International Energy Agency

CO-OPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1
Exchange and dissemination of information on PV power systems

National Survey Report of PV Power Applications in *Australia 2006*

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i Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the organisation for Economic Co-operation and Development (OECD), which carries out a comprehensive programme of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The nineteen participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), The Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), The United Kingdom (GBR) and The United States of America (USA). The European Commission and the European Photovoltaic Industry Association are also members.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (tasks) is the responsibility of Operating Agents. Ten tasks have been established and currently six are active. Information about these tasks can be found on the public website www.iea-pvps.org. A new task concerning PV environmental safety and health is now being developed.

The objective of Task 1 is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems.

ii Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems. An important deliverable of Task 1 is the annual ***Trends in photovoltaic applications*** report. This report gives information on trends in PV power applications in the PVPS member and other countries and is largely based on the information provided in the National Survey Reports which are produced annually by each Task 1 participant. The public PVPS website also plays an important role in disseminating information arising from the programme, including national information. This template is intended to assist national experts and other participants of Task 1 in the preparation of their annual PVPS National Survey Reports.

As the ***Trends in photovoltaic applications*** report is based on the National Survey Reports it is important that experts follow this template when preparing their national reports. The ***Trends*** report is an external publication of the IEA-PVPS Implementing Agreement so it must not contain confidential information. Similarly, the National Survey Reports are now presented on

the public PVPS website and Task 1 participants should make their own arrangements with their sources on how to treat confidential information (e.g. by ensuring anonymity of the data).

National Survey Reports should be produced before the end of May to enable the ***Trends*** report to be published by the end of August.

When preparing their national reports, experts must ensure that all the data are as accurate and correct as possible and follow the definitions given in this template. All sections must be completed as comprehensively as possible.

Iii Definitions, Symbols and Abbreviations

For the purposes of the National Survey Reports, the following definitions apply:

PV power system market: The market for all nationally installed (terrestrial) PV applications with a PV power capacity of 40 W or more.

Installed PV power: Power delivered by a PV module or a PV array under standard test conditions (STC) – irradiance of 1 000 W/m^2, cell junction temperature of 25^{o}C, AM 1,5 solar spectrum – (also see 'Rated power').

Rated power: Amount of power produced by a PV module or array under STC, written as W.

PV system: Set of interconnected elements such as PV modules, inverters that convert d.c. current of the modules into a.c. current, storage batteries and all installation and control components with a PV power capacity of 40 W or more.

Module manufacturer: An organisation carrying out the encapsulation in the process of the production of PV modules.

Off-grid domestic PV power system: System installed to provide power mainly to a household or village not connected to the (main) utility grid(s). Often a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'. Can also provide power to domestic and community users (plus some other applications) via a 'mini-grid', often as a hybrid with another source of power.

Off-grid non-domestic PV power system: System used for a variety of industrial and agricultural applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as 'stand-alone PV power system'.

Grid-connected distributed PV power system: System installed to provide power to a grid-connected customer or directly to the electricity grid (specifically where that part of the electricity grid is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on or integrated into the customer's premises often on the demand side of the electricity meter, on public and commercial buildings, or simply in the built environment on motorway sound barriers etc. They may be specifically designed for support of the utility distribution grid. Size is not a determining

feature – while a 1 MW PV system on a rooftop may be large by PV standards, this is not the case for other forms of distributed generation.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station. The power supplied by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity grid other than the supply of bulk power. Typically ground mounted and functioning independently of any nearby development.

Turnkey price: Price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid PV system, the prices associated with storage battery maintenance/replacement are excluded. If additional costs are incurred for reasons not directly related to the PV system, these should be excluded. (E.g. If extra costs are incurred fitting PV modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Equally the additional transport costs of installing a telecommunication systems in a remote area are excluded).

Field Test Programme: A programme to test the performance of PV systems/components in real conditions.

Demonstration Programme: A programme to demonstrate the operation of PV systems and their application to potential users/owners.

Market deployment initiative: Initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives etc. These may be implemented by government, the finance industry, utilities etc.

Final annual yield: Total PV energy delivered to the load during the year per kW of power installed.

Performance ratio: Ratio of the final annual (monthly, daily) yield to the reference annual (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoretical annual (monthly, daily) available energy per kW of installed PV power.

1 Executive summary

- Installed PV power

PV installations in Australia in 2006 totalled 9.72 MWp, an 16% growth since 2005. Of this, central grid installations accounted for 2.1 MW, off-grid residential 3.37 MW, off-grid industrial and agricultural 3.58 MWp and diesel grids 0.625 MWp. Grid installations grew at a rate of 31% and now account for nearly 13% of installed capacity.

- Costs & prices

PV module and system prices increased by 4-10% in 2006, with the flow through of earlier international silicon prices as well as more stringent training and OH&S procedures. Module prices averaged AUD 8,50 and rooftop systems AUD 12,50 per Wp.

- PV production

PV production remained steady, with 36 MW of silicon cells and 7,6 MW of flat plate modules produced. 0,29 MW of concentrator PV systems were also produced.

- Budgets for PV

Public budgets for PV R&D, demonstration and market development increased in 2006. AUD 6.95M was spent on research at universities and research institutes; AUD 0.59M on demonstration and AUD 23.7M on market support programmes, the largest portion of which was spent on off-grid PV applications to displace diesel fuel use.

2 The implementation of PV systems

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries.

2.1 Applications for photovoltaics in Australia

The largest installed capacity of PV in Australia is for off-grid industrial and agricultural applications. These include power systems for telecommunications, signalling, cathodic protection, water pumping and lighting. Significant markets also exist for off grid residential and commercial power supplies and increasingly for fuel saving and peak load reduction on community diesel grid systems. Some of this market is supported by government grants aimed at reducing diesel fuel use. There is a growing market for recreational PV applications, for caravans, boats and off-road vehicles. PV installations connected to central grids increased strongly, with the majority of installations taking advantage of government grant programs which currently contribute 20-25% of up front capital costs. The main applications are rooftop systems for private residences, schools and community buildings, although commercial interest is also growing.

2.2 Total photovoltaic power installed

The total cumulative installed PV power for each sub-market on the 31 December of each year from 1992 onwards is shown in Table 1.

2.2.1 Key PV policy initiatives, promotional activities and market drivers in 2006

A number of Australian Government programmes support the PV market in Australia. The most important ones are the PV Rebate Programme and the Renewable Remote Power Generation Programme. Some support is also provided via the Mandatory Renewable Energy Target (MRET) and Green Power programmes, while the Solar Cities Programme will begin to provide support from 2007.

Several State Governments are considering feed-in-tariffs for PV, although to date only the South Australian Government has put forward a proposal. State Governments have also put forward a proposal for an Emissions Trading scheme and for renewable energy targets on top of the MRET.

These programmes and proposals, in addition to the heightened awareness of climate change issues in the Australian community during 2006, served to stimulate the PV market towards the end of the year. With a federal government election in 2007, a number of commitments to continue PV support have already been made by the Government and the opposition parties. These include doubling the PV Rebate to AUD 8 per Wp to a cap of AUD 8000 and extending the RRPG Programme.

2.2.2 Key electricity utility and public stakeholder developments in 2006

Utility interest in PV has been rekindled by the Solar Cities Programme, with 3 utilities now actively involved. In addition, the inclusion of fringe of grid locations in the eligibility list for RRPGP support has resulted in some interest in the use of PV for grid support. Four States are now examining options in this area.

The release of the Stern and IPCC Reports, Al Gore's film "An Inconvenient Truth" and the continuing drought in Australia have resulted in a sudden increase in media coverage and political interest in climate change, an issue the Australian Government had previously downplayed. Public interest is now high and new climate change programmes are expected to be announced in 2007. Key sectors which are already moving ahead include Local Government and several major building companies. Although PV remains a high cost option, because of Australia's low electricity prices, it is a more straightforward one for the community than many other energy options, with few aesthetic, noise, water or emission issues arising. Hence, with Australia's good solar resources and increased rebates, the PV market is expected to grow more rapidly over the coming year.

Table 1: Cumulative installed PV power in 5 sub-markets.

Sub-market/ application	31 Dec 1992 kWp	31 Dec 1993 kWp	31 Dec 1994 kWp	31 Dec 1995 kWp	31 Dec 1996 kWp	31 Dec 1997 kWp	31 Dec 1998 kWp	31 Dec 1999 kWp	31 Dec 2000 kWp	31 Dec 2001 kWp	31 Dec 2002 kWp	31 Dec 2003 kWp	31 Dec 2004 kWp	31 Dec 2005 kWp	31 Dec 2006 kWp
off-grid domestic*	1 560	2 030	2 600	3 270	4 080	4 860	5 960	6 820	9 110	10 960	12 140	13 590	15 900	18 768	22 138
off-grid non-domestic	5 760	6 865	8 080	9 380	11 520	13 320	15 080	16 360	17 060	19 170	22 740	26 060	29 640	33 073	36 653
grid-connected distributed		5	20	30	80	200	850	1 490	2 390	2 800	3 400	4 630	5 410	6 860	9 005
grid-connected centralized				20	20	210	520	540	540	540	540	660	660	760	760
diesel grids						110	110	110	110	110	310	690	690	1 120	1 745
TOTAL	**7 300**	**8 900**	**10 700**	**12 700**	**15 700**	**18 700**	**22 520**	**25 320**	**29 210**	**33 580**	**39 130**	**45 630**	**52 300**	**60 580**	**70 300**

***** including recreational market – caravans, off-road vehicles, boats, holiday homes

2.3 PV implementation highlights, major projects, demonstration and field test programmes

2.3.1 PVRP – Photovoltaic Rebate Programme

The PVRP provides government assistance to householders and owners of community buildings, such as schools, to install photovoltaic systems in order to reduce greenhouse emissions, assist in the development of the Australian PV industry and increase public awareness of renewable energy.

The Programme is funded by the Australian Government, with administration by the State Governments. Householders are eligible for a rebate of 4 AUD/W capped at 4 000 AUD per residential system. (This will increase to 8 AUD/W in 2007, capped at 8000 AUD). One million Australian dollars is allocated to fund projects by residential housing developers and display home builders. A rebate of AUD 3,50/Wp is available to developers in AUD 50 000 blocks.

1230 systems were installed in 2006, amounting to 1.85 MWp. 67% of customers, accounting for 75% of installed capacity, were on grid connected buildings and around AUD 4.9 million was allocated in rebates. Grid systems average 1.5 kWp and off-grid systems 1 kWp Since the start of the programme in 2000, more than 8000 systems, using 10 MWp of PV, have been installed and rebates of over AUD 40 million have been provided. From 2007 an additional AUD 150 million over 5 years has been allocated to the programme.

2.3.2 Renewable Remote Power Generation Programme

This is an Australian Government programme, administered by State and Territory Governments which aims to increase the use of renewable energy for power generation in off-grid and fringe of grid areas, to reduce diesel use, to assist the Australian renewable energy industry, to assist in meeting the infrastructure needs of indigenous communities and to reduce long-term greenhouse gas emissions. The target groups are indigenous and other small communities, commercial operations, including pastoral properties, tourist facilities and mining operations, water pumping and isolated households that operate within diesel grids, use direct diesel generation or are at the end of long grid lines. Grants of up to 50% of the capital cost of renewable generation and essential enabling equipment are available, with additional funding provided by some States. From 2007, expenditure on energy efficiency measures will also qualify for grants.

1.64 MWp of PV was installed under RRPGP in 2006, bringing the total installed capacity to 7 MWp under this programme, of which 1.44 MWp is installed in large utility run diesel grid systems. The latter includes 0.72 MWp of solar concentrating dishes commissioned in the NT.

An additional allocation of AUD 123.5 million was made to the Programme in 2006, on top of the original allocation of AUD 205 million, of which around AUD 166 million had been allocated by end 2006. In addition, AUD 7.5 million has been allocated to industry support activities, including test facilities, standards development, training, feasibility studies and demonstration projects.

Within the additional allocation made in 2006 is AUD 11 million, on top of an original allocation of AUD 8 million, for the *Bushlight* programme to assist with the development of industry capability and local understanding of renewable energy systems in small indigenous communities and to install household and community systems.

A total of approximately AUD 18.6 million was paid towards PV based renewable energy systems during 2006. Around 75% of the small systems installed in 2006 were for residential purposes and 25% for agricultural / industrial uses, including water pumping systems. Under the *Bushlight* programme, 100 PV powered household systems have now been installed, with specifications developed in consultation with the end-users.

2.3.3 Solar Cities

75 million Australian dollars have been allocated over 5 years to demonstrate high penetration uptake of solar technologies, energy efficiency, smart metering and other options aimed at improving the market for distributed generation and demand side energy solutions. Consortia were formed to bid for the Solar City funding and comprise a mix of PV companies, banks, local governments, utilities, building companies and research groups. 4 of an expected 5 Solar Cities have been announced – Adelaide, South Australia, Townsville, Queensland, Blacktown, New South Wales and Alice Springs, Northern Territory. 5 MWp of PV is expected to be installed in the 4 Cities, although this may not all be in addition to the PVRP. Installations are expected to commence in some of the Cities in 2007. A variety of finance packages and feed-in tariffs are expected to be trialed.

2.4 Highlights of R&D

Photovoltaics research and development is undertaken across a range of university, government and industry facilities. University research groups largely undertake fundamental device research, while industry-based and collaborative research involves PV manufacturing processes and PV systems.

2.4.1 Universities and Research Centres

Many Australian universities have some PV research underway, however, only the activities of the main research groups are reported here. Much of the remaining work involves the fundamentals of various semiconductor devices, anti-reflection coatings and nanostructures. Others, including Monash University, Curtin University, University of Technology Sydney, University of South Australia and University of Wollongong undertake PV systems research, covering applications such as remote area and mini-grid power systems, commuter cars, water pumping and water purification.

The Centre of Excellence in Advanced Silicon Photovoltaics and Photonics, University of NSW (PV Centre) undertakes research in three interlinked strands aimed at near-term "first-generation" product based on silicon wafers, medium-term "second-generation" thin-film cell technology and long-term "third-generation" solar cells with both high-efficiency and thin-film. Research is also undertaken in the development of silicon-based light-emitting diodes and silicon lasers.

The PV Centre's first-generation research is focussed on streamlining manufacturing to reduce costs while, at the same time, improving the energy conversion efficiency of the product. Major emphasis in the PV Centre's work is on the "buried-contact" solar cell, originally developed by PV Centre researchers, and the first of the modern high-efficiency cell technologies to be successfully commercialised. Of key interest is the development of buried-contact sequences for substrates doped with phosphorus, rather than boron, to avoid the boron-oxygen defect problem.

In its second generation PV work, CSG Solar has commercialised an approach pioneered by PV Centre researchers that uses high quality silicon deposited as a thin layer onto glass.

Research continues on improving the quality of the silicon films by using thin crystallographic templates and on the development of lower-cost deposition approaches.

Third generation work includes development of tandem cells based on bandgap-engineering using nanostructures. This involves the engineering of a new class of mixed-phase semiconductor material based on partly-ordered silicon quantum-dots in an insulating amorphous matrix; photon up- and down-conversion as a way of "supercharging" performance and investigation of schemes for implementing hot-carrier cells.

The Centre for Sustainable Energy Systems at the Australian National University (CSES), which also hosts the ARC Centre of Excellence for Solar Energy Systems, undertakes research into solar thermal and photovoltaic technologies including cell performance, thin films, efficiency and processing, parabolic trough and paraboloidal dish PV concentrator systems, and associated concentrator cells, trackers, controllers and mirrors, as well as PV-thermal systems. It is also undertaking research into thermochemical storage and phase change energy storage materials. The ARC Centre is undertaking research specifically on improved silicon concentrator cells for 10-50 sun linear concentrators.

One of the CSES's inventions is a major new PV technology, Sliver™ cells, which is being commercialised by the Australian company Origin Energy. The Sliver process uses standard silicon wafers (~1mm thick) which are micro-machined to create thousands of narrow grooves that extend through the wafer. The grooves lead to the creation of a series of thin silicon strips ("Slivers"). In the Sliver cell process, cells are formed in the wafer volume – essentially a 3-dimensional process, which produces a dramatic increase in the active surface area of solar cells per unit volume of silicon consumed and per wafer that is processed with reductions in silicon consumption by a factor of 10-15 and reductions in wafer throughput per Megawatt by a factor of 20-50. Sliver modules can be manufactured using techniques adapted from conventional module manufacture with the metallised contacts placed at the end of each Sliver cell and spacing of cells varied according to transparency requirements. Sliver modules can thus be efficient, low cost, bifacial, transparent, flexible, shadow-tolerant and lightweight. Efficiencies of 20% have been achieved from Sliver cells in laboratory tests.

Another technology developed at ANU and currently in demonstration phase is the photovoltaic-thermal Combined Heat and Power System (CHAPS) which comprises 24 metre long, single axis reflective solar concentrating collectors. Each collector incorporates a tracking support structure that is controlled by a microprocessor. Mirrors focus light onto high efficiency monocrystalline silicon solar cells suitable for mid-range concentration. Heat is removed from the solar cells using a fluid, which flows through a passage in the cell housings. The fluid then passes through a heat exchanger that transfers heat to hot water storage tanks. Prototype systems have achieved combined electricity and heat production efficiencies over 60%.

Murdoch University has an amorphous silicon research group, investigating cell designs which improve performance. They have used a variety of surface analysis techniques to study the electronic structure of amorphous silicon alloys and have proposed a mechanism for the photo-degradation process. Methods of limiting or reversing photo-degradation and increasing cell efficiency are now being trialled. New cell designs, using a combination of nanocrystalline and amorphous silicon alloys are being developed and improved methods of producing solar grade silicon directly from metallurgical grade material are being investigated.

Murdoch University also hosts the *Research Institute for Sustainable Energy (RISE)*, which in turn runs *ResLab*, a renewable energy test and standards centre. RISE is actively involved in PV module testing, PV based remote area power supply system modelling and development and PV standards development and verification.

University of Melbourne, with partners Monash University, Securency, BP Solar, Merck, Blue Scope Steel, and NanoVic, is undertaking research into organic "plastic" PV cells with the possibility of producing flexible solar cells, or coatings that function as sunlight harvesting paints on roofs or as an integral part of fabrics to produce electricity from sunlight. The cells are made by chemically doping conjugated polymers to increase their electronic conductivity by several orders of magnitude. The research includes improved power conversion efficiencies, which are currently around 5%.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has a growing research programme in organic (plastic) photovoltaics, with expertise in synthesis of light-harvesting molecular materials, organic device fabrication and characterisation of photovoltaic performance. It is working in collaboration with the Melbourne University based team described above as well as with international partners as part of the International Consortium for Organic Solar Cells (ICOS). CSIRO's program aims to address two clear needs of the Australian photovoltaics community; i) to work with universities to demonstrate promising organic-based technologies on a manufacturing scale, and ii) to provide a base of expertise and infrastructure for accurate characterisation of PV devices. The vision is to expand the existing National Solar Energy Centre at Newcastle to include a world-class photovoltaics characterisation facility, catering for the special requirements of organic photovoltaic devices, whilst working to standardise measurements across the entire Australian PV community.

2.4.2 Australian Industry Research

BP Solar is the largest commercial PV manufacturer in Australia. In-house research, some of which is carried out in conjunction with Australian university research groups, includes development of automated production equipment, improved cell and module manufacturing processes and integrated systems. It is also active in the development of safe and efficient installation systems and procedures including new frame types, mounting systems, integrated solar water heaters, smart communications and modular pre-designed packaged systems.

CSG Solar commenced commercial module production in Germany during 2006 but continues its research in Australia on Crystalline Silicon on Glass, a thin film PV technology based on initial research at the University of NSW.

Dyesol is the industrial research hub for the world's network of researchers into Dye Solar Cell (DSC) technology. Dyesol researches, develops and manufactures DSC materials and components, including nanoparticulate pastes and dyes, as well as equipment specifically designed to research and manufacture DSC.

Origin Energy is commercialising the "Sliver cell" PV technology developed by the Australian National University as described above. The technology promises crystalline Si cell performance with significantly lower wafer requirements. A 5 MW Pilot Plant was installed in Adelaide in 2004 and trial 10 W and 70 W modules have been produced. The company is undertaking extensive development of the Sliver cell manufacturing process and more extensive pilot manufacture is anticipated in 2007.

PV Solar Energy Pty Ltd has developed a PV roof tile which uses a low cost pluggable PV junction box and monocrystalline solar cell laminates. Installation options include active air flow in the roof space below the modules to keep them cool and to allow warm air circulation into the building during winter months.

Solar Systems Ltd. has developed and commercialised a PV tracking concentrator dish system for off-grid community power supplies and end of grid applications. Current systems achieve

500 times concentration and use air or water cooling. Overall system efficiencies of 20 per cent have been achieved. The systems were initially based on silicon cells, but testing of higher efficiency non-silicon devices is now underway.

2.4.3 Commonwealth Government R&D Support for PV Industries

PV R&D funding for industry has increased in 2006, with the introduction of a number of new programs. Funding for university based research is via standard Australian Research Council programmes, with no funds specifically earmarked for energy generally or PV in particular.

The *Low Emissions Technology and Abatement* (LETA) programme has AUD 26.9 million to reduce greenhouse gas emissions over the longer term by supporting the identification and implementation of cost effective abatement opportunities and the uptake of small-scale low emission technologies in business, industry and local communities. Support for renewables is provided via an industry development sub-programme and will be available to State and Territory Government agencies and renewable energy industry associations.

There is also support for *Advanced Electricity Storage Technologies*, including batteries, electro-mechanical, thermal and chemical storage, to overcome barriers to renewables and other intermittent energy sources. PV related projects funded so far are:

- *ZBB Technologies* AUD 3.1 million to demonstrate an integrated 500 kWh zinc-bromine battery at CSIRO's National Solar Energy Centre at Newcastle.
- *Pinnacle VRB AUD* 1.8 million for demonstration of vanadium-redox batteries with PV panels and wind turbines at the remote fishing community of Windy Harbour in WA.
- *V-Fuel* AUD 0.26 million for demonstrating innovative vanadium-flow batteries with PV panels and a wind turbine on Cockatoo Island and the Environmental Research Institute for Art at Homebush in Sydney.

The AUD 500 million *Low Emissions Technology Demonstration Fund* supports the commercial demonstration of technologies that have the potential to deliver large-scale greenhouse gas emission reductions in the energy sector. It is designed to leverage AUD 1 billion in additional private sector investment. Photovoltaic concentrator company *Solar Systems* has been granted AUD 75 million towards a 154 MW heliostat PV concentrator power plant to be built in Mildura in northern Victoria. The Victorian Government is contributing a further AUD 50 million to the project as part of its renewable energy target. Installation will commence in 2008.

2.5 Public budgets for market stimulation, demonstration / field test programmes and R&D

Table 2 gives figures for the year on budgets from the Federal, State and Territory Governments for R&D, demonstration/field test programmes and market incentives.

Table 2: Public budgets for R&D, demonstration/field test programmes and market incentives.

	R & D	Demo/Field test	Market
Federal	4.57		23.5
State/Territory	2.38	0.59	0.2
Total	6.95	0.59	23.7

3 Industry and growth

3.1 Production of photovoltaic cells and modules

Table 3: Production and production capacity for 2006 for Australian manufacturers

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)			Maximum production capacity (MW/yr)		
		Cell	Module	Concentrators	Cell	Module	Concentrators
BP Solar	sc-Si	**36**	**7.6**		**50**	**10**	
	mc-Si						
Concentrators							
Solar Systems	Si $GaInP_2$/GaAs/Ge			**0.29**			**5**
TOTALS		**36**	**7.6**	**0.29**	**50**	**10**	**5**

3.1.1 Cell Production

BP Solar produces its own cells using imported wafers.

Solar Systems uses both in-house and imported triple junction $GaInP_2$/GaAs/Ge concentrator cells (jointly developed with Spectrolab).

3.1.2 Exports

Approximately 28 MW of Australian made cells were exported by BP Solar and 3.9 MWp of modules. Other companies re-exported approximately 0.6 MWp of PV as modules or in systems.

3.1.3 Specially designed products

PV Solar Tile Pty Ltd has developed a roof product which replaces conventional roof tiles. The air flow under the tiles can be redirected in winter to provide space heating.

Solar Systems has developed modular PV concentrator dishes which can be installed singly or in groups for power supply to mini or main grids.

As the PV water pumping market continues to grow, a number of companies have developed water pumping systems. These include *Solar Sales*, *Mono Pumps* and *Grundfos Australia*.

Bushlight was established under the RRPGP to provide sustainable energy services to remote aboriginal communities. It has developed a modular, scalable renewable energy

power supply system consisting of an equipment enclosure that houses solar regulators, an inverter and all electrical control equipment in a high quality, dust free, temperature controlled cabinet. The Bushlight systems can supply loads between 2 and 32 kWh per day, with provision for a diesel generator to cater for higher loads if required. The systems are designed in conjunction with the community, which is also provided with appropriate educational material. Energy management units are installed at each residence in a community and place a daily limit on the amount of energy each house can draw from the central system. This protects the system from overuse by any one house and ensures supply is maintained for the whole community. Once the daily limit is reached, power is cut to all but essential loads (refrigeration, lights and smoke detectors). Other loads are reconnected once the system is reset at midday each day.

3.1.4 New developments and new products that arrived on the market during 2006

BP Solar and Dux have developed a combined PV / solar water heater kit, sold as the BP Solar Energizer Plus. It is available in several PV and water heater sizes and aims to streamline household solar conversion.

Table 4: Typical module prices in Australia 1994-2006

Year	1994	1996	1998	2000	2002	2004	2006
Module price: Typical	7	8	8	8	7	8	8.5*

* Range AUD 7.5 to 9.0.

3.2 Manufacturers and suppliers of other components

Balance of system component manufacture and supply is an important part of the PV system value chain.

There are a number of Australian manufacturers of inverters, battery charge controllers and inverter/chargers, particularly catering for the off-grid system market, including Selectronics, Plasmatronics, Latronics and Solar Energy Australia. Some of these manufacturers also supply inverters suitable for grid interconnection. Inverter prices typically range from AUD 0.5 – 1.5 per W.

Although some battery components are made in Australia, only a few companies manufacture complete solar batteries. These include Exide's Energystore products and Battery Energy's Suncycle range. Battery Energy, in conjunction with the Commonwealth Scientific & Industrial Research Organisation (CSIRO), has also developed a new solar gel battery, Sungel.

There is an increased interest in the use of trackers for off-grid pumping and power supply systems. Passive gas and electronic controlled trackers are used and expect to increase power output by up to 40% compared with non-tracked systems.

There a several hundred companies around Australia which distribute and install solar systems. A number of these have now become significantly sized systems houses, providing products and systems for a range of applications in Australia and worldwide.

3.3 System prices

Table 5 shows typical turnkey prices (excluding Goods and Services tax) per Wp for various categories of installation. Prices do not include recurring charges after installation, such as battery replacement or operation and maintenance. Additional costs incurred due to the remoteness of the site or special installation requirements are also not included.

Table 5: Typical Turnkey (installed) Prices of PV Applications Australia 2006 (ex GST)

Category/Size	Typical applications in your country and brief details	Current prices AUD per W
OFF-GRID Up to 1 kW	Water pumps, household power supplies, lighting, pastoral stations, cathodic protection	20-25
OFF-GRID >1 kW	PV in diesel power stations	15
GRID-CONNECTED	1-3 kW roof-mounted systems (modules, roof mounting kit, wiring, inverter)	12.5
GRID-CONNECTED Up to 10 kW	Commercial and government buildings	10
GRID-CONNECTED >10 kW		10

Table 5a: Australian trends in typical system prices (current AUD) for off-grid applications up to 5 kWp

YEAR	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Price /Wp:	**24**		**22**		**30**	**30**	**30**	**22**	**22**	**20**	**20**	**20**	**20**	**22**

Table 5b: Australian trends in typical system prices (current AUD) for grid applications up to 5 kWp

YEAR	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Price /Wp:	**11**	**12**	**12**	**14**	**14**	**13**	**10**	**12**	**12**	**12.5**

3.4 Labour places

The following is an estimate of labour places in the various PV related sectors:

a) Research and development (not including companies); 110

b) Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D; 500

c) All other, including within electricity companies, installation companies etc.

- c1) Distributors of PV products; 400
- c2) System and installation companies; 400
- c3) Utilities and government; 30

3.5 Business value

Table 6: Value of PV business

Sub-market	**Capacity installed *in 2006* (kW)**	**Price AUD per Wp**	**Value AUD million (2006)**	**Totals AUD million (2006)**
Off-grid domestic	3370	22	74,14	
Off-grid non-domestic	3580	22	78,76	
Grid-connected distributed	2145	12.5	26,81	
Diesel Grid	625	15	9,38	
				189
Export of PV products				135
Import of PV products				128
Value of PV business				**195**

In documents sent to the Australian Government to support extensions of current PV programmes, the Australian Business Council for Sustainable Energy estimated that the Government investment of AUD 80 million in the PV industry over the last 5 years through grants to consumers has leveraged industry sales to AUD 1,100 million, including AUD 500 million in exports.

4 Framework for deployment (Non-technical factors)

The following table summarizes PV support in place in Australia during 2006:

Table 7: PV support measures

	National / State / Local
Enhanced feed-in tariffs	
Direct capital subsidies	National
Green electricity schemes	Utility
PV-specific green electricity schemes	Utility
Renewable portfolio standard (MRET)	National
PV requirement in RPS	
Investment funds for PV	
Tax credits	
Net metering	Utility
Net billing	Utility
Commercial bank activities	Local
Electricity utility activities	Local/State/Utility
Sustainable building requirements	State / Local

4.1 New initiatives

No new support measures were introduced in 2006, although several jurisdictions have discussed the possible introduction of enhanced feed-in tariffs. These are now being discussed for South Australia and Victoria, as well as at a city level for the new Alice Springs Solar City. A tightening of the NSW Government Building Sustainability Index (BASIX) requirements during 2006 has seen an increased interest in PV, particularly for larger houses.

As previously discussed, the PV Rebate Programme and the Renewable Remote Power Generation Programme are the most significant support measures for PV at present and both will be extended in 2007. As the Solar Cities Programme develops, it is expected to trial new support measures, initially for the Solar Cities themselves, but eventually for more widespread application.

4.2 Indirect policy issues

Please give one paragraph on any policy initiatives that may influence the implementation of PV power systems in your country. This could include details of:

4.2.1 international policies affecting the use of PV Power Systems;

International development of climate change strategies had been watched carefully by Australia, especially emissions trading schemes and renewable energy support programs.

The success of feed-in tariffs in Germany and Spain have resulted in several States undertaking studies of how such tariffs could be applied in Australia.

4.2.2 the introduction of any favourable environmental regulations;

Energy standards have been added to residential and commercial building codes in most States. These usually apply to new buildings or major renovations and are providing opportunities for PV, particularly where other options are difficult to implement. With the higher PV rebates available from 2007, PV uptake to meet building codes is likely to increase significantly.

4.2.3 taxes on pollution (e.g. carbon tax);

Interest in placing a price on carbon has increased significantly in Australia during 2006. The State Governments have agreed to implement an emissions trading scheme by 2010 if the Federal Government does not do so. The Australian Government has commissioned a report on emissions trading, which will be discussed in 2007.

4.2.4 national policies and programmes to promote the use of PV in non-IEA countries.

Australia's participation in the Asia Pacific Partnership on Clean Development and Climate (AP6) is expected to facilitate renewable energy projects with India and China. Trade delegations have been undertaken and negotiations are underway for a range of projects, including renewable energy education programs and large scale PV plants. The Australian overseas aid organisation AUSAID has recently appointed specialists in renewable energy and so may undertake more PV aid projects in future.

4.3 Standards and codes

4.3.1 Revision of AS 4509 "Stand Alone Power Systems" Parts 1-3

Australian Standards Committee EL42 is currently reviewing and revising this standard. It covers design, installation and maintenance of stand alone power systems. The standard is being carefully aligned with the Australian Wiring rules (AS/NZS 3000) and a new revision of AS/NZS 3000 will cross reference the new revised AS/NZS 4509.

4.3.2 ResLab expands NATA Accreditation for Battery Charge Controllers

ResLab, the renewable energy systems testing laboratory at Murdoch University's Research Institute for Sustainable Energy (RISE), was accredited by the National Association of Testing Authorities, Australia (NATA) in May 2005 for performance testing of inverters. In October 2006, ResLab gained accreditation for testing of battery charge controllers.

The NATA accreditation is part of ResLab's program to support Australia's renewable energy industry by providing independent high quality testing services to the renewable energy industry. It specialises in testing inverters, remote area power supply (RAPS) systems and balance of system (BOS) components, solar home systems and battery charge controllers for solar photovoltaic (PV) systems. Obtaining the accreditation has involved the development of a quality system that complies with the requirements of AS/IEC/ISO17025-

2005 the Laboratory management system standard. This has included the development of procedures and techniques, staff training and the documentation of many of the laboratories activities. ResLab is further aiming to expand this accreditation to testing for other products and for testing to international standards. Typically, these services provide industry with the ability to improve their products and make them more competitive, thus providing access to new national and international markets.

ResLab was established in 2003 and is supported by funding provided by the Australian Greenhouse Office (AGO through the Renewable Remote Power Generation Program (RRPGP), which is administered in Western Australia by the Office of Energy, and the Renewable Energy Commercialisation Program.

4.3.3 Building energy codes

The NSW Building Sustainability Index (BASIX) allows the use of PV to count towards achieving the energy rating and greenhouse gas reduction targets of residential buildings. For larger houses, PV can be one of the most straightforward means of reaching the required rating. Similarly, PV can be used in the Greenstar rating system for office buildings to improve the building's energy rating.

5 Highlights and prospects

The Australian PV market has been growing steadily over the past decade, assisted by government grant programs, but began to increase markedly towards the end of 2006 when public awareness and discussion of climate change increased. From 2007 the PV market is expected to grow at a faster rate since Federal Government grant programs have been extended or increased and several State Governments have announced local renewable energy targets. In addition, the 4 Solar Cities will begin installations in 2007 and, if their implementation models are successful, will result in a steady increase in PV uptake even after their original programs are complete.

BP Solar is the only flat plate PV manufacturer in Australia at present, with a production capacity far in excess of current local use. There is interest in establishing other PV plants, particularly for thin film manufacture, so an increase in the local market may stimulate some proposals. It may also encourage local commercialisation of new PV technology, most of which currently goes overseas.

Solar Systems continues its development and installation of concentrator PV systems and will began work on its 154 MW heliostat plant over the coming year. At the same time, interest in its smaller scale concentrator dishes is increasing both in Australia and internationally, particularly for use in diesel grids. Australia has more than 400 MW of diesel generation which will be impacted by both diesel price increases and any introduction of a carbon price, so that this market is also likely to grow strongly over the next five years.

Annex A Method and accuracy of data

a) A summary of the methods used to gather, process and analyse the data.

Most data is gathered directly from industry, government agencies and research groups. Other information is taken from annual reports and other publications.

b) An estimate of the accuracy of the data

Data in Table 1 is probably accurate to ±100kW.

c) If a country cannot provide the necessary data please give the reason here.

- Businesses are reluctant to disclose information on sales breakdown, costs or prices.
- It is difficult to separate out sales, which may be on a long term project basis, from installations actually occurring in any one year.
- It is difficult to separate out component and system costs from overall project costs, since tenders may be on the latter basis and include provision for transport, installation and after sales service.

Annex B Country information

This information is simply to give the reader some background about the national environment in which PV is being deployed. It is not guaranteed to be 100 % accurate nor intended for analysis, and the reader should do their own research if they require more detailed data. There are often large differences between States and electricity retailers and, for diesel prices especially, variations over the year.

1) retail electricity prices vary between retailers and also have different fixed charges and step rates. Typical flat tariffs range from AUD 0.12-0.17 per kWh for households, with summer tariffs of AUD 0.20 or more in some jurisdictions and off-peak hot water tariffs of around AUD 0.05 per kWh also available. For commercial customers, time of use tariffs are more common and range from around AUD 0.05 to 0.10 to 0.20 per kWh for off-peak, shoulder and peak times. However, various standing charges also apply and increasing numbers of customers are on private contracts. The latter may include packages with electricity, gas and other services provided.
2) average household electricity consumption - 7000 kWh per year. This can be higher in areas where gas is not available and may be twice this level in households with air conditioning.
3) typical metering arrangements and tariff structures for electricity customers – most residential consumers in Australia do not have interval meters, although they are being introduced progressively. TOU tariffs are available, but most households have a flat tariff. Net metering for PV systems is available from some retailers.
4) average household income - AUD 29 300 per year
5) typical mortgage interest rate – 7.5%
6) voltage – 240 volts
7) The electricity sector has separate retail, distribution and transmission businesses. Some States have privatized sections of their industry, but most remain publicly owned. The Australian Energy Market Commission (AEMC) is the body responsible for energy market rule-making and market development at the national level. The Australian Energy Regulator (AER) performs economic regulation of the wholesale electricity market and electricity transmission networks in the National Electricity Market (NEM). It is also responsible for the enforcement of the National Electricity Law and National Electricity Rules.
8) price of diesel fuel: AUD 1.2-1.6 per litre
9) typical values of kWh / kW for PV systems in Australia: 1000-2000 kWh/kW per year depending on location.