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 2003*

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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 twenty participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), Finland (FIN), 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 is also a member.

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. Nine tasks have been established, and currently six are active. Information about these tasks can be found on the public website www.iea-pvps.org. The new task concerning urban-scale deployment of PV systems is now underway.

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

An important deliverable of Task 1 is the annual International Survey Report on PV power applications. This report gives information on trends in PV power applications in the twenty member countries and is 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.

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 in households and villages that are not connected to the utility grid. Usually a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'.

Off-grid non-domestic PV power system: System used for a variety of 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 on consumers' premises usually on the demand side of the electricity meter. This includes grid-connected domestic PV systems and other grid-connected PV systems on commercial buildings, motorway sound barriers. etc. These may be used for support of the utility distribution grid.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station.

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.

NC: National Currency

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

PV activity in Australia continued to grow at a steady rate during 2003. Over the last decade installed PV capacity in Australia has grown from just over 7 MWp to over 45 MWp, with annual installations growing at an average of 17% per year and now standing at 6.5 MWp. The off-grid market accounts for 87% of installed capacity and is expected to remain the dominant market under current policy projections. However, planned removal of excise duty on diesel fuel used for power generation may see the off-grid market stall, while the grid market will be impacted negatively by completion of the PV rooftop rebate programme which has operated for 4 years, and positively by new plans for a "solar cities" demonstration programme.

Prices for modules and for off-grid systems remained stable, but prices for grid systems dropped by over 20%. Production capacity at BP Solar continues to increase, with a growing percentage of product being exported. Pilot production continues of STI's DSC cells, while Origin Energy's Sliver cell technology will begin pilot production in 2004/05. However, Pacific Solar's Crystalline Silicon on Glass technology, which has been in pilot production in Sydney, will be manufactured in Germany, where the market is currently more robust.

The PV sector has been working on a PV Roadmap for Australia, using a scenario approach to examine various growth pathways. The Roadmap will provide a sound basis for further technology development, industry activity and government PV support for the coming decade.

- **Installed PV power**

A total of 6.5MWp of PV was installed in Australia in 2003, taking the cumulative installed capacity to 45.6MWp. Both installations and installed capacity grew by about 17% during 2003. Off grid industrial applications continue to dominate the Australian market, accounting for 51% of 2003 installations and 57% of installed capacity. Off grid residential applications were also strong, accounting for 22% of 2003 installations and now representing 30% of installed capacity. PV is also increasingly being used in central diesel grid power systems, to provide fuel savings and peak load supplies. The off grid market, including diesel grids, is being greatly assisted by the Australian Government's Renewable Remote Power Generation Programme. Grid connected applications, including diesel grids, are increasing gradually and now account for 13% of installed capacity. Distributed PV systems on buildings, both grid connected and off-grid, are currently assisted by the Government's PV Rooftop Programme.

- **Costs & prices**

Module prices remained at an average of AUD 7 per Wp. Typical prices for small off-grid systems also remained steady, at an average of AUD 20 per Wp, although prices for larger off-grid systems decreased by around 9%. For grid systems, prices dropped more substantially due to standardisation, competition and BOS cost decreases, particularly inverters. Typical systems up to 10 kWp are now selling at around AUD 10 per Wp, a drop of 23% on 2002 prices. Australia now has some of the lowest system prices in the world.

- **PV production and value**

Cell production increased in 2003 from 20.5 to 26.3MWp and module production from 7 to 9.6MWp. Cell production capacity also increased and stood at 33.5 MWp by end 2003, with a further 5MWp capacity in concentrator systems. Capacity will increase further in 2004/05, with planned expansion to 40MWp by BP Solar and a new 5MWp pilot production facility by Origin Energy. 64% of locally manufactured cells and 49% of modules were exported, while around 30% of modules installed in Australia in 2003 were imported. The industry has a net value in Australia of around AUD 165 million, not including education, R&D, ongoing operation and maintenance or BOS exports.

- **Budgets for PV R,D&D and Market Incentives**

The Commonwealth and State governments provided AUD 5.57 million for R&D in 2003 and AUD 5.79 million for demonstration systems and field tests. However the major support, totalling AUD 19.5 million was provided for market incentives. Total government support for PV increased by nearly AUD 10 million from 2002 to 2003. Government expenditure on R&D and market development is more than matched by Australian industry expenditure. The Government has proposed a new Renewable Energy Development initiative, which will provide targeted funding for commercial development and will move the emphasis of government support back towards R&D.

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

The main applications for PV in Australia are for off-grid industrial and agricultural applications. These include power systems for telecommunications, signalling, cathodic protection, water pumping. Significant markets also exist for off grid residential power supplies and increasingly for fuel saving and peak load reduction on community diesel grid systems. Grid connected PV applications have increased in recent years, largely as a result of government grant programs. The main applications are rooftop systems for private residences, schools and community buildings. A number of large grid installations have been undertaken, including a town square, a city museum, a high rise commercial building and an existing central market rooftop.

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.

Table 1. Cumulative installed PV power in Australia by sub-market.

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
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
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
grid-connected distributed		5	20	30	80	200	850	1 490	2 390	2 800	3 400	4 630
grid-connected centralized				20	20	320	630	650	650	650	850	1 350
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**

Notes to Table 1

1. Grid connected centralized systems include flat plate and concentrator PV power stations connected both to main and to diesel grid systems, with their own substation. These include several large building rooftop systems.
2. A variety of small modules (<40 Wp) are also used extensively around Australia, typically for consumer appliances and lighting.

2.3 Major projects, demonstration and field test programmes

PVRP – Photovoltaic Rebate Programme

a) reasons for, and goals of, embarking on the programme;

To encourage the development and use of building integrated PV.

b) size and main technical and economic data;

1,025 systems were installed in 2003, amounting to 1.37 MWp. Over 60% of customers, accounting for almost 70% of installed capacity, were on grid connected buildings and a total of AUD 6.03 million was allocated in rebates. Since the start of the programme in 2000, more than 4,800 systems, using 5.4 MWp of PV, have been installed and rebates of AUD 26.4 million have been provided.

c) funding sources and cost sharing;

Australian Government funded, with administration by the State Governments. An initial amount of AUD 31 million was allocated over 4 years, with grants of AUD 5,000 per kWp provided, to a maximum of AUD 7,500 per residential system and AUD 10,000 per community building system. A further allocation of AUD 5.8 million was allocated in 2003 and the programme has been extended to 2005. Grants have been reduced to AUD 4,000 for residential systems and 8,000 for community systems.

d) main accomplishments by the end of the reporting year;

Approvals for grid connected systems overtook those for off-grid systems by mid 2002 and now account for the majority of installations. System sizes have remained steady with grid systems averaging around 1.5 kWp and off-grid systems around 1.1 kWp.

e) problems encountered and lessons learned;

The Programme was initially accessed largely by off-grid customers installing new systems or expanding existing ones. The rules were changed to limit availability of funding for system expansion and subsequently off-grid sales declined. At the same time, PV industry development and promotion of grid connect products increased and this market segment grew, to the point where grant funds for 2003 were overcommitted. Grant funding was restricted for some months, until an extension to the programme was negotiated between industry and government. Funding uncertainty resulted in industry promotion being reduced. Combined with the lower grants, this has resulted in lower installation rates.

f) planned continuation of the programme and plans for new activities.

The budget is expected to be expended by end 2004 or mid 2005, after which the programme will cease.

Renewable Remote Power Generation Programme

a) reasons for, and goals of, embarking on the programme;

To increase the use of renewable energy for power generation in off-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.

Each participating jurisdiction has established a slightly different programme, to meet the specific needs of local off-grid applications. However, in general, 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 or use direct diesel generation.

b) size and main technical and economic data;

2.13 MWp of PV has so far been installed under this programme in small systems and a further 0.28 MWp in utility run diesel grid systems. Although it is not PV specific, almost all small systems installed to date include some PV and PV makes up 91% of installed capacity. Major projects (> AUD 0.5 million) supported under the Programme have been predominantly wind. The overall programme has funds up to AUD 264 million allocated to it (although the actual budget is based on diesel fuel excise paid by public power generators over the period 1 July 2000 to 30 June 2004), of which AUD 25 million had been allocated to small projects by end 2003 and a further AUD 14.7 million to major projects. In addition, AUD 5.9 million has been allocated to industry support activities, including test facilities, standards and certification.

c) funding sources and cost sharing;

Core funding for this programme is provided to the participating jurisdictions by the Australian Government. Grants of up to 50% of the capital cost of renewable generation and essential enabling equipment that displace diesel generation are available. The programme is administered by State and Territory governments, with additional funding provided by some States. The Programme will extend to 2009/2010, though most participating jurisdictions are likely to expend their allocation before then.

A specific allocation of AUD 8 million has been made to the Aboriginal and Torres Strait Islander Services (ATSIS) for the *Bushlight* programme to assist with the development of industry capability and local understanding of renewable energy systems in small indigenous communities.

d) main accomplishments by the end of the reporting year;

To end 2003, grants of AUD 25.5 million had been paid for 2,000 small systems, which included 2.13 MWp of PV. Around 50% of the small systems installed in 2003 were for residential purposes and 50% for agricultural / industrial uses, including water pumping systems.

e) problems encountered and lessons learned;

Because the funding provided to each participating jurisdiction is based on diesel fuel excise paid by public power generators in remote areas, some States receive very little or no funding, while others have significant funds. While the overall budget for the

programme is high, applicants must source at least 50% of project costs, which may pose a barrier to implementation in remote communities.

f) planned continuation of the programme and plans for new activities.

The Programme will continue until 2010 or until funds are expended. While initial applications have mainly been for small systems, an increasing number of larger, community-sized systems are now being installed.

Northern Territory Power and Water Corporation Diesel Grid PV Programme

a) reasons for, and goals of, embarking on the programme;

To reduce diesel fuel requirements and peak loads on remote community diesel grids.

b) size and main technical and economic data;

A 56 kWp a-Si array was installed at the remote Aboriginal community of Bulman in 2002 at a cost of AUD 0.9 million and a 225 kWp c-Si array was installed at a national park tourist facility in Kings Canyon in 2003 at a cost of AUD 2.9 million. The PV systems provide power directly to the load via AES grid interactive inverters. No batteries are used.

c) funding sources and cost sharing;

The PV systems have been jointly funded by the NT Power and Water Corporation and the Australian Government, via the Renewable Remote Power Generation Programme.

d) main accomplishments by the end of the reporting year;

The Bulman PV system is expected to save 25,000 litres of diesel and reduce greenhouse gas emissions by 73 tonnes annually. The Kings Canyon PV system is expected to save 105,000 litres of diesel and reduce greenhouse gas emissions by 331 tonnes of carbon dioxide equivalent each year.

e) planned continuation of the programme and plans for new activities.

Plans are underway for 30 Solar System PV concentrator dishes to be connected to 3 remote diesel grid systems around the Northern Territory over the next 18 months.

2.4 Highlights of R&D

A new **Centre of Excellence in Advanced Silicon Photovoltaics and Photonics** has been established at the Centre for PV Engineering, University of NSW. Research streams are focussed on short (1st generation), medium (2nd generation) and long term (3rd generation) technology needs. 1st generation work includes continued improvement of the buried contact cell, the use of phosphorous doping in place of boron, and fabrication on thinner wafers. 2nd generation research includes support for Pacific Solar in commercialising its crystalline silicon on glass product, as well as independent research into improved silicon deposition quality and grain size, manufacturing cost reduction and non-metal contacts. 3rd generation technology is expected to be both high efficiency and thin film, with research focussing on all-silicon tandem cells based on bandgap-engineering, silicon light emitting devices and lasers, and light trapping. Other researchers at the University of NSW are working on GaAs solar cells.

The **Centre for Sustainable Energy Systems** at the Australian National University undertakes research into solar thermal and photovoltaic technologies. Origin Energy is commercialising its thin crystalline "Sliver cell" technology (see below). The ANU team is also developing parabolic trough and paraboloidal dish PV concentrator systems, and associated concentrator cells, trackers, controllers and mirrors, as well as a Combined Heat and Power Solar System. It is also undertaking research into thermochemical storage and phase change energy storage materials.

The **Solar Energy Applications Research Group** at Monash University undertakes research into renewable energy power systems design, analysis and storage. It works with off-grid and grid applications.

Origin Energy is commercialising the "Sliver cell" PV technology developed by the Australian National University. The technology promises crystalline Si cell performance with significantly lower wafer requirements. Construction of a 5 MW Pilot Plant is underway in Adelaide, with production expected in 2005. The pilot plant will be expandable to approximately 25 MW p.a. capacity if pilot production is successful.

BP Solar significantly increased both its mono and poly silicon cell efficiencies by installation of new plasma enhanced chemical vapour deposition (PECVD) Silicon Nitride systems on its production lines at Homebush Bay, Sydney. For typical modules, power output has been increased by 6%. BP continues its development of automated production equipment and is working with research groups in Australia and elsewhere on improved cell and module manufacture.

Pacific Solar has developed a thin film PV technology called Crystalline Silicon on Glass (CSG) based on initial research at the UNSW. In addition to its R&D on CSG modules, Pacific Solar developed and commercialised its own module inverters and roof mounting systems which have now been sold as a separate business. CSG cell and module manufacture is scheduled for 2006 in Germany by CSG Solar, while R&D on the CSG technology will continue in Sydney.

Sustainable Technologies International (STI) focussed on developing improvements to its DSC technology and increasing its patent portfolio, while seeking to raise the capital needed to establish a volume manufacturing plant. In 2004, STI will complete an R&D Start project resulting in a 25% improvement of commercial DSC product daily output. Five new patent applications for 3rd generation PV products are being filed. An agreement with Greatcell

Solar in Switzerland is expected to see manufacture in Europe of the STI DSC Façade panels, which were demonstrated in the STI pilot manufacturing facility in Queanbeyan.

Solar Systems Ltd. continues development and commercialisation of its PV tracking concentrator dishes for off-grid community power supplies and end of grid applications. Current systems achieve 500 times concentration and use air or water cooling. System efficiencies of 20 per cent have been achieved. The systems are currently based on silicon cells, but work is continuing on development of non-silicon devices, which are expected to achieve 40 per cent efficiency.

PV Solar Energy Pty Ltd has developed and demonstrated a new PV roof tile, based upon a versatile extruded aluminium frame. The tile uses a new low cost pluggable PV junction box, developed by Tyco Electronics and monocrystalline solar cell laminates. Installation options include active air flow in the roof space below the modules to keep them cool and allow for warm air circulation into the building during winter months.

Other universities with PV programs include:

- Murdoch University - methods of producing low cost silicon from a number of new sources for both wafer based and thin-film silicon solar cells.
- Flinders University - improved dye sensitised solar cells.
- University of Queensland - semiconductor biopolymers
- Newcastle University – nanoscale polymer devices

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

Table 2. Public budgets for R&D, demonstration/field test programmes and market incentives
current Australian Dollars (million)

	R & D	Demo/ Field test	Market
National/federal	5.201	5.79	18.964
State/regional	0.372		0.525
Total	5.573	5.79	19.489

3 Industry and growth

3.1 Production of photovoltaic cells and modules

Table 3: Production and production capacity information for the year for each manufacturer

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)		Maximum production capacity (MW/yr)	
		Cells	Modules	Cells	Modules
1 BP Solar	sc-Si	5.2	9.0	33.0	12.0
2 BP Solar	mc-Si	21.0			
Thin film manufacturers					
1 STI	DCS	0.1	0.1	0.5	0.5
Concentrator Systems					
1 Solar Systems*	Si		0.5		5
TOTALS		26.3	9.6	33.5	17.5

* Concentrator systems are rated according to final output.

a) General description of the main steps of the production process employed for each manufacturer

BP Solar: Cell fabrication from imported wafers, through to module fabrication as well as total system production.

STI: In-house manufacturing of all the key materials for DSC technology: titania paste, dye, electrolytes, catalytic paste, interconnecting material and internal sealants. The manufacturing process includes laser isolation of the conductive glass screen-printing of working electrode (titanium dioxide, a range of electrodes per substrate) and counter electrode (catalytic layer, 6 electrodes per substrate), deposition of sealants and interconnection on the substrates, bonding the substrates and filling with a proprietary electrolyte. External sealing finalises manufacture of tiles (180x100mm). Modules are glass-glass using liquid lamination.

b) Cell production

The majority of cells used in Australia are processed in-house; STI produces its own DSC cells; silicon cells are made from imported wafers.

c) Amount of production exported from the country

Cell exports for 2003 were 17.2 MW, 64% of total production. Module exports were 4.8 MW, 49% of production.

d) New developments and new modules that arrived on the market during 2003.

BP Solar's module ratings continued to increase, with typical modules now rated at 160 Wp.

Sydney based company PV Solar Energy has designed a building integrated PV Solar Tile™ product which can now be used with an innovative PV AirFlow™ ventilation or heat extraction system. The tile itself can be used as a weatherproof roofing material, with good thermal performance characteristics, while the airflow system improves PV performance in Australia's hot conditions. The PV AirFlow™ support structure allows air to flow behind the PV panels and into the roof cavity, whence it can be externally vented in summer (or used for other purposes) or internally vented in winter with the use of a low power, thermostatically operated fan.

e) Details of module production capacity under construction at end of 2003 but not yet in production.

BP Solar continues to expand its cell production capacity and expects to reach 40 MW by end 2004. Module production capacity is not expected to increase. Origin Energy has begun construction of a 5 MW pilot line for production of Sliver™ cells, which will begin production in 2005.

f) Outlook for manufacturing and products

Manufacturing is expected to increase along with capacity expansion, with the major portion of product exported. No major changes are anticipated in technology type for 2004.

Table 4: Typical module prices (current AUD) 1994-2003

Year	1994	1996	1998	2000	2002	2003
Module price(s): AUD per Wp	7	8	8	8	7	7

3.2 Manufacturers and suppliers of balance of system components

There are several Australian manufacturers of inverters, controllers, system regulators, maximum power point trackers, batteries and other balance of system components. They include Advanced Energy Systems (AES), EnerTec Australia, Latronic Sunpower, Plasmatronics, Powercor Australia, Power Solutions Australia, Solar Energy Australia (SEA), Rainbow Power Company, RF Electronics, Selectronic Australia and Battery Energy South Pacific, Exide and Century Yuasa as major battery suppliers. Their products cover small and large systems in both grid and off-grid markets. Several companies service both Australian and international markets, especially for off-grid applications.

- **PV inverters and controllers**

Inverter prices fell markedly in 2003, after being relatively stable for some years. This will have significant positive impacts on the overall cost of PV systems. Typical prices range from AUD 1.3-1.9 per W for inverters up to 2.5 kW and AUD 0.4-1.0 for larger sizes. Grid interactive inverters, three phase inverters and inverter chargers are slightly higher.

New products introduced in 2003 include:

- Power Solutions - grid interactive inverter with battery, which allows autonomous operation of grid connected systems during power failures.
- AES – improved charge regulators and maximum power point trackers, 'Enviromax PV' inverters which can be current controlled to limit input to a diesel power station, matching diesel loading requirements and site loads.
- Powercorp – MICROLINK automatic and remote control for power systems.
- Latronics, EnerTec and SEA – new inverter ranges
- Selectronic Australia – Thermal Share Technology to reduce inverter heat stress, thereby achieving the same rating at 40 deg C as previously achieved at 25 deg C.

- **Storage batteries and charge controllers**

Typical battery prices for small systems are around AUD 1.5 per Ah for 6V batteries, AUD 4.5-5.5 per Ah for 12V batteries less than 55Ah and AUD 2.5-3.5 for 12V batteries larger than 55 Ah.

Plasmatronics has released a new series of PV battery charge controllers, incorporating LCD displays, system monitoring and data logging capabilities.

- **Supporting structures**

Most of the major Remote Area Powers Supply companies offer a range of PV mounting frames. Ergon Energy's station**power**® systems use an innovative curved array frame which also acts as housing for the power system.

The PV AirFlow™ support structure developed by PV Solar Energy allows air to flow behind the PV panels and into the roof cavity, whence it can be externally vented in summer (or used for other purposes) or internally vented in winter with the use of a low power, thermostatically operated fan.

- **Kits and Systems**

BP Solar released its Solar Energiser Rooftop PV kits, which are available in standard sizes for rapid installation on tiled or metal roofs. The kits are available with mono crystalline (grey backed) or multi-crystalline (blue backed) modules and grid interactive inverters. Weather station, monitoring and display devices are also available.

Perth based company Advanced Energy Systems has developed a 30 kWp power conditioning, or Total Distributed Generation system. It has an 8 kWp PV array and can grid feed with excess daily solar power. The load is always backed up if the grid fails and the inverter maintains high quality power to the load. A small battery keeps the system available 24 hours per day.

Perth based company Solar Energy Systems has developed a low maintenance PVC poly-piston PV water pump which is being used for lowering saline groundwater. The company has also developed Solarflow, a reverse osmosis unit which can be powered directly from a single solar module. The unit produces high quality drinking water that meets World Health Organisation standards. The system is completely automatic, can be combined with a PV water pump and Sun Tracer® tracking systems, and is designed for easy maintenance.

Mono pumps has developed a complete PV water pumping system using a 4 module tracking array, a Controller (or Maximum Power Point Tracker), a submersible brushless DC motor and a positive displacement pump which achieves high efficiencies and performs well from water heads of 15m or more.

Victorian based company Solar Systems has begun commercial production of concentrating PV systems for use in mini diesel grids. A 10 dish, 220 kWp system is in operation in South Australia and a further 30 dishes (720 kWp) are under construction for use in the Northern Territory. The technology is also suited to end of grid applications, hydrogen production and combined heat and power production. Each dish comprises 112 curved mirrors which focus sunlight onto a central receiver to provide a 500 X concentrator effect. The dishes are cooled and independently tracked.

A combined heat and power system, using parabolic trough concentrators, is under construction by the Centre for Sustainable Energy Systems at an Australian National University student residential hall. The 15% efficienct PV systems are connected to the main grid via a 40 kW inverter and the thermal output will be used for space and water heating.

Queensland based energy utility, Ergon Energy, has developed an off-grid PV hybrid system, station**power**®, able to cater for loads from 20 to 150 kWh a day. The systems are modular, transportable, and can be supplied self contained or as additions to existing diesel generating sets. PV is supplied in one or more 2.1kWp adjustable, steel frame bays. Wind and hydro can also be used, with automatic switching between generation types. Australian made SunGel valve regulated lead acid gel batteries and Power Solutions Australia 5 kW, 120V DC interactive inverters, with built in battery chargers, are used. Simple weatherproof plug interconnects allow for easy replacement of components and system upgrade. Station**power**® systems are designed for harsh environments, with rugged construction, and dust, water and vermin proof enclosures. Diesel enclosures provide sound attenuation and battery enclosures are thermally insulated.

3.3 System prices

Table 5: Turnkey Prices of Typical Applications

Category/Size	Typical applications and brief details	Current prices per W in AUD
OFF-GRID Up to 1 kW	Residential, water pumping, telemetry, electric fences, lighting	18-24
OFF-GRID >1 kW	Community power stations, diesel grid, pastoral stations, roadhouses, telecommunications, cathodic protection	12-18
GRID-CONNECTED	1-3 kW roof-mounted systems for households and schools	8-12
GRID-CONNECTED Up to 10 kW	Community, industrial and commercial buildings	7-10
GRID-CONNECTED >10 kW	Community, industrial and commercial buildings	6-10

Table 5a: Australian trends in average system prices (current AUD) for off-grid applications up to 1 kWp

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

Table 5b: Australian trends in average system prices (current AUD) for grid applications up to 10 kWp

YEAR	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Price /Wp:					**11**	**12**	**12**	**14**	**14**	**13**	**10**

3.4 Labour places

a) Research and development (not including companies); 85

b) Manufacturing of PV system components, including company R&D; 350

c) All other, including within electricity companies, installation companies etc. 260

System distributors, installers and contractors; 235
Utilities and government: 25

Data for (a) and (b) collected directly from research groups and manufacturers with estimates for (c) from industry associations and government reports.

3.5 Business value

Based on the installations of PV in the different sectors in Australia, reported in Table 1, as well as exported cells, modules and systems, all valued as reported in Table 5, the business value of the Australian PV industry is estimated as follows:

Australian market:

Sector	KW	AUD per Wp	Sector Value AUD millions
RAPS domestic	1,450	20	29.0
RAPS industrial	3,320	15	49.8
Grid	1,230	10	12.3
Central	500	8	4.0
TOTAL	6,500		95.1

Exports: AUD 106.26 million

TOTAL Value AUD 201.36 million

Imports:

All wafers used for Si cell production were imported, as were over 2 MW of modules installed in 2003. Wafer and module costs were based on international prices. The value to the Australian industry is reduced by this amount.

TOTAL wafer & module imports AUD 36.56 million

Net Industry Value AUD 164.8 million

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

a) Utility perception of PV (ownership of and liability for PV systems; non-utility production of electricity; grid support; peak load reduction; etc.)

A number of electricity utilities are directly involved with PV system sales, including Origin Energy, which markets grid connect kits, and Ergon Energy, which markets off-grid systems. Utilities which service remote communities have a particular interest in PV options, since diesel fuel delivery and generator maintenance are costly and difficult in remote areas. The NT Power and Water Corporation has connected 2 flat plate and one concentrator PV system into remote diesel grids and has commissioned several more. Australian Inland Energy has tested a grid connected concentrator system and is considering the installation of others for energy supply and voltage support at the end of long grid lines. Utilities such as Integral Energy are involved with Solar Schools programs and maintain an active interest in PV for peak load power supply, while Energy Australia operates some of Australia's largest grid connected PV systems – a central power plant and a series of building integrated PV systems in an inner city community. These utilities typically use PV generated electricity to service their Greenpower customers. Greenpower sales in Australia continue to grow, with an increasing percentage going to commercial customers.

b) Changes in public perceptions of PV

PV is well accepted and widely utilized in rural areas of Australia. Over the last year or two marketing of PV systems has been stronger in urban areas. This has increased interest in grid connected systems, so much so that government grant programs were over-subscribed in 2003 and subsequently reduced. This is an indication of public interest in solar options and also that government grants improve consumer confidence in and acceptance of technology new to them.

Solar school programs around the country are increasing awareness and understanding of PV. Many local governments are also increasing their use of PV, particularly for lighting systems, but also for public buildings. Large PV systems have been installed on the roof of the South Australian Museum in Adelaide, the Queen Victoria Markets in Melbourne and the Kogarah Town Square in Sydney.

The first graduates of the new PV and Solar Energy Engineering Degree from the University of NSW entered the workforce in 2003 and are expected to greatly improve perceptions of PV in professional areas over time. The degree program includes training in technology development, manufacturing, quality control, reliability and lifecycle analysis, cell interconnection and encapsulation, the full range of solar cell applications, system design, maintenance and fault diagnosis, marketing, policy development and the use of a range of renewable energy technologies. Considerable emphasis is placed on gaining hands-on experience of working with photovoltaic devices, modules and systems through undergraduate projects in a student's second and fourth year.

c) Planned developments

The Northern Territory Power and Water Corporation plans to continue its development and use of PV systems for diesel grids, with 720 kWp of new concentrator systems on order. However, the Federal Government's proposal to remove fuel excise duty for power generators will erode the cost effectiveness of PV as a diesel fuel saver and may see mooted projects shelved.

For grid connected PV, the Government has announced a new 7 year Solar Cities initiative which will provide funding for solar, energy efficiency, smart metering and other options aimed at improving the market for distributed generation and demand side energy solutions. Although details of this initiative have not yet been released, it is expected that several urban areas will be selected for high penetration uptake of PV and other distributed generation options, with detailed monitoring and associated marketing and financing also being supported.

4.2 Indirect policy issues

Recommendations to increase the Mandatory Renewable Energy Target and to provide specific support for PV have not been adopted by the Government so that this measure is likely to remain a second order driver in the PV market.

Significant new funding for renewable energy and low emission technology research and development has been announced. This will add to generic research funding available to universities and may replace some of the market incentives currently available for PV.

4.3 Standards and codes

A range of Australian standards relevant to PV systems is shown in Table 6. A standard for PV array wiring is almost complete. The standard for stand alone inverters is needed urgently as some imported product without isolation between the battery and the 230V output has already caused one death and raises significant safety issues for the industry, not only in Australia but internationally. There is also a need for a safety and performance standard for charge controllers.

The grid connection standard covers installation, inverter requirements and protection requirements including safety of the installation, islanding protection, harmonic and power factor requirements. There is still a need for general agreement on a standard interconnection application and approval process with all utilities in Australia. Having this in place would greatly facilitate diffusion of PV in grid connected applications. A review of current procedures has been undertaken by the Australian Greenhouse Office and options for standardization are currently under discussion with electricity utilities.

Table 6: Australian PV and System Standards- Existing and Under Development

Area	Standard No.	Title	Current Date of Amendment
Battery	AS4086.1	Secondary Batteries for use with Stand-alone power systems: Part 1 General Requirements	1993
Battery	AS4086.2	Secondary Batteries for use with Stand-alone power systems: Part 2 Installation and Maintenance	1997
General	AS/NZS3000	Wiring Rules	2000
General	AS3100	AS3100 Approval and test specification - General requirements for electrical equipment	2002
Genset	AS3010.1	Electrical Installations- Supply by Generating Set- Internal Combustion engine driven sets	1987
Grid	AS4777.1	Grid Connection of energy systems via inverters: Part 1 Installation Requirements	2002
Grid	AS4777.2	Grid Connection of energy systems via inverters: Part 2 Inverter Requirements	2002
Grid	AS4777.3	Grid Connection of energy systems via inverters: Part 3 Grid Protection Requirements	2002
System	AS1170.1	Minimum design loads on structures – Part 1 Dead and Live Loads and load combinations	1989
System	AS1170.2	Minimum design loads on structures – Part 2 Wind Loads	1989
System	AS1170.3	Minimum design loads on structures – Part 3 Snow Loads	1989
System	AS4509.1	Stand Alone Power Systems: Part 1 Safety Requirements	1999
System	AS4509.2	Stand Alone Power Systems: Part 2 System Design Guidelines	2002
System	AS4509.3	Stand Alone Power Systems: Part 3 Installation and Maintenance	1999
System	DR03389	Installation of Photovoltaic (PV) Arrays	Under Development
BOS Components		Stand alone inverters, Safety and Performance	Under Development

Funding was provided through the Australian Government's Renewable Energy Industry Development Programme (REID) to assist with developing the PV array standard (expected mid 2004), the inverter standard for stand alone power systems (end 2005) and standard contracts between installers and stand alone power system owners.

As part of the implementation process for new PV guidelines and standards, materials for training and accreditation for industry are developed and seminars, short courses and trade certificate courses are available across Australia. A limited amount of Renewable Remote Power Generation Programme funding is available for accreditation purposes.

The PV industry is currently undertaking a customer feedback survey, in order to estimate costs and establish mechanisms to deal with after sales customer service, particularly in off-grid areas.

Support for evaluation/modelling, accreditation, and national standards has also been provided for a national facility dedicated to testing and accrediting renewable energy systems, RESLab, (formerly ACRELab). RESLab is currently doing commercial testing of renewable energy systems and components. Its facilities include a solar simulator, a large PV array, PV module tester, power quality analysers and extensive systems test beds including configurable battery energy storage systems and battery capacity test facilities and constant temperature baths, along with other associated test and monitoring equipment.

For building integrated PV systems, funding was provided by the Australian Government through the Australian Greenhouse Office REID Programme for best practice guidelines explaining PV installation requirements to builders, architects, planners, financiers and electricians. These guidelines will be published by the Business Council for Sustainable Energy. They cover feasibility and evaluation, design, implementation, compliance testing, commissioning, monitoring, maintenance and decommissioning.

5 Highlights and prospects

The major PV industry developments in Australia in 2003 were a continued increase in BP Solar's production capacity to 33 MWp, commencement of construction of Origin Energy's "Sliver" cell pilot line and successful commissioning of Solar System's first commercial concentrator system. These developments set the scene for significant production increases, new technologies and new markets.

The major portion of PV production is exported and this will continue, unless local markets expand more rapidly. Origin Energy will be introducing pilot production of its new "Sliver" cell technology into the market in 2005. Its decision to expand into full scale production in Australia will be dependent on an increased local market. Pacific Solar has completed its pilot production phase and has announced plans to establish full scale manufacture in Germany, where markets are growing rapidly and where government establishment support has also been provided.

The Australian PV industry is working on a PV Roadmap, which includes targets and strategies for the different PV market sectors. The overall target being considered is for an installed capacity in Australia of 350 MWp by 2010, a significant increase from the 45 MWp installed to end 2003. To achieve this will require rapid inroads to be made into the grid connect market, as well as accelerated displacement of diesel in diesel grid systems.

Annex A Method and accuracy of data

a) The information contained in this report is collected from the Australian PV industry, State and Australian Government agencies and research groups, both through direct contact and via publications and information circulated during the year.

b) The data is considered to have an accuracy of ±10 %, unless otherwise indicated.

c) Because of the small number of industry players in the Australian PV market, some data is difficult to report without breach of confidentiality. In these instances generic or aggregated information has been provided.