigated by scaling costs for a doubling of the plant size to 44 MW. This would require approximately double the land requirements but other non-plant costs were assumed to remain the same. Plant cost would increase from $101 million (i.e. $4,600/kW) to $150 million for the larger 44 MW plant. This results in a lower specific cost of $3,416/kW. Other costs are discussed in Section 13.

Current investigations of large 500 MW solar thermal plants in Victoria and Queensland are driven by the desire to capture economies of scale to reduce costs to a level that, after the introduction of carbon trading, would allow solar thermal to be cost competitive with a coal or gas plant.

5.10 Future expansion of the solar plant

Both PV and solar thermal technologies in the ACT would be suitable for further development of the initial project, subject to the availability of additional land.

The modular nature of PV technology would make expansion easier than a trough CST plant. The trough CST plant could be expanded in, say 22 MW stages as, for the reasons described in 5.9 above, larger plant increments are likely to produce lower costs.

5.11 Land required

The land area required for the solar plant is dependent on the amount of solar energy falling on the Earth, the efficiency of conversion of solar energy to electricity and the amount of open space between the collectors.

The solar thermal plant requires 120 ha (14 to 15 m^2/MWh), including the open area required for access to reflectors and the additional collector area needed to provide energy storage. This is equivalent to 5.5 ha/MW. The fixed flat panel PV would require 75 ha. This is equivalent to 1.3 ha/MW of capacity.

5.12 Potential suppliers of ACT CST plant

There are a number of organisations with an interest in solar thermal projects, who are associated with overseas projects and who are likely to be interested in the ACT project and its hardware. These are organisations who have, or who have access to, engineering, management and equipment supply capability.

There is growing interest in solar thermal power generation in Australia following overseas developments, and a number of organisations including the Queensland and Victorian Governments, electricity generators and other organisations are actively investigating projects at various levels. This could result in additional overseas organisations with the capability to engineer and to develop projects becoming involved. As a consequence, it is expected that the number of organisations with or with the capability to engineer, supply and construct solar thermal plants in Australia will increase in the short term.

5.13 Distributed generation compared with the solar plant

Distributed generation is electricity generation embedded in the local distribution network that is owned and operated by the Distribution Network Service Provider (DNSP), in this case ActewAGL Distribution. It is sometimes referred to as parallel or embedded generation. This could be rooftop PV installed on houses or commercial buildings in the region and connected directly to the local distribution network at low voltage (415v), landfill gas generation located at landfill sites in the area that could be connected at higher voltage, and other relatively small generation, such as hydro or a small wood waste generator.

5.14 Technologies already proposed for the ACT solar plant

A number of proposals for solar thermal and PV plant have already been made to the joint parties. These proposals were made in response to a broad set of criteria prepared by PB. They have been reviewed and will be recorded by the joint parties for reference should the project proceed to a more detailed analysis.

This study is based on a broad evaluation of the technologies that are available and is not an evaluation of the equipment or proposals that may be available from particular suppliers.

6. Location for the ACT solar plant

6.1 Selection criteria

Based on a nominal 22 MW solar thermal development, an area of 120 ha would be required.

Required physical characteristics for a location include:

- cleared land with no significant shading from vegetation, structures or hills;
- level land with only a gentle gradient, preferably north-facing;
- land suitable for access roads to all parts of the plant to allow regular vehicular access to solar reflectors
- located as near as practical to a connection point to ActewAGL Distribution's high voltage transmission network;
- access to a suitable gas supply, suitable for a nominal 22 MW gas-fired generation plant;
- access to a water supply and waste water disposal;
- appropriate separation from domestic residences and noise and visual impact-sensitive areas;
- located so the site is not overlooked by significant population centres;
- located away from major plumes or sources of dust which could obscure sunlight and coat reflector surfaces with a film that would reduce plant efficiency; and
- appropriate zoning and environmental considerations.

Note that this is a preliminary list of criteria. It is expected that sites would undergo a rigorous environmental and planning assessment and inspection and confirmation of connection points as part of the selection process.

6.2 Site identification methodology

Based on the information provided by PB, a number of potential sites were nominally identified by ACT Government agencies as having sufficient size for possible development of a solar power plant.

In the context of a preliminary assessment of possible options, there was no discussion of these sites with parties outside the immediate working group and there was no consultation with any stakeholders at this initial stage in the project. No environmental or social impact assessment was undertaken, and no sites outside those identified by the ACT Government were considered. These processes would need to be built into any subsequent process of site identification.

Formal evaluation of identified sites will only occur if the project is found to be viable and progresses to a more detailed study - at which time potential sites would undergo a rigorous environmental and planning assessment.

7. Electrical connection to the network

7.1 General

ActewAGL Distribution owns and operates a high voltage transmission and distribution network in the ACT. The extent of this network, along with other infrastructure is shown in Appendix D. It is envisaged that the solar generation plant will be connected to the 132 kV high voltage network.

For the purposes of this study, it is estimated that 7.5 km of new transmission line will be required to connect the project to the existing 132 kV network.

Before finalisation of the connection arrangements, it will be necessary to negotiate a network connection and access agreement and undertake further activities, such as:

- stability studies;
- investigation of connection issues including assessment of the need to upgrade or modify ActewAGL equipment due to an increase in fault levels;
- protection modifications; and
- NEMMCO/TransGrid studies and approvals.

7.2 Network connection

The solar thermal project size is proposed to be 22 MW. However, the PV option, because of its lower ACF, would be 57MW. This higher rating is used for grid connection designs.

The proposed plant will be connected to the 132kV transmission system through an 11kV/132kV substation. This involves an 11kV/132 kV power transformer, underground cables and overhead lines at 11kV and 132kV with at least 60MVA rated capacity. The network connection is designed to carry rated power on a 24-hour basis.

For connection to the 132kV transmission grid, it is necessary to adhere to National Electricity Rules and the connection must meet NEMMCO/TransGrid requirements. This requires a series of studies and designs, including:

- load flow studies;
- fault level analysis;
- dynamic stability assessment;
- connection substation concept design; and
- protection design (connection substation and transmission line).

The studies would need to be conducted according to normal industry practice and with network information from NEMMCO and in consultation with ActewAGL Distribution.

7.3 Cost

The studies and design for network connection are proposed to take place during a two-year period - the lead time required by TransGrid/ActewAGL Distribution for meetings and negotiations. The estimated cost of the proposed network connection is shown in Table 7-1.

Figure 7-1: Cost of network connection studies and design

Item	Cost ($)
Network connection studies and design	500,000
Nominal substation at solar farm and modification of existing works	20,450,000
Transmission line (132kV) cost (estimate based on a nominal length of 7.5 km)	3,750,000
Total	**24,700,000**

7.4 Metering

As required by NEMMCO, an energy and revenue meter will need to be installed on the 132kV side of the substation. Factors to be considered when selecting meters are the:

- possible harmonics content of metering signals;
- associated degree of inaccuracy of the meter selected; and
- site specifics that need to be considered in metering design.

8. Services and infrastructure

8.1 General

This project will require the normal services and infrastructure expected for any small power generation plant.

8.2 Water

Water requirements for the solar thermal power station would be similar to a conventional thermal power station of similar output plus additional water that would be used for solar reflector cleaning. For a wet cooled system the total water consumption would be around 276 ML/a, while if dry cooling was introduced this could fall to around 36 ML/a. The major water using systems for 80 GWh/a of electricity are presented in Table 8-1.

Given the potential to reduce water use, in this case by 87%, by adopting dry cooling instead of wet cooling, it is recommended that dry cooling be considered. This will increase capital costs and may result in a loss of energy conversion efficiency, but these negatives must be weighed against the larger benefit of reduced water use.

Figure 8-1: Solar power station water use

Use	Water consumption (ML/a)		Notes
	Wet cooling	Dry cooling	
Condenser cooling	240	-	Base on 3 kL/MWh for wet system
General services	16	16	Estimate
Reflector cleaning	20	20	Estimate
Total	276	36	

Wastewater would be around 48 ML/a for a wet cooled station and 10 ML/a for dry cooling.

8.3 Gas

If it was decided to use natural gas as an auxiliary fuel, this would need to be piped into the plant. In practice, this would require a pipeline to be laid from a suitable connection point within the existing gas supply network.

Gas to run a boiler for a 22 MW (e) generator would require 320 GJ/hour of gas.

The nominal capital cost of the gas connection was estimated to be $1,500,000, based on a nominal 7.5 km pipeline to a connection point with a supply pipeline.

8.4 Roads and access

Road access, water and wastewater connections was estimated to be $1,000,000.

9. Environmental, planning and carbon trading considerations

9.1 Environmental

A trough solar thermal generating plant will occupy a significant area, about 120 ha, and unless it is well-shielded, it is likely to be a prominent visual feature. It will combine the physical features of the large solar field with a small thermal power station.

While the solar technology itself is considered to be relatively benign, it is likely to require consideration of similar environmental issues as a small gas-fired power station and the issues raised by the large land area required. Some specific issues to be considered are:

- area required for the solar field and the consequent impacts on visual amenity and local flora and fauna;
- reflections from the solar field. Concentrated solar radiation is unlikely to pose a risk as the points of focus of the concentrators will be relatively close to the reflector itself. However, further consideration should be given to the impacts on any residences, facilities and transport within line of sight of the reflector field;
- risks associated with possible spillages of oil and other fluids from broken pipe-work;
- stack emissions associated with back-up gas plant;
- noise associated with generation plant; and
- use of water for cooling or air cooling with attendant performance degradation and performance loss.

9.2 Planning and approvals

The ACT planning and approvals process is dependant on whether the site in question is subject to the provisions of the National Capital Plan (managed by the Commonwealth Government) or the Territory Plan (managed by the ACT on behalf of the Commonwealth). While the presence of two separate planning schemes complicates the process, the same general principles apply to each. Details of the ACT planning and approvals process are presented in Appendix E.

Following successful completion of the environmental studies and the granting of a DA, the project could proceed.

9.3 Carbon trading

The first act of the new Rudd Government was to ratify the Kyoto Protocol, under which developed countries agreed at Kyoto in 1997 to limit their greenhouse gas (GHG) emissions. The Rudd Government’s aim is for the Australian Emissions Trading Scheme (AETS) to be implemented by 2010 to set an Australia-wide cost/value of carbon emissions/removals.

The Garnaut Climate Change Review has been commissioned by Australia's Commonwealth, State and Territory governments to examine the impacts, challenges and opportunities of climate change for Australia, and will review the basis and overarching design principles of an AETS. The Garnaut Review is clearly arguing from a ‘first best’ theoretical economic efficiency argument basis, and as such ignores constraints from slow physical stock turnover and other sunk investment effects.

The Garnaut Review is critical both of the proposed increase in an Australia-wide MRET to 20% of Australia’s electricity generation by 2020, as well as Australian carbon emitters being able to use Clean Development Mechanism (CDM) GHG project reductions from developing countries, such as in China, India or Indonesia. The Garnaut Review argues that a soundly based AETS would make an expanded MRET target unnecessary, and that CDM projects are generally not additional in practice (that is that the CDM projects are cost effective and would happen anyway in the absence of the CDM mechanism).

Ultimately the outcome of the Garnaut Review may be an increased MRET, a range of industry assistance funds, and modest AETS obligation by 2010. This likely outcome would drive up the value of the RECs or equivalent produced by the ACT solar plant over the price of carbon, from a comprehensive AETS where firms and players with carbon obligations could use CDM credits to meet their Australian GHG emission reductions. Therefore current REC prices equivalent to $50 to $55/MWh seem likely to continue for the foreseeable future. This is in spite of the current CDM Certificate market price being around $10-20/CER which is much lower than the $55/REC price.

The consensus view of international carbon market experts (from 3,703 questionnaire responses in early 2008 and Point Carbon’s own research) is that the future price of CER/EUAs (Certified Emission Reduction (Kyoto) and European Union Allocation certificates) is expected to increase to $55/ton CO2e (€35) per CER/EUA by 2020[11].

9.4 Broader sustainability issues

There are a range of drivers for renewable energy, over and above GHG reductions, in particular the environmental impacts of conventional power generation plants.

Renewable energy projects however, generally also have a range of other environmental impacts, including visual amenity, noise, and wildlife impacts. For either PV or trough solar thermal plant these environmental impacts are unlikely to be major constraints if an appropriate site is chosen.

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[11] “Carbon 2008 – Post 2012 is now”, Roine K., Tvinnereim E., and Hasselknippe H., Point Carbon, 60p, 11 March 2008.

10. Electricity sales and revenue

10.1 General

For the purposes of this pre-feasibility study, it is assumed that electricity produced by the solar farm would be sold under a long term Power Purchase Agreement (PPA). The electricity could be contracted as a bundled product for a single price, comprising two components, the black electricity, and the renewable or green power component.

For the purposes of this study, a nominal bundled price of $95/MWh has been estimated from market data.

10.2 Renewable energy/green power

Subject to meeting the ACT environmental and planning requirements, the electricity produced by any of the solar technologies identified in this study should meet the requirements of the Office of Renewable Energy Regulator and therefore should qualify as Renewable Energy under the current MRET legislation. This being the case, the electricity produced would generate RECs at the rate of one REC for each megawatt hour of electricity produced. These could be sold bundled with the black electricity product or sold or traded separately.

Similarly, electricity from this project should also meet the requirements of the National Green Power Accreditation Program (NGAP) and, if so, could be sold branded as such.

In each case, the value of either RECs or Green Power would be a premium to black energy, and provide the bulk of the price of $95/MWh (estimated from market data). Indicative value of RECs is in the range $50 to $55, equivalent to $50 to $55/MWh.

The project itself must be accredited by the Office of the Renewable Energy Regulator for RECs. This is done by direct application to the Office of the Renewable Energy Regulator who will evaluate it against the criteria set out in the legislation. It should be noted that accreditation requires acceptance of the EIS (or other environmental evaluation) and a DA. Until these are received, only provisional accreditation can be received.

If it is desired to sell electricity from the project as Green Power, a similar certification program is undertaken by the Manager of NGAP. Acceptance of this project by the Renewable Energy Regulator would almost certainly mean it would be acceptable as Green Power. However, as is the case with some other renewable energy products, this cannot be assumed and it is necessary to go through the NGAP accreditation if Green Power is to be part of the marketing strategy. It is assumed that the commercial benefit to the project of both Green Power and RECs is the same.

11. Government policy and support

11.1 Australian Government policy

The Australian Government has a policy of encouraging low carbon intensity in energy and this includes more low carbon generation. This is given effect through MRET and other existing programs such as the Generator Efficiency Program and the Low Emission Technology Demonstration Fund. Carbon trading will be key example of such a scheme.

As an electrical retailer who purchases electricity in the wholesale electricity market, ActewAGL Retail accrues a liability to acquire and to acquit RECs, which under the MRET conditions was approximately 2% of electricity sales. Assuming ActewAGL Retail purchases the output of the solar farm with RECs, this will go toward this meeting the liability under existing and changed MRET arrangements.

The ACT solar generation plant, whatever the technology, will be a low emission generator and will be consistent with the policy direction of the Australian Government. There are no known regulatory requirements of the Department of Environment relating to the approval of a solar power generation although, as part of the environmental approvals process, it is likely that ActewAGL as one project proponent would need to demonstrate Best Available Technology/Practice for the plant. This should not be a barrier for a plant employing such leading edge technology as part of a solar generation plant that is competently implemented.

11.2 ACT Government policy

ACT greenhouse reduction initiatives target 60% of 2000 levels by 2050 (as stated in the ACT Climate Change Strategy). This long term target is in line with other Australian and international jurisdictions. An interim target of the 2000 levels has been set for 2025.

The annual reduction required from 2005 to 2050 is 2,825,000 tonnes per year. The proposed 80 GWh/a solar project will contribute about 80,000 t/a (3%) toward this target, based on an assumed displacement of the same amount of electricity with an emission coefficient of 1 tonne of carbon dioxide per MWh. Electricity contributes about 75% of ACT greenhouse gas emissions. The solar project would contribute about 4% of electricity's share.

11.3 Other policy

The solar energy contribution, being a zero contribution to greenhouse emissions, would contribute to ActewAGL Retail liabilities under the ACT and NSW Greenhouse Gas Abatement Scheme.

11.4 Government support

11.4.1 General

This project could attract substantial financial support from the Federal and ACT Governments. This could take the form of one or more capital contributions under the programs announced in the recent Commonwealth Budget, through preferential depreciation or tax measures, and some form of revenue support, such as a feed-in tariff arrangement.

11.4.2 Australian Government support

Renewable energy fund

This is a new fund that is to provide $500 million over seven years to accelerate the development, commercialisation and deployment of renewable energy technologies in Australia. It aims to expand the range of renewable technologies, and assist demonstration of a project's viability on a technical and economic basis. It is expected that this will support large scale demonstration of technologies. Solar thermal is a priority area.

The way the fund will operate has not been announced. However, there are similarities with the objectives of the Low Emission Technology Demonstration Fund (LETDF) of the previous government. This fund offered grants on a 2:1 basis (i.e. 33% of capital cost), typically in the range $20 to $100 million. Other renewable energy programs, such as the Remote Renewable Power Generation Program, offered up to 50% capital contribution. At this time and until the details of the funds are finalised, it is not possible to be definitive as to the funding expected. However, for initial planning, funding between 25% and 50% and a possible cap between $20 million and $100 million is assumed.

Expanded renewable energy target

The Government intends to increase the current MRET to about 20% of Australia's electricity supply by 2020. This will open a market for qualifying renewable energy to 45,000 GWh/a by 2020.

This is likely to increase the market for renewable energy substantially. If this program operates like the current scheme, it could support the revenue by the value of the RECs, less any handling charges. Currently the forward value of RECs is in the range $50 to $55.

This could be expected to give retailers confidence to plan on the take up of additional renewable energy.

Energy innovation fund

This is a new $150 million fund that is to boost clean energy research and development capabilities in Australia. This includes $100 million for solar research.

This fund is to be focused on research rather than commercialisation and includes a proposed Solar Energy Institute, which is to include CSIRO and ANU. Although conditions of the fund have not been announced, solar thermal will be a priority area. The Institute and the ability to access additional research funds through this fund will provide important support to the project.

Most funding is likely to be on the basis of $1 from government for every $2 from the proponent.

11.4.3 Accessing Australian Government support

Renewable Energy Fund

This fund is offered through the Department of Energy, Resources and Tourism. While there is a formal application process, it is recommended that the project team establish good links with senior personnel early in the project evaluation period. In particular, the project team should keep the Department informed and seek advice on how the application should be framed.

11.4.4 ACT Government support

Support from the ACT Government is not clearly defined. It could take the form of assistance with land packages and relief from local duties and taxes. Some direct capital assistance may be possible although usually such additional support is likely to be considered in the context of the total ACT Government funding support.

12. Risk assessment

A high level, qualitative risk assessment has been undertaken for the project. This focuses on the main project areas. The assessment criteria are presented below and results of the assessment are given in Table 12-1.

Adverse events	The problem that could occur.
Consequences of an adverse event	These are rated in terms of the impact on the project as Critical, Serious and Low.
Possibility of an adverse event	Rated in terms of the likelihood of an adverse event occurring, rated as High, Moderate and Low. These ratings assume appropriate risk mitigation steps are taken.
Magnitude of risk	Based on the Consequences and Possibility assessments, a qualitative level of risk is assigned in terms of High, Moderate and Low. Note the final magnitude of the risk assumes that appropriate risk mitigation measures will be put in place.
Management of risk and its mitigation	Comment on how the risk may be managed.

Table 12-1: Risk assessment

Project area	Possible adverse event	Consequences of an adverse event	Possibility of an adverse event	Magnitude of risk	Management/mitigation
Solar energy resource assessment	Estimate of solar resource availability at the site not met	Serious (lower than expected production and lower revenue)	Low	Medium	Appropriate solar monitoring of direct radiation at the site is required. This should be correlated with long term solar data measurement record for Canberra
Technology selection and engineering	Select poorly performing systems Underestimate timelines and project requirements	Critical (plant may not meet completion timeline and may not perform to specification)	Moderate	High (technology is immature but technically proven and new to Australia)	Need to undertake a comprehensive engineering study with experienced and competent personnel. Need a clear definition of key performance factors. Select proven technology and apply top quality engineering and project management
Electricity production	Lower than design production	Serious (reduced revenue)	Moderate	Moderate (as above)	As above
Plant cost	Underestimate of plant capital and operating costs	Critical (overspend budget)	High	High (as above)	As above.
Transmission and infrastructure	Underestimate requirements, timelines and cost of transmission and infrastructure	Serious	Low	Low (understandable and predictable)	Understanding of issues. Implement good planning and execution. Take competent, experienced advice The requirement for auxiliary fuel increases the risk

Project area	Possible adverse event	Consequences of an adverse event	Possibility of an adverse event	Magnitude of risk	Management/mitigation
Environmental	Unable to secure acceptance of EIS. Particularly land requirements, visibility and emissions	Critical	High	High	Need careful management of the process
Planning and community issues	Unable to secure DA and/or lack of community support	Critical	High	High	Need careful management of the process and engagement of the community. Provide timely, credible and reliable information
Sovereign risk. Government support for the project and compliance with government rules	Unable to secure high level government support for funding and planning	Critical Project economics will suffer without government financial support	Moderate/high	High	Maintain close and ongoing links with government agencies and at the political level to maximise government support

13. Project evaluation

13.1 Key inputs to modelling

Base data used in modelling the options are listed below in Table 13-1:

Table 13-1: Plant and infrastructure cost and details

Technology	Capacity (MW)	Capital Cost 0f Plant ($ m)	O&M Cost ($ m/a)	ACF
Solar thermal				
ACT Plant	22	101	1.95	42%
Nevada Solar One	39	177	2.9	23%
Andasol Plant	22	205	2.9	42%
PV				
Flat panel	57	378	1.9	16%
Tracking flat panel	48	436	3.1	19%
CPV	45	384	2.9	20%

Infrastructure	Capital cost ($ m)	Comments
Total infrastructure and land	37	Includes land, network connection, gas and other infrastructure such as drainage and roads.

13.2 Summary of modelling

For the purposes of comparing the solar technologies and other renewable energy technologies, a levelised unit cost of generation and NPV cost analysis were performed, using a proprietary DCF model, adapted to model the various inputs and assumptions attributable to the alternative projects. This did not include any debt financing costs, taxation effects or take into account any revenue from electricity sales. The NPV analysis employs a discount rate WACC of 9.5% which assumes all-equity project funding excluding any government grants.

13.2.1 Results of solar technology comparison

The solar technology options were modelled and results of this analysis are shown below in Table 13-2:

Table 13-2: Results of modelling options

	NPV($m)	Levelised Power Cost $/MWh	Total Project Cost ($m)	O&M ($m/yr)
ACT Trough Plant	-136	254	141	1.95
Nevada Solar One	-210	392	219	2.9
Andasol	-234	435	247	2.9
PV flat panel, fixed	-374	697	424	1.9
PV single axis tracking	-434	808	482	3.1
CPV	-387	720	429	2.9

The ACT solar trough plant has the lowest capital cost and produces the lowest unit cost of generation and NPV. This option was selected as the preferred option for further sensitivity and detailed cash flow modelling analysis.

13.2.2 Further cost analysis of selected solar farm option

The ACT solar trough project was subjected to sensitivity analysis of the plant capital. Two alternative scenarios were created, one being the original plant capital of $4,600/kW (identified as the base case) and the other using the reduced plant capital of $2,500/kW (assuming lower capital cost for the ACT project). For each scenario the plant cost was further reduced by 50% and then 33% to demonstrate the effect of a 50% and 33% subsidy of plant capital.

Three further scenarios were developed around the base case:

- an increase in the grant for the $2500/kW plant scenario, to a level which provides a levelised unit cost of generation of $95/MWh;
- plant capital cost of $4,300/kW with no grant and electricity generation of 93 GWh/a. This represents location in an area of higher solar such as Mildura; and
- lower WACC of 7.5% on the base case, no grant scenario to determine the effect of a 2% reduction in the WACC, from 9.5% to 7.5%. This scenario was chosen to illustrate the impact of discount rate on the electricity cost.

An increase in plant size to 44 MW would result in some economies of scale, lowering the basic plant cost to $3,416/kW from $4,600/kW. At a base plant cost of $2,500/kW, doubling plant cost to 44 MW could be expected to lower plant cost to $1,895/kW. This is discussed further in Section 13.4.

The main inputs for the sensitivity analysis are shown below:

Table 13-3: Sensitivity analysis inputs

Plant Cost	Scenario	Plant capital ($m)
Base case $4,600 / kW	No grant	101
	50% grant	101
	33% grant	101
$2,500 / kW	No grant	55
	50% grant	55
	33% grant	55
$95/MWh, $2,500/kW	57% grant	55
$4,300[12] / kW (93 GWh/a)	No grant	95
WACC = 7.5%, $4,600/kW	No grant	101
Double plant size to 44 MW, based on $4,600/kW plant cost	33% grant	150
Double plant size to 44 MW, based on $2,500/kW plant cost.	33% grant	83

The results of the sensitivity analysis are shown below.

Table 13-4: Results of sensitivity analysis

Option	Project NPV ($m)	Levelised cost ($/MWh)	TotalpProject cost ($m)
Base case - no grant	-137	254	141
Base case - 33% grant	-97	181	95
Base case - 50% grant	-77	141	71
$2,500 / kW - no grant	-97	180	94
$2,500 / kW- 33% grant	-70	131	63
$2,500 / kW - 50% grant	-57	106	47
$95/MWh – 57% grant, $2,500/kW	-51	95	40
$4,300 / kW - no grant, 93GWh/a	-131	210	135
WACC = 7.5% - no grant, $4,600/kW	-145	220	141

13.3 Effect of size

Most major power and process plants show significant economies of scale, particularly when increasing size from relatively small sizes, like 22 MW, This was explored by scaling the plant cost for a larger 44 MW plant and estimating electricity cost.

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[12] Smaller collector field reduces the capital cost of the plant.

Based on the original $4,600/kW plant cost, the capital cost for 44 MW reduces to $3,416/kW. This gives a levelised power cost of $191/MWh, which is down 25% from the original cost of $254/MWh for the 22 MW plant (no grant).

The lower $2,500/kW plant cost for 22 MW reduces to $1,895/kW for 44 MW, which reduces power cost a similar amount to 137/MWh (before grants). However, it should be noted that this latter comparison has limited practical, value because the starting point of $2,500/kW was already low, having been arrived at by making a judgement on how much capital cost could be driven down with early-stage technology development.

13.4 Other locations

A key consideration for solar energy plants is the level of solar radiation. The ACT plant has the solar collector area expanded to compensate for the lower solar radiation. If the plant was built at Mildura where the solar radiation is 21.7 $MJ/m^2/day$[13] (about 20% higher than Canberra), this would lead to a reduction in plant cost by about $300/kW to $4300/kW and benefit from the higher level of solar radiation. This would reduce electricity cost from $254/MWh to $210/MWh or about 17% (Table 13-4). This reduction is significant at this level of study and, even after taking account of additional transmission losses, could deliver a lower market cost of electricity.

13.5 Other renewable energy projects in the ACT

A number of other renewable energy projects evaluated by ActewAGL were compared with the ACT trough project. These were wind, biomass (wood residue) landfill gas and small hydro. All are mature technologies. Subject to the availability of an appropriate energy resource and securing environmental and DAs, all could be considered as realistic development options. Provided that the appropriate project accreditation is received from the Office of the Renewable Energy Regulator (ORER) and under the National Green Power Accreditation program, these would all qualify for RECs and Green Power.

Details of the renewable energy projects with costs are presented in Table 13-8.

All the options could have resource, environment and community-acceptance issues, such as biomass (because of limited resource availability and emissions) and landfill gas (because of gas availability and the likely short life of the landfill gas resource). None have the potential for large scale deployment because of limitations on the available primary energy resource. However, as shown in Table 13-8, all would produce significantly cheaper electricity than the solar plant.

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[13] See Section 4.3.

Table 13-5: Other renewable energy resources for the ACT

Plant type	Wind	Biomass	Landfill gas	Hydro
Capacity (MW)	50	22	2	1.1
Capital cost	$115 - $130m	$40 - $50m	$2.4 -3.6m	$3.3 - $4m
Capacity factor	38%	90%	93%	50%
Fuel cost	Nil	$25/t	Nil	Nil
Amount of fuel	Nil	250,000 t/a	Nil	Nil
Levelised power cost	$120	$90	$50	$120

14. Conclusions and recommendations

14.1 Conclusions

The key conclusions drawn are:

- solar thermal represents a true zero carbon emission generation option;
- there is established commercial experience with solar thermal trough technology that makes it the preferred choice for a solar energy project at Canberra. This technology continues to be chosen by commercial developers for new projects in the USA and Europe, ahead of other solar thermal technologies;
- the operating experience accumulated over some 20 years make it lower risk than the other solar thermal technologies because of their lack of commercial experience;
- solar thermal technology offers significantly lower capital and operating costs than PV technology;
- an alternative lower risk but much higher cost option is PV technology. The high cost makes it less attractive than solar thermal;
- significant research and development of solar power generation is being funded, particularly in the USA and Europe. This ongoing research and development investment provides the potential for significant reductions in cost and increases in performance and this could lead to any one of solar technologies that have been considered in this study 'leap-frogging' others to attain the preferred status;
- a high level of government financial assistance (that varies between jurisdictions) could be expected;
- there is generally wide community support for all the solar technologies; although community reaction to a large-scale solar plant in the ACT is untested;
- the cost of sent-out energy is high. A financial evaluation, assuming 100% equity funding with a 9.5% WACC was carried out, with outcomes as follows:
    - the project would cost $141 million and return a levelised cost of $254/MWh, before any financial assistance;
    - after allowing for financial assistance in the form of a 50% capital cost grant, and a reduction in project cost to $47 million (net, including a lower $2,500/kW plant cost, as is forecast for this technology), levelised electricity cost was $106/MWh;
    - 57% of capital cost grant funding was required for the 9.5% hurdle rate with an assumed $95/MWh market PPA electricity selling price;
    - the key factors behind the relatively high cost of generation are the high capital cost of plant itself, the high proportion of infrastructure and land and the relatively low productivity (measured by the 42% capacity factor). Larger plant size would significantly improve the economics by spreading the infrastructure costs over a larger productive plant, and capturing economies of scale of the production plant itself;

  - A doubling of the plant size to 44 MW could be expected to lower capital cost by about 25% and this would lead to a reduction in sent-out electricity by a similar amount.
  - reduction in the discount rate by 2% to 7.5% lowered the sent out electricity cost by about $40/MWh (before rebates);
  - higher solar radiation levels such as at Mildura would lower electricity cost by about $50/MWh, or 17% (before rebates);
- the Sun is a reliable but intermittent and diffuse source of energy. There is strong daily and seasonal variation and availability may be limited or interrupted by cloud cover. To extend power generation beyond periods of sunlight and to allow a steady supply of heat, two approaches to solar thermal plant energy storage were proposed:
  - storage of heat at the plant and use of this heat when direct sunlight is not available. This would give an extra six to eight hours operation without the Sun shining;
  - use of natural gas as an auxiliary fuel to supply heat as an alternative. If this is supplied by the waste heat from a cogeneration plant, an additional 47 MW could be generated by a gas turbine. The use of gas auxiliary fuel does not affect the eligibility of solar generation as renewable or green energy under the current regulatory arrangements, but may have some impact on community perceptions;
- the local solar resource at Canberra is lower than at some other centres. This increases the capital cost because it requires a greater area of collectors than other locations with higher levels of solar radiation. This increases the cost of sent-out energy, but is not a technology limitation;
- there is a lack of reliable and verified data on the local direct solar resource at Canberra. While some data is available, further information on the amount of solar energy is required;
- the intermittent and variable nature of solar energy makes energy storage preferred, particularly for solar thermal and this is included in the ACT proposal;
- the provision of gas as an auxiliary fuel would allow dispatch able operation and operation during extended cloudy periods;
- under the current regulatory arrangements the use gas for auxiliary firing does not affect the certification for RECs or Green Energy;
- the additional non-solar heat could be supplied by a gas turbine or gas engine combined cycle plant. This would allow additional despatchable generation of around 47 MW or more, depending on the configuration. Alternatively, a boiler could provide stand-by heat input at times of low solar energy availability;
- no special skills, of a standard beyond that currently needed to operate and maintain a thermal power generation plant, would be required. Personnel would be required as plant operators (on shift) and for servicing and maintenance;.
- a preliminary list of physical characteristics required for a site were identified. It is expected that sites would undergo a rigorous environmental and planning assessment, and an inspection and confirmation of connection points would occur as part of the selection process;
- the solar plant could be connected to the existing ActewAGL 132 kV transmission network, subject to the normal planning, design and approvals processes;

- the plant would require connection to the existing gas, water and waste water services; and
- an EIS will be required.

14.2 Recommendations

Key recommendations for high priority work, prior to implementation are:

- undertake a full feasibility study preceded by a short scoping study. The feasibility study would include engineering, project development, environmental and project planning. This could be a staged study that could run for 18 months, with outcomes including a clear project schedule and costs and performance estimates with a contingency of around 10%
- in parallel with this work, commercial studies should be undertaken with ongoing project viability reviews;
- the engineering study should evaluate energy storage as an option to increase output;
- while focussing on trough technology, it is important to maintain a close watch on the development of the other solar thermal and PV technologies and their relative advantages. This would allow advances in the other technologies to be leveraged;
- identify potential sites upon which to base the feasibility study;
- set up a program to collect and verify solar resource data in Canberra and investigate differences between sites by site monitoring; and
- study options for providing auxiliary heat and integration with gas turbine or gas engine plant as a means of providing additional generation that is gas-fired.

Appendix A

Photovoltaic Options

ActewAGL

Photovoltaic Feasibility Assessment

July, 2008

Parsons Brinckerhoff

Parsons Brinckerhoff Australia Pty Limited ABN 80 078 004 798

Level 4, Northbank Plaza
69 Ann Street
Brisbane QLD 4000
GPO Box 2907
Brisbane QLD 4001
Australia
Telephone +61 7 3854 6200
Facsimile +61 7 3854 6500
Email brisbane@pb.com.au

NCSI Certified Quality System ISO 9001

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1. Introduction

1.1 Objective

The ACT Government and ActewAGL believe that a solar power generation plant may be an appropriate project and have committed to a study to investigate the feasibility of such a facility, to be completed by 1 July, 2008.

1.2 Background

ActewAGL is the ACT's largest supplier of energy, delivering electricity to more than 136,000 customers in ACT. ActewAGL is working with the ACT government to address climate change through series of comprehensive Action Plans, including a plan to reduce ACT greenhouse emissions by 60% of 2000 levels, by 2050.

1.3 Process

PB's study methodology has been developed to integrate into the process of concept and design development, the management of safety, risk, operations, maintenance, stakeholder interfaces and budgets.

PB's approach to the study will be to focus on achieving a practical, cost effective and low risk outcome, to meet the ActewAGL scope of work and budget and to assist ActewAGL in managing stakeholder expectations.

PB has reviewed different PV technologies to give ActewAGL a broad view of options to consider for this project. PB will develop costing for the project in three output phases:

Phase 1: Annual electricity output of 16Gwh

Phase 2: Annual electricity output of 40Gwh

Phase 3: Annual electricity output of 80Gwh

PB Power has used solar data from Canberra at 35.3° S 149.1° E and modeled the output for a solar power plant.

1.4 Glossary of terms

MJ/m2/day: Mega Joule per meter squared per day

MW: Megawatt

PV: Photovoltaic

RPS: Renewable Portfolio Standard

We: Watt of electric output

Wp: Watt peak. Unit of power capacity for PV modules

2. Site

2.1 Location

The proposed site is within the ACT boundaries, in Canberra. The site is relatively flat with no obvious shading from building or the surrounding topography. The desired location has 100-160 hectares of land are available for the PV plant.

2.2 Infrastructure

There is a 133kV transmission line near the proposed site.

2.3 Climate

Canberra has four distinct seasons, because of its latitude, elevation and distance from the coast. The climates of most Australian coastal areas, which include all the state capital cities, are moderated by the sea. Canberra experiences hot, dry summers, and cold winters with heavy fog and frequent frosts. Records are based on data from Canberra Airport.

Mean annual rainfall of 629 mm

Annual mean temperature of 12-15 degrees Celsius

Annual mean minimum temperature of 3-6 degrees Celsius

Annual mean maximum temperature of 18-21 degrees Celsius

Annual mean relative humidity of 50%-60%

2.4 Energy resource

Modeled solar statistics for the site were generated using the NASA Solar Meteorology and Solar Energy tables; also collaborating data from ANZSES (Australia and New Zealand Solar Energy Society's "Australia Solar Radiation Data Handbook,2006". This gave annual average insolation incident on a horizontal surface of 6kWh/m^2/day, annual average diffuse radiation incident on a horizontal surface of 1.64kWh/m^2/day and annual average direct normal radiation of 5.48kWh/m2/day.

3. Solar technologies

3.1 Photovoltaics

3.1.1 Principles

Photovoltaic cells use the ‘photoelectric effect’ to generate electricity on exposure to sunlight. There are different types of photovoltaic technology based on the materials used in the modules. The different types are:

Monocrystalline silicon: This is the most efficient technology to date. The PV is made from single crystals of silicon. This type of PV is the most expensive. Sliced from single-crystal boules of grown silicon, these wafers/cells are now cut as thin as 200 microns. Research cells have reached nearly 28 percent efficiency; with commercial modules of single-crystal cells exceeding 18percent.

Multicrystalline silicon: Multicrystalline PV involves a cheaper manufacturing process than monocrystalline silicon with the cells being cut from an ingot of melted and re-crystallized silicon. Sliced from blocks of cast silicon, these wafers/cells are both less expensive to manufacture and less efficient than single-crystal silicon cells. Research cells approach 24-percent efficiency, and commercial modules approach 16-percent efficiency.

Thin film: Various materials are used to make thin film PV, such as amorphous silicon, Cadmium Telluride and Copper Indium Diselluride (CIS). These are cheaper technologies with lower efficiencies than for crystalline silicon PV. Amorphous silicon PV in particular is suited to low cost applications where a high efficiency is not required.

Monocrystalline and multicrystalline silicon PV are the dominant technologies in the marketplace and have been on the market longer than thin film technologies.

PV is sold in modules of up to 220Wp. As an example the BP3160 (produced by BP Solar) polycrystalline silicon PV module is 160Wp and is 1.26m2 in area (dimensions: 1209x537x50 mm). The voltage at maximum power is 35.1 Volts and the current at maximum power is 4.55 Amps.

PV modules are connected in strings to generate electricity at the required voltage and current level. PV modules generate DC current. Connection to the electricity network (or if used to power AC appliances) requires the use of an inverter(s) to produce AC current.

There are 4 sectors of PV applications:

Off grid industrial: communications repeater stations, cathodic protection

Off grid residential: solar home systems

On grid applications: domestic systems, commercial systems, PV power plants

Consumer products: calculators, watches

The relevant application for this study is the on-grid application.

Figure 3-1: PV power plant, Domaine Carneros Winery, Napa, CA - 120 kW [Copyright: PowerLight Corporation]

3.1.2 Level of maturity

PV is a relatively mature technology with many years of operating experience. Current technology has proved to be reliable and systems, particularly grid connected systems, are generally low in maintenance. It should be noted, however, that there are low quality PV products on the market which have shorter life expectancies. Modules should be chosen that comply with the standard IEC 61215 "Crystalline silicon terrestrial PV modules – Design qualification and type approval[1]."

Generally for grid connected PV systems it is the inverter that requires the most intervention; the PV panels are designed to operate without maintenance. It would be expected that cleaning of the panels would be required on a regular basis. There is ongoing development of PV systems to increase the cell efficiencies of modules and reduce system costs.

3.1.3 Limiting factors

The main limiting factor to the development of PV in the grid connect market is the economic return of the systems. PV has a high capital cost and high electricity prices are required for the system to be economic over its lifetime. The grid connect market is currently dependant on market support programs, such as grants or preferential tariffs for PV generated electricity.

A secondary limiting factor to the expansion of the current PV market is the lack of availability of silicon feedstock. The silicon for PV manufacture is taken from the waste products of the electronics industry; this keeps the costs of PV manufacture down but creates a dependency which has limited production expansion. During the past two years, solar grade silicon manufacturers have expanded operations to meet the growing needs of the industry. Many solar cell and module manufacturer's have invested in this expansion to also expand there own operations.

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[1] IEC 61215 "Crystalline silicon terrestrial PV modules – Design qualification and type approval"

http://www.iecee.org/ctl/equipment/pdf_word/PV/EL_IEC61215_Ed1_final.pdf

3.1.4 Global utilization

World solar photovoltaic (PV) market installations reached a record high of 1,744 megawatts (MW) in 2006, representing growth of 19% over the previous year.

Germany's grid connect PV market grew 16% to 960 Megawatts in 2006 and now accounts for 55% of the world market. While Japan's market size barely advanced last year, Spain and the United States were the strong performers. The Spanish market was up over 200% in 2006, while the US market grew 33%.

The world PV production in 2007 was 2.44GWp. Globally, Sharp Solar is the largest manufacturer of PV products. Major manufacturing expansions have been started around the world and the predicted solar PV capacity could reach 10GWp by 2012[2].

Australian Manufacturers:

BP Solar has manufacturing capacity for 50MW cells and 15MW for modules. BP solar uses mono and multi crystalline silicone to produce there products.

Origin Energy uses it “Sliver” cell technology to produce cells and modules.

CSG Solar is a new type of thin film application that has been developed in NSW, and is being produced in Germany.

Dyesol uses there patented DSC to produce a thin film product using non-silicon based applications.

Solar Systems has developed and commercialized a PV tracking concentrator disk off-grid and on-grid applications.

3.1.5 PV in Australia

The predominant market for PV in Australia has been for off-grid applications: solar home systems, battery charging stations, water pumping etc. Project Example:

Hermannsburg, Yuendumu and Lajamanu

“Solar Systems” has completed construction of three concentrator dish power stations at Hermannsburg, Yuendumu and Lajamanu. Together they generate 720kW and 1,555,000 kWh per year.

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[2] Solarbuzz (www.solarbuzz.com)

3.1.6 Other PV installations

There are many examples of PV installations; those listed below have been chosen for their size or comparability to the ActewAGL proposed project.

Phase One of 40 MW German Solar Park in Bolanden, Germany

The "Waldpolenz" solar park, a 40 megawatt (MW) solar generation power plant; is under way at a former military base in the Saxon region of Germany. It will be comprised of approximately 550,000 First Solar thin-film modules; building on an area of more than a million square meters, it's comparable to about 200 soccer fields[3].

Bavaria Solar Park, 10 MW, Germany

The Bavaria Solar Park consists of 3 ground mounted systems; 6.3 MW on an undeveloped area in Mühlhausen, and two 1.9 MW systems in the Bavarian municipalities Günching and Dietersburg. The systems have a combined power of 10.1 MW. The systems use the single-axis PowerTracker tracking system. In all, 57,680 monocrystalline Sharp modules with 175 W each are mounted on the PowerTracker. The modules are connected to the utility Eon's grid with Sinvert-Solar inverters from Siemens.

Geiseltasee Tank Farm in Germany, 4MW

The 4 megawatt system, funded by a consortium of investors, supplies enough power for 1000 four person households to the local grid. The plant was built on a former mineral oil plant. There are plans to add a further 2 Megawatts.

3.1.7 Costs

Capital costs for a PV power plant of these sizes range around $AUD 6.2 - $7.4 million per MW. Currently monocrystalline and multicrystalline PV are selling for around the same price per Wp. As a result the difference between the economics of the two technologies is marginal. Indicative operating costs for a PV plant are up to 1% of capital costs.

3.2 Concentrated photovoltaic (CPV)

3.2.1 Principles

Concentrator photovoltaic (CPV) is a term used when sunlight is concentrated onto photovoltaic surfaces for the purpose of electrical power production. Solar concentrators of all varieties may be used for this, often mounted on a solar tracker in order to keep the focal point upon the cell as the sun moves across the sky.

Compared to conventional flat panel solar cells, CPV is advantageous because the solar collector is less expensive than an equivalent area of solar cells. Semiconductor properties allow solar cells to operate more efficiently in concentrated light, as long as the cell junction temperature is kept cool by suitable heat sinks. CPV operates most effectively in sunny weather, since clouds and overcast conditions create diffuse light which essentially can not be concentrated.

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[3] Renewable Energy Access, www.renewableenergyaccess.com

3.2.2 Level of maturity

The idea of concentrating sunlight to reduce the size of solar cells--and therefore to cut costs--has been around for decades. Previous concentrated technologies and designs produced higher output than non-concentrated designs, but were not cost effective.

The technology advances in solar cells, which absorb light and convert it into electricity, and the mirror- or lens-based concentrator systems that focus light on them have improved rapidly. The technology could soon make solar power as cheap as electricity from the grid. Interest in the technology has picked up in the past 2 years, advancements in the CPV technology are proceeding to reduce cost and improve electrical output.

3.2.3 Limiting factors

Because they align with the sun very closely, a concentrating photovoltaic power plant will not perform as well on cloudy days, whereas a power field with hundreds of traditional flat-plate solar panels could still generate a significant amount of electricity. The 10-megawatt solar park in Bavaria, Germany, uses flat panels with tracking devices.

Different solar technologies are better suited for different environments. The Southwest regions of the U.S and Spain have emerged as two of the most desirable places to install these plants.

One good aspect of this technology: that when new advancements to the solar panel arrive the panel can easily be introduced to the system with little disruption to the overall system. Unlike flat plate modules; mismatching of low and high efficiency modules causes problems within the system.

3.2.4 Global utilization

In the last two years there has been a surge of interest in CPV technology increasing output from just 1 MW in 2004 to 18 MW in 2006[4]. Last month, Japanese electronics giant Sharp Corporation showed off its new system for focusing sunlight with a fresnel lens (like the one used in lighthouses) onto super efficient solar cells, which are about twice as efficient as conventional silicon cells. Other companies, such as SolFocus, based in Palo Alto, CA, and Energy Innovations, based in Pasadena, CA, are rolling out new concentrators. And the company that supplied the long-lived photovoltaic cells for the Mars rovers, Boeing subsidiary Spectrolab, based in Sylmar, CA, is supplying more than a million cells for concentrator projects, including one in Australia that will generate enough power for 3,500 homes[5].

In Australia, Solar Systems is the only manufacturer of this technology, but the market is growing and Australia will see further R&D and manufacturers in the near future.

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[4] CPV TODAY

[5] By Kevin Bullis "Cheap, Superefficient Solar" in Technology Review Thursday, November 09, 2006

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3-megawatt solar power plant in southern Spain

The first 200 kilowatts of solar power to go live will be part of 500 kilowatts that SolFocus will provide in a project sponsored by Spain's Institute of Concentration Photovoltaic Systems (ISFOC).

Solar power station in Victoria Solar Systems is to build the world’s most advanced photovoltaic (PV) heliostat solar concentrator power station in north-western Victoria, Australia. The 154 megawatt (MW) project will generate 270,000 MWh per year.

4. Project scenarios

4.1 PV solar power plant with fixed panels

4.1.1 Key parameters of design

The scope of work is to review different PV technologies at 3 different power output phases.

Phase1: Annual system output 16Gwh (about 10MW installed)

Phase2: Annual system output 40Gwh (about 25MW installed)

Phase3: Annual system output 80Gwh (about 55MW installed)

4.1.2 Product Spec's for the Analysis

For this study the following products were used in the project analysis

Thin Film: Uni-Solar US-64, 64watt

Monocrystalline: "Sharp-Nt175U1" 175wp

Multicrystalline: "Sharp-ND216U2" 216wp

CPV: SolFocus "Gen1 System" 2.25kwp

The panels will be ground mounted and tilted 10 degrees to face the sun. The ground mounting will require a flat level surface and will be set into concrete. The panels will require an area that is unshaded from the sun. Any vegetation underneath the panels will need to be kept to a level below that of the panels in order to avoid shading.

All the panels will be at least 1.5m from the ground. It is assumed that this is adequate to keep the panels above the flood height of the site.

The panels will be mounted in rows and electrically connected with cables. The cables will need to be made safe and tamper proof.

The electrical output from the PV panels will be fed via cables to a bank of inverters. The inverters will be housed in a structure to protect them from the weather and from tampering. A design decision based on cost will need to be made whether the inverters are all located in one area or are interspersed around the site.

The power plant will have a SCADA system to monitor the output of the rows of panels. In this way, any system faults can be detected to a particular array and rectified.

Electrical protection equipment with be required, to be specified in conjunction with PEA, for the connection of the PV plant to the electrical network.

4.1.3 Estimated project costs

The estimated capital costs for the project are given in the table below. The following assumptions have been made:

The labour for design, engineering and project management cost $150 per man hour with an assumption of 2 hours per kWp. The labour for installation cost $50 per man hour with an assumption of 12 hours per kWp. The labour required is civil site preparation work and fitting the PV structures. These figures are estimates of labour costs and should be reviewed for their applicability to Australia.

The capital costs of the project are around AUD$6.16-6.8 million per MWp. The cost of the electrical connection is up to the AC terminals of the inverter.

Concrete volume of 0.64m3 per kWp (this will be site dependent).

Table 4-1: Estimated capital costs for a Fixed Panel PV power plant (cost in AUD$)

Phase 1: 16Gwh/annual	Thin Film	Monocrystalline	Mulíticrystalline
Panel Output	**64 watt**	**175 watt**	**216 watt**
Solar Modules	45,219,840	52,094,448	47,565,222
Array Structure	8,462,762	3,132,056	2,312,177
Electrical	6,439,553	6,623,979	6,237,512
Inverters	6,623,979	6,655,882	6,955,178
Design, Engineering and Project Management	3,532,800	3,651,480	1,983,744
Installation hardware- Civil, Shed, Fencing	4,358,200	2,597,682	1,917,686
Labour - installation	7,065,600	7,302,960	6,843,917
Packing and Freight	4,478,064	1,657,326	1,223,487
Total capex	**86,180,799**	**83,715,813**	**75,038,923**
Capex per kWp	**7,318**	**6,878**	**6,579**
Land Use (ha)	32.67	19.48	14.38
Phase 2: 40Gwh/annual			
Solar Modules	112,066,560	118,344,996	117,879,028
Array Structure	20,972,933	7,267,121	6,019,232
Electrical	15,958,892	15,120,427	15,458,182
Inverters	16,415,947	16,415,947	16,415,947
Design, Engineering and PM	8,755,200	8,295,210	8,480,506
Installation hardware- Civil, Shed, Fencing	10,800,757	4,810,045	4,992,263

Labour - installation	17,510,400	16,590,420	16,961,011
Packing and Freight	11,097,812	3,845,392	3,185,072
Total capex	**213,578,501**	**190,689,558**	**189,391,240**
Capex per kWp	**7,318**	**6,896**	**6,700**
Land Use (ha)	80.98	36.06	37.43
Phase 3: 80Gwh/annual	**Thin Film**	**Monocrystalline**	**Muliticrystalline**
Solar Modules	224,133,120	236,689,992	235,758,056
Array Structure	41,945,865	14,534,242	12,038,463
Electrical	31,917,785	30,240,854	30,916,364
Inverters	32,831,895	32,831,895	32,831,895
Design, Engineering and PM	17,510,400	16,590,420	16,961,011
Installation hardware- Civil, Shed, Fencing	21,601,514	9,620,090	9,984,525
Labour - installation	35,020,800	33,180,840	33,922,022
Packing and Freight	22,195,623	7,690,784	6,370,144
Total capex	**427,157,003**	**381,379,117**	**378,782,481**
Capex per kWp	**7,318**	**6,896**	**6,700**
Land Use	162.0	72.1	74.9

4.1.4 Energy generation

The annual generation from each phase is within the desired scope (16Gwh/a, 40Gwh/a, and 80Gwh/a). The thin film modules are less than half the power of the Mono and Multi modules, but are almost the same size. Land usage is almost doubled of the other module type. Meaning more civil works, construction, and materials are needed to produce the same results.

4.1.5 O&M considerations

The costs for operation and maintenance of the PV power plant are shown in the table below.

Table 4-2: Estimated O&M costs for fixed panel PV power plant (Cost in AUD$)

Phase 1: 16Gwh	Thin Film	Monocrystalline	Multicrystalline
O & M of modules	706,560	365,148	342,196
O & M of BOS	41,216	42,601	39,923
Total O&M	**747,776**	**407,749**	**382,119**

Phase 2: 40Gwh	**Thin Film**	**Monocrystalline**	**Multicrystalline**
O & M of modules	1,751,040	829,521	848,051
O & M of BOS	102,144	96,777	98,939
Total O&M	**1,853,184**	**926,298**	**946,990**
Phase 3: 80Gwh	**Thin Film**	**Monocrystalline**	**Multicrystalline**
O & M of modules	3,502,080	1,659,042	1,696,101
O & M of BOS	204,288	193,555	197,878
Total O&M	**3,706,368**	**1,852,597**	**1,893,980**

These figures assume operation and maintenance costs for the modules of 0.6 man hours per kW (except for Thin Film which is doubled) and 0.05 man hours per kW for the balance of system (BOS). The cost of the labour for the module O&M is AUD$50/man hour and AUD$70/man hour for the BOS.

The maintenance on the modules requires 0.6 man hours per kWp at a cost of $10 per man hour. This involves cleaning of the modules and up keep of the site such as cutting back vegetation beneath the panels.

The maintenance on the BOS requires 0.05 man hours per kWp at a cost of $70 per man hour. This requires the skills of an electrical technician doing work such as operation of the inverter.

Further details of the maintenance are given in the table below.

Table 4-3: Details of maintenance requirements: component typical activity

Solar array structure	Visual inspection for corrosion, damage and general integrity of structure. Removal of vermin.
Solar modules	Glass cleaning. Visual inspection for corrosion, damage and general integrity. Removal of vermin. Replacement of damaged modules.
Wiring and junction boxes	Visual inspection for corrosion, damage, such as chafing, damage by rodents and birds. Visual inspection for overheating of cables and connections.
Inverters	Monitoring of output and action taken if required at the inverter, wiring or solar module damage Visual inspection for overheating of cables and connections.
Safety devices	Checking connections, functionality of isolators and circuit breakers. Check for signs of overheating.
Land	General maintenance to keep land clear of vegetation that may shade the solar array or present a fire hazard or even reptile hazard.

These figures used for maintenance are estimates of labour costs and should be reviewed for their applicability to Australia.

4.2 PV solar power plant with polar (two axis) tracking

4.2.1 Key parameters of design

This is essentially the same design parameters as the plant with fixed panels except the panels track the sun. The panels rotate automatically on the east-west axis in order to receive more solar radiation. The panels have a fixed tilt in the north-south axis.

The CPV system is on a duel axis tracking system, which almost doubles the cost.

The same module types are used as in the fixed panel estimation.

4.2.2 Estimated project costs

The estimated capital costs for the project are given in the table below. The following assumptions have been made:

The concrete volume is 0.64m^3 per kWp for Thin Film and Crystalline modules, and 1.43m^3 for CPV System (this will be site dependent).

Table 4-4: Estimated capital costs for a PV power plant with tracking

Phase 1: 16Gwh/annual	Thin Film	Monocrystalline	Muliticrystalline	CPV
Panel Output	**64 watt**	**175 watt**	**216 watt**	**2.25kw**
Solar Modules	39,321,600	45,299,520	41,361,062	29,632,500
Tracking Structure	33,850,000	21,568,397	23,883,647	31,498,250
Electrical	5,599,611	5,787,723	5,423,924	5,401,383
Inverters	5,759,982	5,759,982	5,759,982	5,759,982
Design, Engineering and PM	3,072,000	3,175,200	2,975,616	2,963,250
Installation hardware-Civil, Shed, Fencing	5,023,608	2,917,242	2,153,594	1,438,265
Labour - installation	6,144,000	6,350,400	5,951,232	5,926,500
Packing and Freight	3,893,969	1,395,643	1,030,305	1,068,526
Total capex	**102,664,770**	**92,254,105**	**88,539,362**	**83,688,655**
Capex per kWp	**10,026**	**8,716**	**8,926**	**8,473**
Land Use (ha)	**37.66**	**21.87**	**16.15**	**10.78**

Phase 2: 40Gwh/annual	**Thin Film**	**Monocrystalline**	**Mulitictrystalline**	**CPV**
Solar Modules	94,371,840	99,658,944	99,266,550	69,754,500
Tracking Structure	81,240,000	50,043,840	62,175,680	74,146,450
Electrical	13,439,067	12,732,991	13,017,417	12,714,782
Inverters	13,823,956	13,823,956	13,823,956	13,823,956
Design, Engineering and PM	7,372,800	6,985,440	7,141,478	6,975,450
Installation hardware- Civil, Shed, Fencing	12,056,659	5,369,352	5,572,758	3,744,197
Labour - installation	14,745,600	13,970,880	14,282,957	13,950,900
Packing and Freight	9,345,526	3,238,225	2,682,166	2,515,296
Total capex	**246,395,448**	**205,823,628**	**217,962,961**	**197,625,530**
Capex per kWp	**10,026**	**8,839**	**9,156**	**8,499**
Land Use (ha)	**90.39**	**40.26**	**41.78**	**28.07**
Phase 3: 80Gwh/annual				
Solar Modules	188,743,680	199,317,888	198,533,100	135,000,000
Tracking Structure	162,480,000	100,087,680	124,351,360	143,500,000
Electrical	26,878,135	25,465,983	26,034,833	24,607,667
Inverters	27,647,911	27,647,911	27,647,911	27,647,911
Design, Engineering and PM	14,745,600	13,970,880	14,282,957	13,500,000
Installation hardware- Civil, Shed, Fencing	24,113,318	10,738,705	11,145,516	7,488,394
Labour - installation	29,491,200	27,941,760	28,565,914	27,000,000
Packing and Freight	18,691,051	6,476,449	5,364,332	4,868,000
Total capex	**492,790,895**	**411,647,256**	**435,925,922**	**383,611,972**
Capex per kWp	**10,026**	**8,839**	**9,156**	**8,525**
Land Use	**180.8**	**80.5**	**83.6**	**56.14**

The capital costs of the project with tracking is between AUD$7.3 – 8.8 million per MWp. The cost of the electrical connection is up to the AC terminals of the inverter.

4.2.3 Energy generation

The annual generation from each phase is within the desired scope (16Gwh/a, 40Gwh/a, and 80Gwh/a). The thin film modules are less than half the power of the Mono and Multi modules, but are almost the same physical size. Land usage is more than doubled of the other module type. Meaning more civil works, construction, and materials are needed to produce the same results.

4.2.4 O&M considerations

The costs for operation and maintenance of the PV power plant with tracking are shown in the table below. The operation and maintenance is higher than for the fixed plant due to the increased complexity of the plant.

Table 4-5: Estimated O&M costs for a PV power plant with tracking

Phase 1: 16Gwh	**Thin Film**	**Monocrystalline**	**Multicrystalline**	**CPV**
O & M of modules	614,400	317,520	297,562	296,325
O & M of BOS	358,400	370,440	347,155	345,713
Total O&M	**972,800**	**687,960**	**644,717**	**642,038**
Phase 2: 40Gwh				
O & M of modules	1,474,560	698,544	714,148	697,545
O & M of BOS	860,160	814,968	833,172	813,803
Total O&M	**2,334,720**	**1,513,512**	**1,547,320**	**1,511,348**
Phase 3: 80Gwh				
O & M of modules	2,949,120	1,397,088	1,428,296	1,350,000
O & M of BOS	1,720,320	1,629,936	1,666,345	1,575,000
Total O&M	**4,669,440**	**3,027,024**	**3,094,641**	**2,925,000**

These figures assume operation and maintenance costs for the modules of 0.6 man hours per kW and 0.5 man hours per kW for the balance of system. The cost of the labour for the module O&M is US$50/man hour and US$70/man hour for the BOS.

The maintenance on the modules is the same as for the fixed panel system.

The maintenance on the BOS requires 0.5 man hours per kWp at a cost of $70 per man hour. This requires the skills of an electrical technician doing work such as operation of the inverter and the tracking system.

These figures are estimates of labour costs and should be reviewed for their applicability to Australia.

It has been assumed that the tracking system will have a life of 25 years; this assumption may have to be revised following further discussions with manufacturers.

4.3 Comparison of fixed versus tracking PV systems

The capex for the tracked system are more expensive than the fixed system even though the increased energy output of the panels per unit of area, and less PV is required. The opex for the tracked system is greater due to increased complexity.

Large CPV systems are not typically fixed on a position. The CPV needs the direct light to efficiently produce power. There is no information to base a correlation between Fixed and tracked CPV systems.

5. Implementation considerations

5.1 Environmental impact

The PV power plant will have negligible environmental impact on the site during operation. There will be no waste products, no requirements for cooling, no moving parts (apart from the tracking system), no noise and no impact on flora and fauna. The largest impact will be visual. There will also be a control building to house the inverters and electrical protection equipment. The reflective sunlight may cause problems if the system is close to a road and is facing in a direction which the reflected light may cause problems (especially for the CPV system). ActewAGL will need to survey the site to understand the correlation between PV system orientation and the surrounding area.

During construction there will be the initial site preparation which can be expected to require machinery, deliveries of concrete and deliveries of the solar plant equipment.

Decommissioning of the plant will require the removal of the plant equipment, removal of concrete bases and the removal of the control building.

The amount of time taken for a PV system to generate the amount of energy, and associated generation of pollution and CO2, that was used in its manufacture is one to four years depending on the PV material used.

5.2 Planning

It is assumed that an environmental impact assessment, EIS, will be required, however given the negligible environmental impacts of PV the EIS is not expected to present a significant hurdle. It is recommended that community support is sought for the PV power plant.

5.3 Project implementation timeline

There is currently a long order time for PV modules. One PV module manufacturer has indicated that they currently have a full order book for PV modules of one to one and a half years.

PB Power is unable to comment on the length of time required to obtain planning permission for the PV power plant, but this can be a significant factor and should be scheduled in. The same applies for the grid connection agreement and grid connection work.

It is estimated that the plant will take 18 months to build.

5.4 Risks

5.4.1 Cost of PV modules

An assumption has been made as to the price of the PV given the extremely large size of the order. This may not be achievable in practice.

5.4.2 Supply of PV modules

There is a risk that the PV modules might not be able to be obtained in time for a 2012 commissioning of the power plant. The project will be dependent on the abilities of the PV manufacturers to meet the order deadline. There have been experiences of long lead times (1-1.5 years) for the supply of PV, due to demand exceeding supply capabilities.

5.4.3 New technologies

Oil prices are at an all time high. “Green-House Gases” is also at an all time high. For this reason many new renewable energy technologies are being developed, utilizing any and all natural resource. During the past decade, many solar companies have been expanding there R&D efforts to improve all aspects to produce the most energy at the cheapest cost. Government Agencies across the globe are assisting manufacturers to increase market share for solar energy (Governments are supporting all Renewable energy sources).

PB can only speculate which breakthrough might occur, as with the computer industry, advancements in the renewable energy sectors are happening all the time.

6. Summary/recommendation

6.1 Recommendation

PB has reviewed the 3 phases of installation. PB believes that cost is the important factor for ActewAGL in the analysis. The 216 watt fixed position system has the lowest cost in all phases, higher energy mass than the others.

Table 6-1: Phase 1: All types, Capex, Opex and Land requirement results of the study

	64 watt 1 Axis	64 watt Fixed	175 watt 1Axis	175 watt Fixed	216 watt 1 Axis	216 watt Fixed	2.25kw CPV
Capex	102,664,770	86,180,799	92,254,105	83,715,813	88,539,362	75,038,923	83,688,655
Opex	972,800	747,776	687,960	407,749	644,717	382,119	642,038
Total	**103,637,570**	**86,928,575**	**92,942,065**	**84,123,562**	**89,184,079**	**75,421,042**	**84,330,693**
Land	37.7	32.7	21.9	19.5	16.1	14.4	10.8

Table 6-2: Phase 2: All types, Capex, Opex and Land requirement results of the study

	64 watt 1 Axis	64 watt Fixed	175 watt 1Axis	175 watt Fixed	216 watt 1 Axis	216watt Fixed	2.25kw CPV
Capex	246,395,448	213,578,501	205,823,628	190,689,558	217,962,961	189,391,240	197,625,530
Opex	2,334,720	1,853,184	1,513,512	926,298	1,547,320	946,990	1,511,348
Total	**248,730,168**	**215,431,685**	**207,337,140**	**191,615,857**	**219,510,282**	**190,338,230**	**199,136,877**
Land Use	90.4	81.0	40.3	36.1	41.8	37.4	28.1

Table 6-3: Phase 3: All types, Capex, Opex and Land requirement results of the study

	64 watt 1 Axis	64 watt Fixed	175 watt 1Axis	175 watt Fixed	216 watt 1 Axis	216watt Fixed	2.25kw CPV
Capex	492,790,895	427,157,003	411,647,256	381,379,117	435,925,922	378,782,481	383,611,972
Opex	4,669,440	3,706,368	3,027,024	1,852,597	3,094,641	1,893,980	2,925,000
Total	**497,460,335**	**430,863,371**	**414,674,280**	**383,231,714**	**439,020,563**	**380,676,460**	**386,536,972**
Land Use	180.8	162.0	80.5	72.1	83.6	74.9	56.1

7. References

A.Der Minassians, R. Farshchi, J.Nelson; “Energy payback Time of a SolFocus Gen1 Concentrator PV system, Dec. 7, 2006

Muriel Watt; Co-Op Program on Photovoltaic Power Systems, Task 1, Information on PV power system National survey report on PV power applications in Australia 2006.

International Energy Agency; “Renewables in Global Energy Supply” January 2007.

“Wattsun Solar tracker retail price sheet”; www.wattsun.com

Appendix B

CST Cost and Performance

CAPITAL COST & PERFORMANCE ESTIMATE

Project	Generation		Cap Factor	Land Area	Collector Area		Area multiplier
	MW	MWh/a		Ha	m2/MWh/a	m2	
Nevada Solar 1	64	130,000	23.2%	140	2.75	357,000	3.92
Andasol	50	179,000	40.9%	202	2.85	510,120	3.96
ACT plant	22	80,000	0.42	121	2.8	224,000	3.94

Cost & Performance of Preferred Option

Base cost of Nevada Solar 1 equivalent			$4,549	per kW	
Allocation of costs					
	Solar Colle	57%	$2,593	per kW	Proportion based on Sargent & Lundy
	Thermal st	18%	$819	per kW	Proportion base on Sargent & Lundy
	Boiler/Gen	15%	$682	per kW	Proportion base on Sargent & Lundy
	BOP	10%	$455	per kW	Proportion base on Sargent & Lundy
			$4,549	per kW	
Additional collector area for 42% capacity factor			87%		Increase in proportion to additional additional
Additional collector area for lower insolation			38%		Increase in inverse proportion to lower insolat
Adjusted cost					
	Solar Collector		$4,586	per kW	
	Thermal storage		$819	per kW	
	Boiler/Generator		$682	per kW	
	BOP		$455	per kW	
	Total		$6,542	per kW	
Allowance for technological improvement			30%		Estimate, based on Sargent & Lundy
Net cost			$4,579		
Round to study value			$4,600	per kW	

Cost impact of staged development A$million)

	Full	Stage 1	Stage 2	
Solar Collector	$70,617	$38,840	$38,840	
Thermal storage	$12,610	$8,319	$8,319	
Boiler/Generator	$10,508	$6,933	$6,933	
BOP	$7,005	$4,622	$4,622	
Total	$100,741	$58,714	$58,714	$117,427

Appendix C

Solar Insulation

Table 1: Data for Figure 4-4

Direct radiation

Site	Value (MJ/m^2/day)	Data source
Canberra	18.1	Table 4.9, ASRDH, 2006 Vol 1, page 178 Vol 3, pages 46 and 112
Longreach	28.4	
Mildura	21.2	
Las Vegas (Nevada Solar 1)	24.9	www.nrel.gov/midc/unlv
Spain (Andasol)	21.7	www.flagsol.com/andasol_project_RD.htm

Global radiation (hourly) - Canberra

Canberra – Global Radiation data

Hour	Fixed, inclined	Sun tracking
1	0	0
2	0	0
3	0	0
4	0	0
5	4	5
6	29	99
7	120	285
8	299	510
9	506	691
10	674	788
11	787	836
12	821	844
13	782	831
14	673	787
15	509	697
16	302	520
17	121	294
18	27	93
19	4	6
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0

Source: Australian Solar Radiation Data Handbook.

Table 4.6 and 4.8

Solar radiation – Canberra

Canberra Solar Radiation Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Global, fixed	25.4	24.7	22.8	18.9	15	12.6	14.1	17.2	20.8	23.7	24.2	24.9
Global, 2 axis tracking	34.2	32	28.6	22.4	17.2	14.1	16	20.2	25.2	30.5	31.8	33.3
Direct, Single axis tracking	24	22.1	20	15.4	11.6	9.1	10.8	13.7	17.3	21.1	21.3	22.4

Source: Australian Solar Radiation Data Handbook, Table 4.5, 4.6 and 4.7

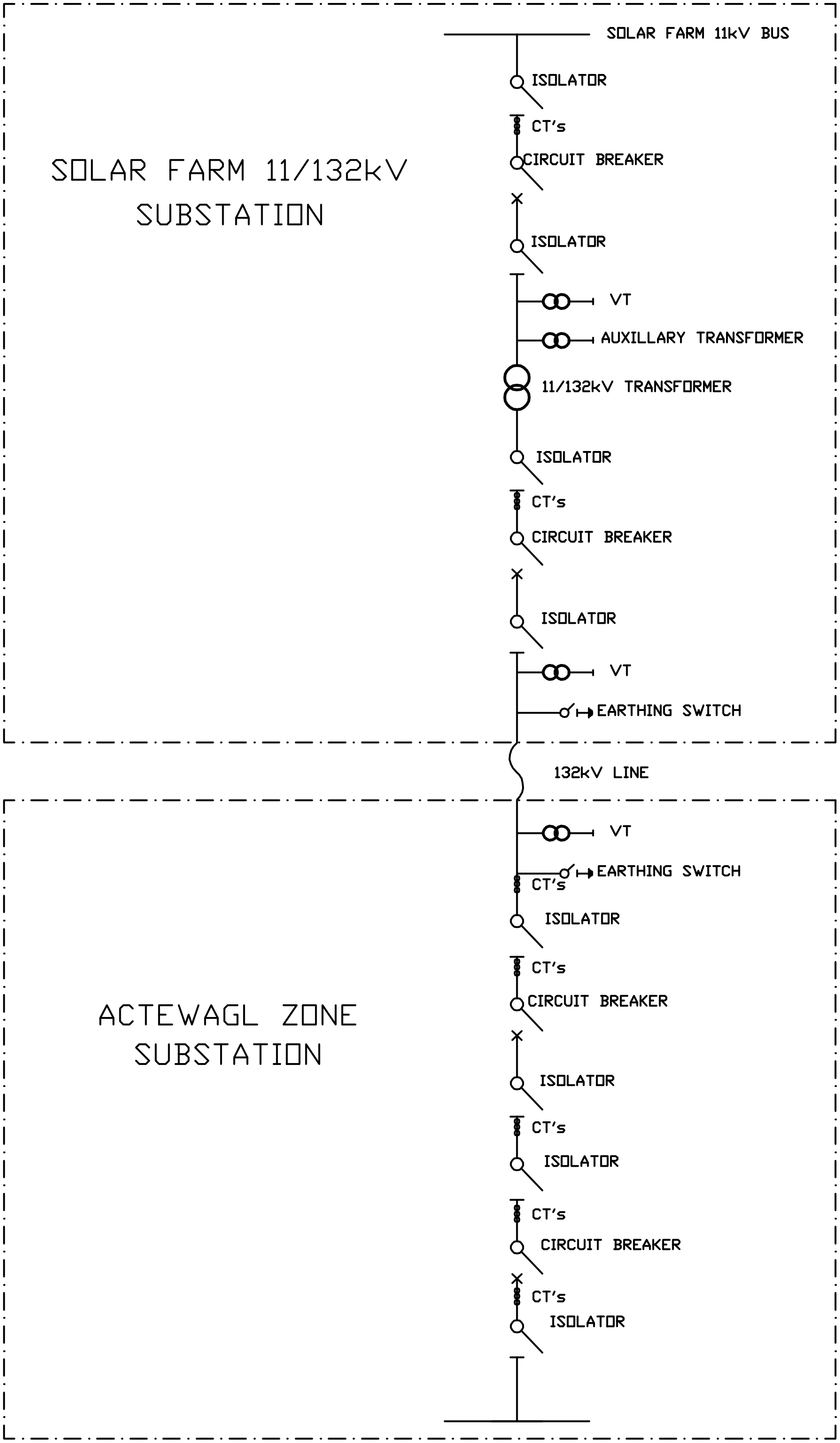
Canberra Solar Radiation Data

	Ave.
Global, fixed	*20.4*
Global, 2 axis tracking	*25.5*
Direct, Single axis tracking	*17.4*

Source: Australian Solar Radiation Data Handbook. Table 4.5, 4.6 and 4.7

Appendix D

Network Connections



No	Revision	Date	Ckd	Auth

ActewAGL

PROPOSED SOLAR FARM CONNECTION TO ACTEWAGL NETWORK

Drawn:
Date:
Designed:
Design Approved:
Branch Engineer:
Branch Manager:
Project Number:
Work Pack:
A4
REV

CADD File Name: C:\Documents and Settings\g_haydon\Desktop\Solar Farm.dwg
Date Plotted: 23/05/2008

Appendix E

Planning Approvals

ACT planning and approval process

The ACT's dual planning framework:

Under the Australian Constitution, the Commonwealth remains the owner of land in the Territory, even after the granting of self government (1989). The *Australian Capital Territory (Planning and Land Management) Act 1988* provides that land used by or on behalf of the Commonwealth may be declared National Land, and managed by the Commonwealth. The remaining lands of the Territory are Territory Land and these lands are managed by the ACT Government on behalf of the Commonwealth.

It should be noted that the ownership or administration of land in the Territory generally has no bearing on the planning or development approvals process.

Statutory framework

Since the introduction of self-government in 1989, the planning and development of the ACT has been the responsibility of both the Commonwealth and the ACT Governments.

Representing these two governments are two separate planning authorities: the National Capital Authority (NCA), being the Commonwealth body having the responsibility for preparing and administering a National Capital Plan; and the ACT Planning Authority, which is the Territory authority required to prepare and administer the Territory Plan.

The ACT Planning Authority is technically the Executive Director of the ACT Planning and Land Authority (ACTPLA), being a statutory authority of the ACT Government.

National Capital Plan

The National Capital Plan (NCP) is the strategic plan for Canberra and the Territory. The purpose of the Plan is to ensure that '*Canberra and the Territory are planned and developed in accordance with their national significance'.*

The NCP provides general planning principles and policies (including land use policies) for all land in Canberra and the Territory, and Detailed Conditions of Planning, Design and Development for Designated Areas. Designated areas are areas of land specified by the NCP as having the special characteristics of the National Capital.

The Designated Areas of the NCP are:

- Lake Burley Griffin and its Foreshores
- the Parliamentary Zone
- the balance of a Central National Area adjoining the lake and the Parliamentary Zone, and extending from the foot of Black Mountain to the airport
- the Inner Hills which form the setting of the Central National Area
- the Main Avenues and Approach Routes between the ACT border and the Central National Area.

Within Designated Areas, the NCA has the responsibility for determining Detailed Conditions of Planning, Design and Development, and for Works Approval.

Relationship to the territory plan

The NCP provides the framework within which the Territory Plan was established. The object of the Territory Plan is to manage land use change and development in a manner consistent with strategic directions set by the ACT Government, Legislative Assembly and the community.

The Territory Plan is a key statutory planning document in the ACT, providing policy framework for the administration of planning in the ACT. The Territory Plan provides more detailed planning controls, through land use specific objectives and policies. The Territory Plan does not apply to any Designated Areas of the NCP, and the Territory Plan provisions are required to be consistent with all provisions of the NCP (ie the superior plan).

ACT leasehold system

The ACT's land tenure system is based on Commonwealth ownership, as established under various provisions of the Constitution, and Commonwealth and Territory legislation. It is a system that consists of unleased Territory Land and public leasehold, with private subleases. The ACT's leasehold and planning systems has resulted in a dual system of land use and development control.

For each leased block of land in the ACT, the applicable Crown Lease includes a Lease Purpose Clause and other provisions relevant to the entitlements to develop that block of land. In pursuing a development approval, it is therefore necessary to consider whether a variation to the lease is required, or to ensure that the specific provisions of a new lease are appropriate to the proposed land use and development. Lease variations are undertaken as part of the development application process and are subject to a Change of Use Charge if there is an assessed increase in the value of the land.

The three sites selected

Two of the sites would be subject to the provisions of the Territory Plan (Block 418 Stromlo District and Block 1652 Tuggeranong District) and the third site, because it is located in a Designated Area (Inner Hills) of the National Capital Plan (Block 498 Stromlo District) would be subject to the provisions of the National Capital Plan.

In all cases the proposed development of a major utility is a permitted use within the provisions of the applicable Plan. What differs are the development assessment and environmental impact assessment processes.

There is no doubt that the sites that are subject to the provisions of the Territory Plan and the ACT Planning and Development Act 2007, will require the preparation of an Environmental Impact Statement, as scoped by ACTPLA, prior to development approval. Accordingly, any development application in relation to these sites would be subject to an impact assessment track, as decribed in the following parapgraphs.

For the third site, subject to the provisions of the National Capital Plan, the project would require Works Approval from the National Capital Authority, and the preparation of an EPBC Act Referral to the Commonwealth Department of Environment Water Heritage and the Arts (DEWHA) for determination if the proposal is a "controlled action" under the EPBC Act. If so, a full EIS would also be required to be submitted to the Commonwealth Government for assessment.

Development assessment tracks

Chapter 7 of the ACT Planning and Development Act 2007 describes the assessment tracks that are to be followed for assessment of different kinds of development proposals. Under the Act there are three types of development proposals:

- **exempt** development for which planning approval is not required
- **assessable** development for which development applications are assessed against the relevant assessment code of the Territory Plan and will be either code, merit or impact track assessable
- **prohibited** development means a development prohibited under the relevant development table of the Territory Plan, or a development by an entity other than the Territory, or a Territory authority in a future urban area.

Development tables for each zone assist in determining the type of development and relevant tracks.

Exempt development

A development proposal is exempt from requiring development approval if it is exempt under:

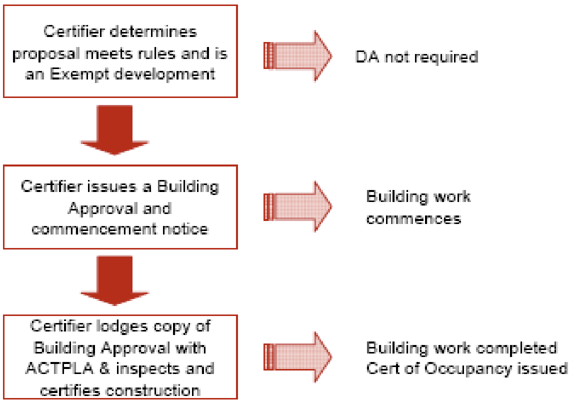
- the relevant development table of the Territory Plan
- Section 134 of the Act; or
- a regulation

(refer to Part 7.2.6 Act)

The Regulation specifies what types of development are exempt from requiring development approval. These may include small pergolas, carport, fence or a single house in a new housing estate (requires building approval) provided they comply with specific requirements of the regulation (refer to Schedule 1 Regulation).

Exempt development may be undertaken without development approval. The following figure outlines the process undertaken for exempt proposals that require building approval.

Figure 1: Exempt proposal



Assessable development

Under Part 7.2 of the Act there are three assessment tracks these include code, merit and impact.

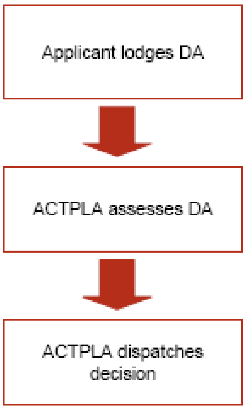
Code track

Under Part 7.1 and Part 7.2.2 of the Act, a Code track DA is assessed against the rules in the applicable assessment code. A Code track DA must comply with all the relevant rules. There is no requirement for public notification and there are no mandatory entity referrals for Code track DAs.

If a Code track development application (DA) requires approval from an entity (eg. ActewAGL) the approval must be obtained prior to lodgement of the DA and submitted as a supporting document.

The following figure outlines the development assessment process for the Code track DAs.

Figure 2 Code track assessment process



(Source: ACTPLA)

Assessment timeframes for making a decision on a Code track DA is 20 working days after the day the application is lodged.

Merit track

Under Part 7.1 and Part 7.2.3 of the Act, a Merit track DA is assessed against the rules or criteria in the applicable assessment code, i.e. development in a Residential Zone or Apartment in a Commercial Zone.

During the assessment process of a Merit track DA the following is considered:

- the relevant Code of the Territory Plan
- objectives for the zone
- suitability of the land for development
- all representations
- entity advice
- a plan of management for any public land
- the probable impact of the development, including environmental impact.

A Merit track DA will not be approved if inconsistent with the following:

- relevant Code of the Territory Plan
- any land management agreement for the land if it is rural lease
- related advice of the Conservator of Flora and Fauna if the proposal will affect a registered tree (refer to *Tree Protection Act 2005*) or declared site
- advice given by an entity, unless the decision maker is satisfied that any applicable guidelines and any realistic alternative to the proposed development have been considered and the decision is consistent with the objects of the Territory Plan.

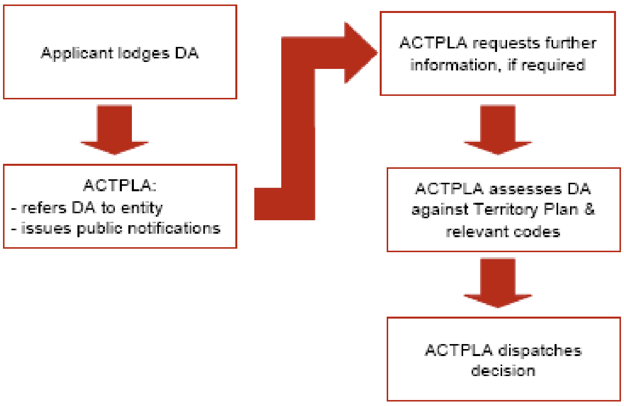
Merit track DAs must be publicly notified by one of the two categories of notification:

- minor – letters sent to adjoining neighbours (with 10 working days in which to make a representation); and
- major – sign placed on the property, notice placed in a newspaper and letters sent to the adjoining neighbours (within 15 working days in which to make a representation).

The category of notification is determined by the *Planning and Development Regulation 2008*.

The following figure outlines the development assessment process for Merit track DAs.

Figure 3 Merit track DAs



(Source: ACTPLA)

Assessment timeframes for making a decision on Merit track DA is 30 days after the lodgement date if no representations are made, or 45 days after the lodgement date if representations are made. Note a DA is not considered lodged until full payment of fees is made.

Impact track

Under Part 7.1 and Part 7.2.4 of the Act Impact track DA are considered against the Territory Plan and an Environmental Impact Statement (EIS) unless exempt by Minister. Impact track DA undergo the broadest level of assessment compared to other tracks as they may include such proposals as constructing a major road, light rail or other transport corridors.

A DA is considered an Impact track development proposal if:

- it meets the criteria in the relevant impact track development table of the Territory Plan
- it is mentioned in Schedule 4 of the Act
- the Minister makes a declaration under s124 of the Act in relation to proposal; or
- it is considered one under relevant legislation such as the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC).

During the assessment process of a Impact track DA the following is considered:

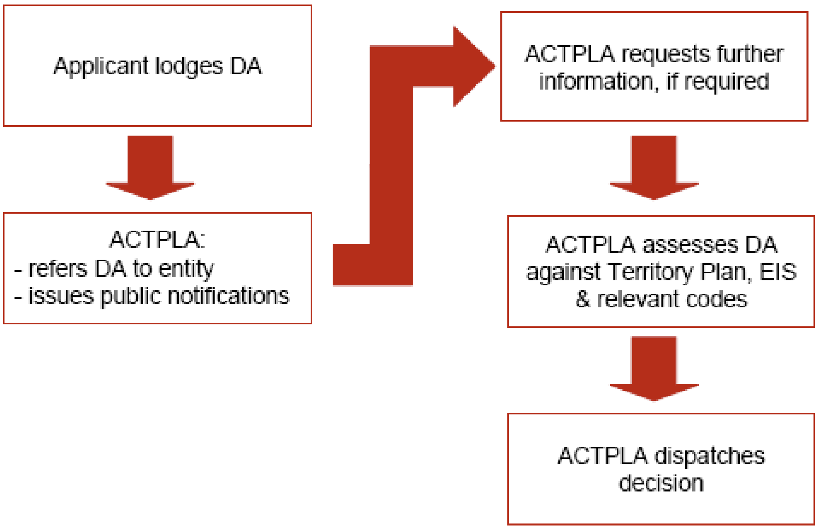
- relevant Code of the Territory Plan
- objectives of the zone
- suitability of the land for the development
- all representations
- entity advice
- a plan of management for any public land
- probable impact of the development including environmental impact
- completed EIS for the proposal
- conclusions of any inquiry about an EIS for the proposal.

An Impact track DA will not be approved unless an EIS has been completed (unless exempt by Minister) or if the proposal is inconsistent with the Territory Plan, any land management agreement, or if it is likely to impact a registered tree or declared site.

Impact track DAs must be publicly notified and will always undergo the major notification process being a sign placed on the property, a notice placed in the newspaper, and letters sent to the adjoining neighbours within 15 working days in which to make a representation.

The following figure outlines the development assessment process for Impact track DAs.

Figure 4 Impact track DAs



(Source: ACTPLA)

Assessment timeframes for making a decision on Impact track DA is 30 days after the lodgement date if no representations are made, or 45 days after the lodgement date if representations are made. Note a DA is not considered lodged until full payment of fees is made.

Prohibited development

Under Part 7.2.2 of the Act the following rules apply to prohibited developments:

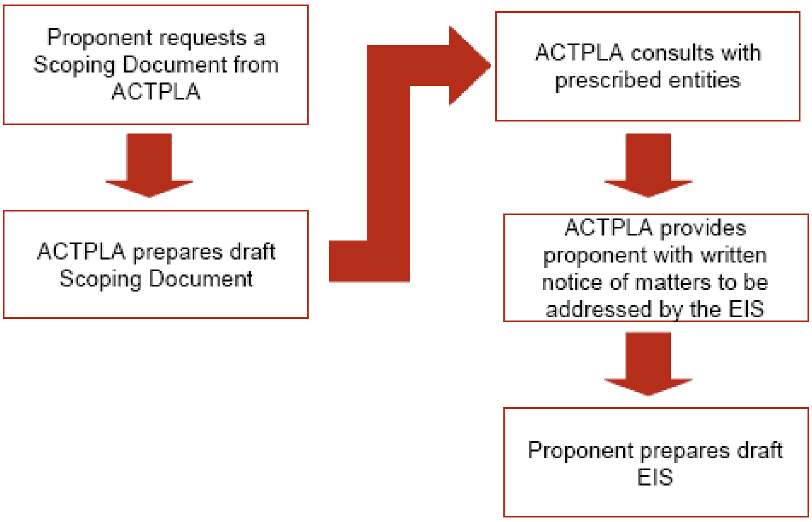
- If a development is prohibited then a person can not apply for approval of the development proposal.
- If a development is authorised by a development approval then subsequently becomes prohibited then the development can continue – a development that is lawful when it begins, continues to be lawful.
- If a development use is allowed under a lease, s246 or a provision Ch 15 of the Act, but beginning the use is a prohibited development, then the proposal is not considered to be a prohibited development. A person may apply for development approval for the proposal and the Impact track will apply.

Environmental impact statements

EIS is the sole method of environmental impact assessment under the provisions of the *Planning and Development Act 2007*. The Minister for Planning can request an EIS in relation to a development (refer to Ch 8, Part 8.2 of the Act) or initiate an EIS where there are potential significant impact to public health or the environment.

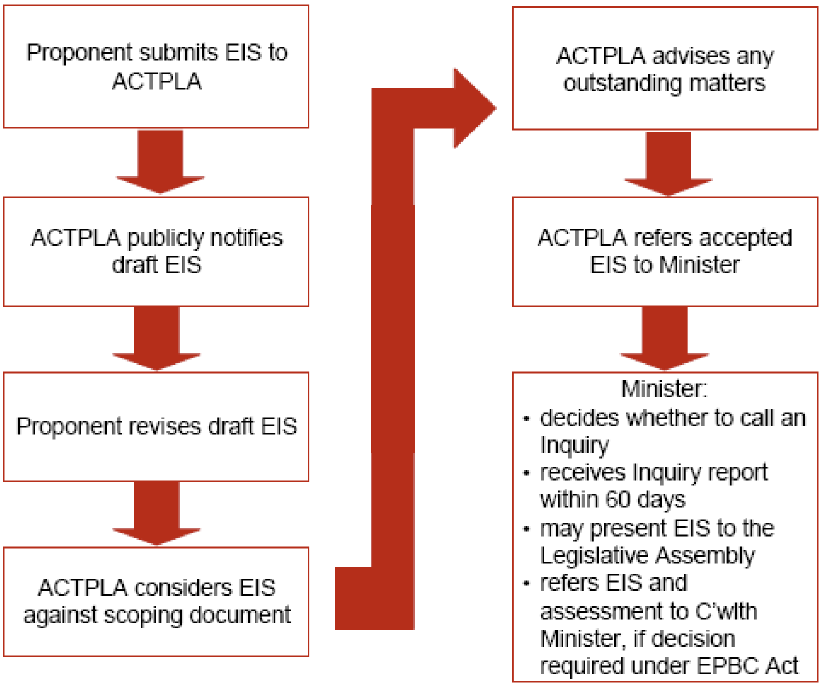
The following figures outline the EIS scoping process and submission process.

Figure 5: EIS scoping process



(Source: ACTPLA)

Figure 6: EIS submission process



(Source: ACTPLA)

Threatened species and ecological communities

The Nature Conservation Act 1980 establishes a formal process for the identification and protection of threatened species and ecological communities in the ACT region. The Act requires the Conservator of Flora and Fauna to prepare an Action Plan in response to each declaration of a threatened species, ecological community or threatening process.

An Action Plan outlines conservation and protection proposals for the species or community concerned, or proposals to minimise the effect of threatening process. The primary objective is to maintain for the long term, viable wild populations of each species and ecological community as components of the indigenous biological resources of the ACT.

Any planning proposal that will have implications on any identified threatened species must consider the objectives of the action plan. Any supporting environment statements or planning studies consider the action plan and ensure that any proposal do not compromise the long term viability of any such species.

Considerations and referrals

Any DA's lodged that are considered to have a potential environmental impact (i.e. tree removal, dams, bulky earthworks) are referred to the relevant Territory Government Agencies for comments. This process is undertaken as part of the DA process.

Works Approval for Designated Areas of the National Capital Plan

The *Australian Capital Territory (Planning and Land Management) Act 1988* (the Act) was proclaimed on 31 January 1989. The Act introduced new arrangements for the planning and development of the Territory, designed to provide for continuing Commonwealth involvement in the development of the National Capital, while ensuring that the interests of the people of Canberra are both fully represented and protected.

The necessity for new planning arrangements was a consequence of the Commonwealth's decision to introduce self government to the Australian Capital Territory.

The Act established the National Capital Authority as a Commonwealth Government agency with the following functions:

a) to prepare and administer a National Capital Plan;

b) to keep the Plan under constant review and to propose amendments to it when necessary;

c) on behalf of the Commonwealth, to commission works to be carried out in Designated Areas in accordance with the Plan where neither a Department of State of the Commonwealth nor any Commonwealth Authority has the responsibility to commission works;

d) to recommend to the Minister the carrying out of works that it considers desirable to maintain or enhance the character of the National Capital;

e) to foster an awareness of Canberra as the National Capital;

f) with the approval of the Minister, to perform planning services for any person or body; whether within Australia or overseas; and

g) with the Minister’s approval, on behalf of the Commonwealth, to manage National Land designated in writing as land required for the purposes of the National Capital.

Section 12 of the Act states:

12. (1) No works shall be performed in Designated Areas unless:

a) the proposal to perform the works has been submitted to the Authority together with such plans and specifications as are required by the Authority;

b) the Authority has approved the works in writing; and

c) the works are in accordance with the Plan.

If the project site is **within a Designated Area of the National Capital Plan** the planning approval authority is the National Capital Authority. The ACT Government has no planning jurisdiction within Designated Areas of the National Capital Plan.

The Act provides that the National Capital Plan may set out the detailed conditions of planning design and development in Designated Areas and the priorities in carrying out such planning, design and development.