Australian PV Association

PV IN AUSTRALIA 2010

Prepared for the International Energy Agency Cooperative Programme on PV Power Systems

by

Australian PV Association

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Task 1

Exchange and dissemination of information on PV power systems

National Survey Report of PV Power Applications in Australia, 2010

ACKNOWLEGEMENTS

This report is prepared on behalf of and with considerable input from members of the Australian PV Association (APVA) and the wider Australian PV sector.

The objective of the APVA is to encourage participation of Australian organisations in PV industry development, policy analysis, standards and accreditation, advocacy and collaborative research and development projects concerning solar photovoltaic electricity.

APVA provides:

- Up to date information on PV developments around the world (research, product development, policy, marketing strategies) as well as issues arising.
- A network of PV industry, government and researchers which undertake local and international PV projects, with associated shared knowledge and understanding.
- Australian input to PV guidelines and standards development.
- Management of Australian participation in IEA-PVPS, including:

  PV Information Exchange and Dissemination;

  PV Hybrid Systems within Mini-grids

  High Penetration PV in Electricity Grids.

The Association receives funding from the **Australian Solar Institute**, to assist with the costs of IEA PVPS membership, Task activities and preparation of this report.

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DEFINITIONS, SYMBOLS AND ABBREVIATIONS

For the purposes of this and all IEA PVPS 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°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 system 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, electricity utility businesses 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.

Currency: The currency unit used throughout this report is the Australian Dollar (AUD).

PV support measures:

Enhanced feed-in tariff	an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility business) at a rate per kWh somewhat higher than the retail electricity rates being paid by the customer
Capital subsidies	direct financial subsidies aimed at tackling the up-front cost barrier, either for specific equipment or total installed PV system cost
Green electricity schemes	allows customers to purchase green electricity based on renewable energy from the electricity utility business, usually at a premium price
PV-specific green electricity schemes	allows customers to purchase green electricity based on PV electricity from the electricity utility business, usually at a premium price
Renewable portfolio standards (RPS)	a mandated requirement that the electricity utility business (often the electricity retailer) source a portion of their electricity supplies from renewable energies (usually characterized by a broad, least-cost approach favouring hydro, wind and biomass)
PV requirement in RPS	a mandated requirement that a portion of the RPS be met by PV electricity supplies (often called a set-aside)
Investment funds for PV	share offerings in private PV investment

	funds plus other schemes that focus on wealth creation and business success using PV as a vehicle to achieve these ends
Income tax credits	allows some or all expenses associated with PV installation to be deducted from taxable income streams
Net metering	in effect the system owner receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period
Net billing	the electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given price
Commercial bank activities	includes activities such as preferential home mortgage terms for houses including PV systems and preferential green loans for the installation of PV systems
Activities of electricity utility businesses	includes 'green power' schemes allowing customers to purchase green electricity, operation of large-scale (utility-scale) PV plants, various PV ownership and financing options with select customers and PV electricity power purchase models
Sustainable building requirements	includes requirements on new building developments (residential and commercial) and also in some cases on properties for sale, where the PV may be included as one option for reducing the building's energy foot print or may be specifically mandated as an inclusion in the building development

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

The overall programme is headed by an Executive Committee composed of one representative from each participating country or organization, while the management of individual Tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org

Australia's participation in the PVPS is undertaken by the Australian PV Association and is supported by the Australian Solar Institute. The Australian Executive Committee representative is Dr Muriel Watt, IT Power (Australia). In 2010 Australia participated in:

- Task 1: Leader and Operating Agent - Mr Greg Watt
- Task 11: Leader - Mr Wolfgang Meike, Novolta
- Task 14: Leader - Associate Professor Iain MacGill, University of NSW.

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. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the Australian National Survey Report for the year 2010. Information from this document will be used as input to the annual PVPS Trends in Photovoltaic Applications report.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

Australian specific information is available from the Australian PV Association website: www.apva.org.au.

EXECUTIVE SUMMARY

Installed PV power

A total of 383 MW of PV was installed in Australia in 2010, a 480% increase over 2009. Of this 99% was grid-connected, taking the cumulative grid-connected portion to 85%, up from 54% last year. Total installed capacity in Australia is now 571 MW. The rapid increase in PV uptake has resulted in the curtailment or reduction of Government support programs and the market may over-correct in the short term.

Costs & prices

Typical module and system prices continued to fall in 2010, although there was still a wide spread of prices. Module prices averaged AUD 3,20/Wp but ranged from AUD 2,0 to 3,70 and small grid system prices averaged AUD 6/Wp, down from AUD 9/W last year.

PV production

Australia has only one flat-plate PV cell and module producer, Silex Solar, and they produced 8 MW of c-Si modules in 2010.

Budgets for PV

A total of AUD 641,3 million was spent by the Australian and State and Territory Governments on PV R&D, demonstration and market stimulation, with the latter accounting for 78% of expenditure, largely due to rebates provided through the Solar Homes and Communities Plan, which has now ended.

Figure 1: 235 kWp Solfocus array at Alice Springs Airport (Photo: Solar Cities)

1 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.

1.1 Applications of photovoltaics

The market for PV installations connected to central grids in Australia continues to increase and represented the largest market for PV in 2010. The majority of installations took advantage of incentives under the Australian Government's Solar Homes and Communities Plan (SHCP) and Renewable Energy Target (RET) mechanisms, with further drivers provided by Feed-in Tariffs in some States and Territories. The main applications are rooftop systems for private residences. There are also installations on community buildings, including schools. The commercial and light industry sector has grown more slowly, with support available to selected projects in certain areas through the Solar Cities and other State government programs.

The second 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 diesel grid systems. There is also a reasonably significant market for recreational PV applications for caravans, boats and off-road vehicles.

1.2 Total photovoltaic power installed

The PV power installed in Australia in 4 sub-markets during 2010 is shown in Table 1. The market is dominated by the high uptake of grid-connected distributed systems, with installations in this sector increasing from 67 MWp in 2009 to 378 MWp in 2010, due to continuing deployment under the SHCP as well as the availability of Solar Credits under the RET, as well as feed-in tariffs. This has led to overall installations increasing from 79 MWp in 2009 to 383 MWp in 2010.

Table 1: PV power installed in Australia during calendar year 2010 in 4 sub-markets.

Sub-market/ application	off-grid domestic	off-grid non-domestic	grid-connected distributed	grid-connected centralized	Total
PV power installed in 2010 (MWp)	3,5	0,4	378,2	1,3	**383,3**

The data in Table 1 was gathered directly from government data bases, industry and government agencies via surveys, emails and phone calls. Inaccuracies in Table 1, and subsequent tables in this report, may arise because:

- businesses are reluctant to disclose detailed information on sales breakdown, costs or prices;
- the Renewable Energy Certificate database kept by the Office of the Renewable Energy Regulator lags actual installations, because installers have up to a year to create certificates;

- the major importing companies do not keep statistics on the end-uses of their modules;
- the accounting periods for different companies vary, with some using the Australian financial year (July to June) but others use the Japanese financial year (April to March) or the calendar year.
- PV companies are busy and unwilling to spend the time collating data.

For Table 1 particularly, it is difficult to separate out sales into end-use categories. In addition, some projects may be long term, with installations actually occurring over a number of years. Hence the overall accuracy of the 2010 installation rate is estimated to be ±10%, but the error bar may be higher within sub-categories.

For cost estimates in subsequent tables, it is difficult to separate out component and system cost from overall project costs, since prices may be quoted on the latter basis and include provision for transport, installation and after sales service.

PV capacity and generation, as a percentage of overall power supply in Australia, are shown in Table 2.

Table 2: PV power and the broader Australian electricity market.

Total Australian PV capacity as a % of total national electricity generation capacity	New (2010) PV capacity (from Table 1) as a % of new electricity generation capacity*	Total PV electricity production as a % of total electricity consumption
1%	20%	0.3%

* This may be high as other small-scale generation capacity may not be included in the non-PV capacity installed.

A summary of the cumulative installed PV power, from 1992-2010, broken down into five sub-markets is shown in Table 3 and Figure 1.

Table 3: The cumulative installed PV power in Australia across 4 sub-markets.

Sub-market	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Off-Grid domestic	1,56	2,03	2,6	3,27	4,08	4,97	6,07	6,93	9,22	11,07	12,45	14,28	16,59	19,89	23,88	27,71	32,68	40,76	44,23
Off-Grid non-domestic	5,76	6,87	8,08	9,38	11,52	13,32	15,08	16,36	17,06	19,17	22,74	26,06	29,64	33,07	36,65	38,73	40,66	43,14	43,57
Grid-connected distributed		0,01	0,02	0,03	0,08	0,20	0,85	1,49	2,39	2,80	3,40	4,63	5,41	6,86	9,01	15,04	29,85	101,21	479,34
Grid-connected centralised				0,02	0,20	0,21	0,52	0,54	0,54	0,54	0,54	0,66	0,66	0,76	0,76	1,01	1,32	2,53	3,79
TOTAL (MWp)	**7,30**	**8,90**	**10,70**	**12,70**	**15,70**	**18,70**	**22,52**	**25,32**	**29,21**	**33,58**	**39,13**	**45,63**	**52,30**	**60,58**	**70,30**	**82,49**	**104,5**	**187,64**	**570,93**

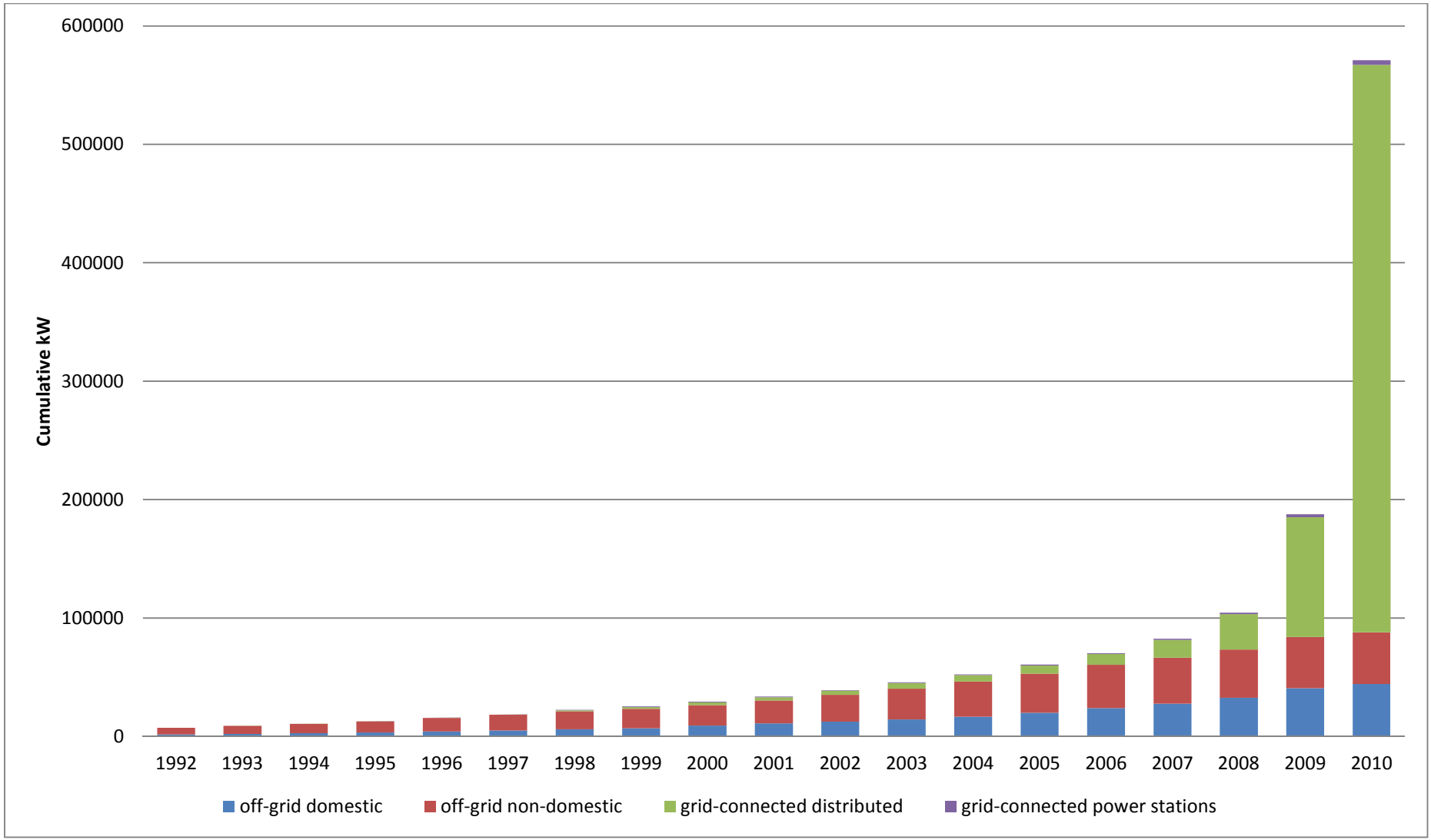


Figure 2: Cumulative PV Installations in Australia 1992 – 2010.

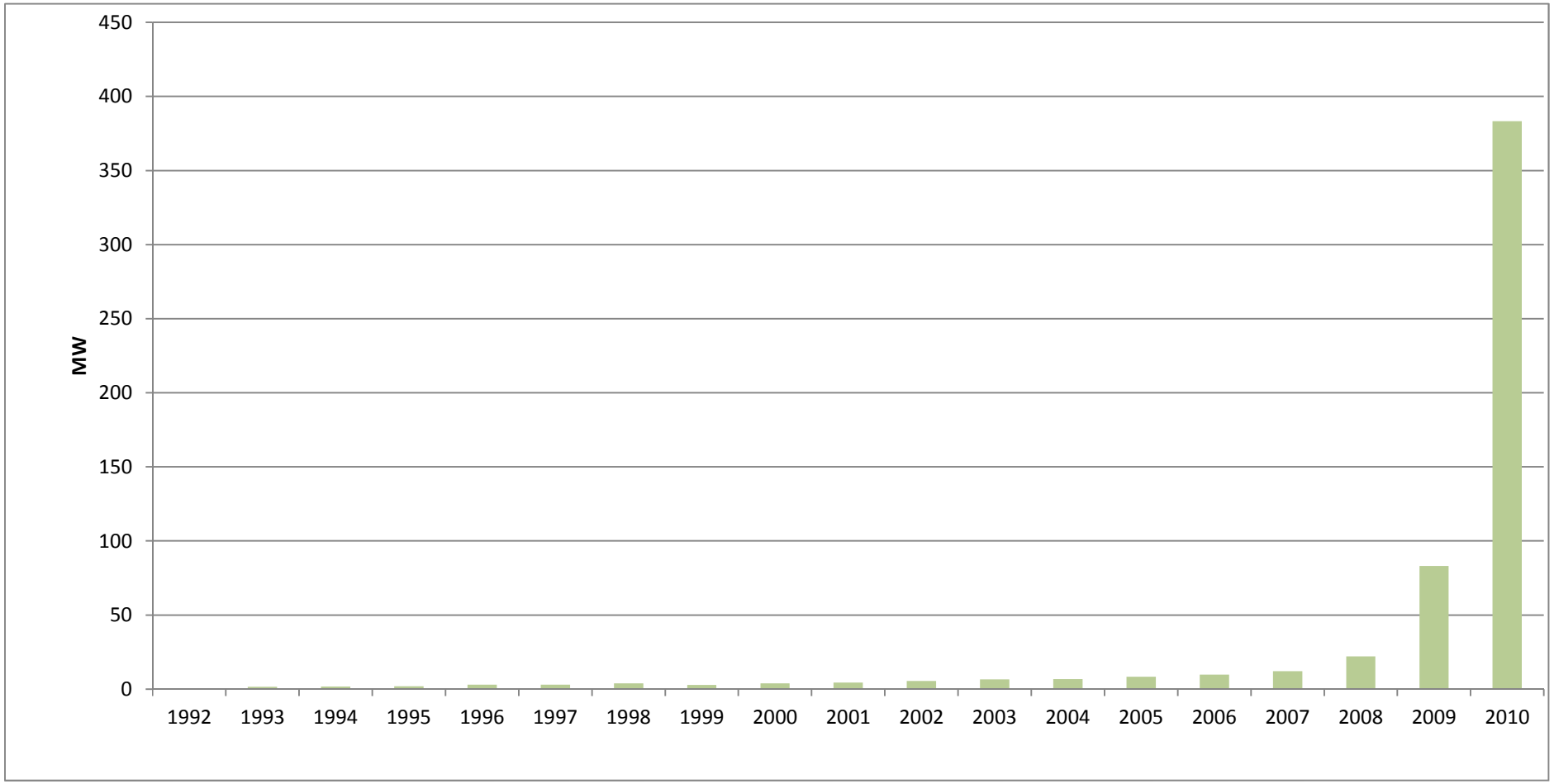


Figure 3: Annual PV Installations 1992-2010 (MWp)

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

Australian Government support programs impacted significantly on the PV market in 2010. Key programs are described below.

1.3.1 The Renewable Energy Target

In June 2010, the 45 000 GWh Renewable Energy Target (RET) was separated into two parts, to commence on 1 January 2011 – the Large–scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). The government expects that combined, the new LRET and SRES will deliver more renewable energy than the previous 45 000 gigawatt-hour target in 2020. Liable entities need to meet obligations under both the SRES and LRET by acquiring and surrendering renewable energy certificates created from both large and small–scale renewable energy technologies.

Large-scale Renewable Energy Target (LRET)

The LRET, covering large-scale renewable energy projects like wind farms, commercial-scale solar and geothermal, will deliver the majority of the 2020 target. The LRET includes legislated annual targets and operates much the same as the previous RET design. From 2011 to 2030, the annual targets for the LRET are set at 4 000 gigawatt-hours (GWh) per year less than the previous RET targets, reaching 41 000 GWh by 2020. However annual targets can be re-set based on SRES uptake, see below.

Small-scale Renewable Energy Scheme (SRES)

The SRES covers small generation units (small-scale solar photovoltaic, small wind turbines and micro hydroelectric systems) and solar water heaters, which can create small-scale technology certificates (STCs). The Renewable Energy Regulator has established a voluntary 'clearing house' as a central point for the transfer of STCs at AUD 40, and liable entities are required to surrender STCs four times a year. There will be no cap on the number of STCs that can be created.

The regulations establish an estimate each year for the number of STCs needed to be acquired by liable entities. The target is set to align with expected rates of STC creation based on historic rates, analysis of government support, and expert judgement. The government can change the solar credit multiplier as well as the clearing house price in order to control the rate of STC creation. Because of the large numbers of small-scale PV systems that were installed during 2010, there is a significant oversupply of STCs, with the result that they dropped to around AUD 25 in the secondary market and the Solar Multiplier will therefore be reduced earlier than planned in 2011.

Solar Credits

Solar Credits provide additional support to households, businesses and community groups that install small renewable energy generation units such as rooftop solar panels. Solar Credits apply to the first 1,5 kilowatts (kW) of capacity for systems connected to a main electricity grid and up to the first 20 kW of capacity for off-grid systems. Output from capacity above 1,5kWp is eligible for 1 STC per MWh.

Solar Credits work by multiplying the number of certificates that these systems would generally be eligible to create under the standard deeming arrangements – which are that for PV systems up to 100 kWp, 15 years' worth of STCs can be claimed up front. The multiplier can be changed by Government to influence demand for small-scale PV systems. The currently anticipated reduction in the multiplier, including changes announced for 2011, is shown in Table 4.

Table 4: Anticipated Reduction in Solar Credit Multipliers

Date installed	9 June 2009 – 30 June 2011	1 July 2011 - 30 June 2012	1 July 2012 - 30 June 2013	From 1 July 2013 onwards
Multiplier	5	3	2	No multiplier (1)

Thus the RET can provide valuable capital cost reductions for small PV systems. PV modules and inverters must meet Australian standards or specifications. This program builds on previous grant-based support schemes which together have seen a rapid increase in the number of PV businesses, training and accreditation.

1.3.2 Solar Homes and Communities Plan (SHCP)

The SHCP provided rebates of up to AUD 8 000 for 1 kWp of PV installed on residential buildings and up to 50% of the cost of PV systems up to 2 kW installed on community buildings. Rebates up to AUD 5 000 were available for system upgrades (at AUD 5/W), if no previous rebates had been received. To be eligible, a household's income had to be less than AUD 100 000 per year.

The SHCP operated on a two stage application process – a pre-approval application which allowed for an eligibility check before purchase and installation, followed by a rebate application after installation. Although the program ended on 9 June 2009, a very large number of pre-approval applications were received in the closing days, and installations under the program are still occurring in 2011. The final cost of the program is estimated to be in the order of AUD 1,1 billion.

This program had a significant impact on the PV market in Australia during 2010, with 69,7 MW of PV installed and grants of AUD 500,8 Million provided, resulting in systems costing AUD 695 million installed. The vast majority of this was for grid-connected installations, with only 8,95 kW off-grid installations. A total of 153,58 MW of PV had been installed under this program to end 2010.

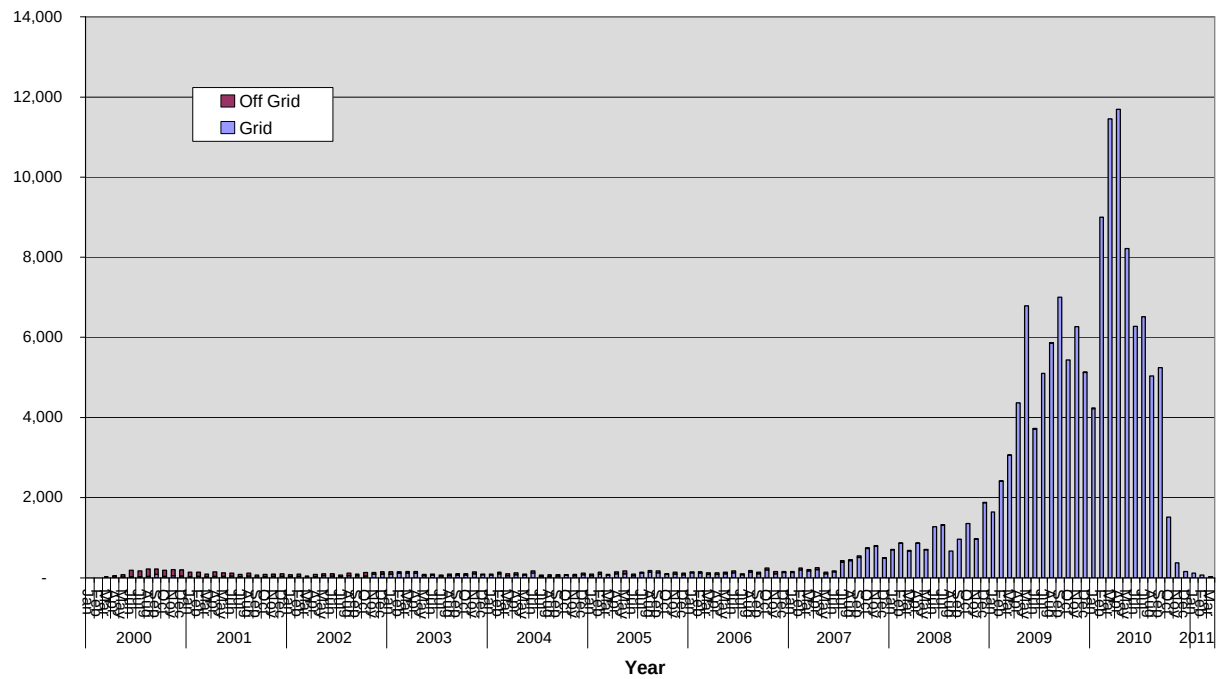


Figure 4 PV Installations under the Photovoltaic Rebate Program and the Solar Homes and Communities Program, 2000 to 2010.

1.3.3 State and Territory Feed-in Tariffs

A range of State based feed-in tariffs applied across Australia in 2010, as shown in Table 5. Note that these show the status of feed-in tariffs in 2010 and that all States have announced changes in 2011.

Table 5: Australian State and Territory Feed-in Tariffs in 2010

State	Start Date	Size Limits	Rate AUDc/kWh	Duration Years	Type	CAP	Eligibility
Victoria	1 Nov 2009	5 kW	60	15	Net	100MW	Residential, community, small business
South Australia	1 July 2008	10 kVA 1Ø 30 kVA 3Ø	44	20	Net	Review at 10MW	A facility that consumes less than 160MWh/yr
ACT	1 March 2009	≤ 30 kW	50,05c ≤ 10kW and 40,04c ≤ 30 kW, then 45,7c from 1 July 2010	20	Gross	15MW	Residential, business
Northern Territory (no longer available)	May 2008-2010 2010 on	AUD5 per day cap -	45,76c 19,23	20 -	Gross Net metering	AUD5/day	Alice Springs Solar City only NT wide
Queensland	1 July 2008	10 kVA 1Ø 30 kVA 3Ø	44	20	Net	Review at 8 MW	Consumers with less than 100MWh/yr
New South Wales (no longer available)	1 Jan 2010	10 kW	60 to Oct, then 20	7 yrs from start of scheme	Gross	300 MW	Residential
Western Australia	1 Aug 2010	5kW (city) 10kW 1Ø 30 kW 3Ø (country)	40 to 30 June 2011. 20 from 1 July 2011	10	Net	150MW	Residential

The changes that occurred in 2010 were:

- The ACT feed-in tariff for systems up to 30 kW decreased to AUD 0,457/kWh for systems installed as of the 1 July 2010.
- The New South Wales AUD 0,60/kWh gross feed-in tariff commenced on the 1 Jan 2010 (although system owners only received the tariff once appropriate meters had been installed), then dropped to AUD 0,20 from 27 Oct 2010.
- The Western Australian AUD 0,40/kWh net feed-in tariff commenced on the 1 Aug 2010. This feed-in tariff is paid in addition to the rate paid by retailers under the Renewable Energy Buyback Scheme.

The changes that will occur in 2011 are summarised in 3.1.2.

1.3.4 Solar Cities

All six of the seven Solar Cities with PV components to their projects installed PV systems in 2010. A total of 1 406 kW of residential PV systems and 739 kW of large scale "iconic" or commercial systems were installed under the program. Many cities are now entering the final reporting and analysis phase of their projects. Of particular interest will be the more successful methods used to engage the Solar Cities communities in the purchase of PV, the potential for PV generation to reduce peaks in demand, grid stability issues (if any) in areas of higher PV penetration, and the operational learnings from sourcing and installing this amount of PV in a community. In total AUD 17,4 million was provided by the Australian Government for the Solar Cities in 2010, with State and local governments, as well as energy utilities and business also proving funding. The following summarises the achievements in 2010.

Alice Solar City

In 2010 Alice Solar City (www.alicesolarcity.com.au) completed their residential installations program, reaching a total of 532 kW installed on approximately 300 households in Alice Springs. The majority of residents have installed 2 kW PV systems. Alice Solar City also installed a 235 kW concentrator tracking array at Alice Springs Airport in 2010. Support has been provided by the NT Government and the RRPGP.

Townsville Solar City

The electricity utility, Ergon Energy, continued to install PV systems on premises on Magnetic Island as part of the Townsville Queensland Solar City, (TSC - www.townsvillesolarcity.com.au). Participating residents in the TSC project volunteered their roof space to "host" Ergon owned and maintained panels for no financial gains to themselves, but to help reduce peak demand on the island and defer costly investment in an undersea power cable. In 2010, 240 kW of PV systems were installed on the island, bringing the total installed capacity to 494 kW.

Central Victoria Solar City

In 2010, Central Victoria Solar City (www.centralvictoriasolarcity.com.au) continued to offer power to householders generated at their two 300 kW solar parks installed in 2009 in Bendigo and Ballarat.

Blacktown Solar City

Located in the Western suburbs of Sydney, Blacktown Solar City (www.blacktownsolarcity.com.au) completed its residential PV element in 2010 with 114 kW's of PV installs during the year. This brought the total capacity of systems installed under the residential program to 474 kW.

Adelaide Solar City

Adelaide Solar City (www.adelaidesolarcity.com.au) installed 92 kW of PV on houses in 2010 and 73 kW through "Iconic" installations, including a 50 kW system at the new Keylink Industrial Estate at Edinburgh Parks.

Perth Solar City

The final Solar City to commence operations, Perth Solar City (www.perthsolarcity.com.au) has already overtaken the other cities for the number of PV installations completed under its program. In 2010 it installed 507 kW of residential PV and 229 kW of "Iconics" including 60 kW at Midland Railway Workshops, 48 kW at the Central Institute of Technology and 90 kW at the Perth Zoo.

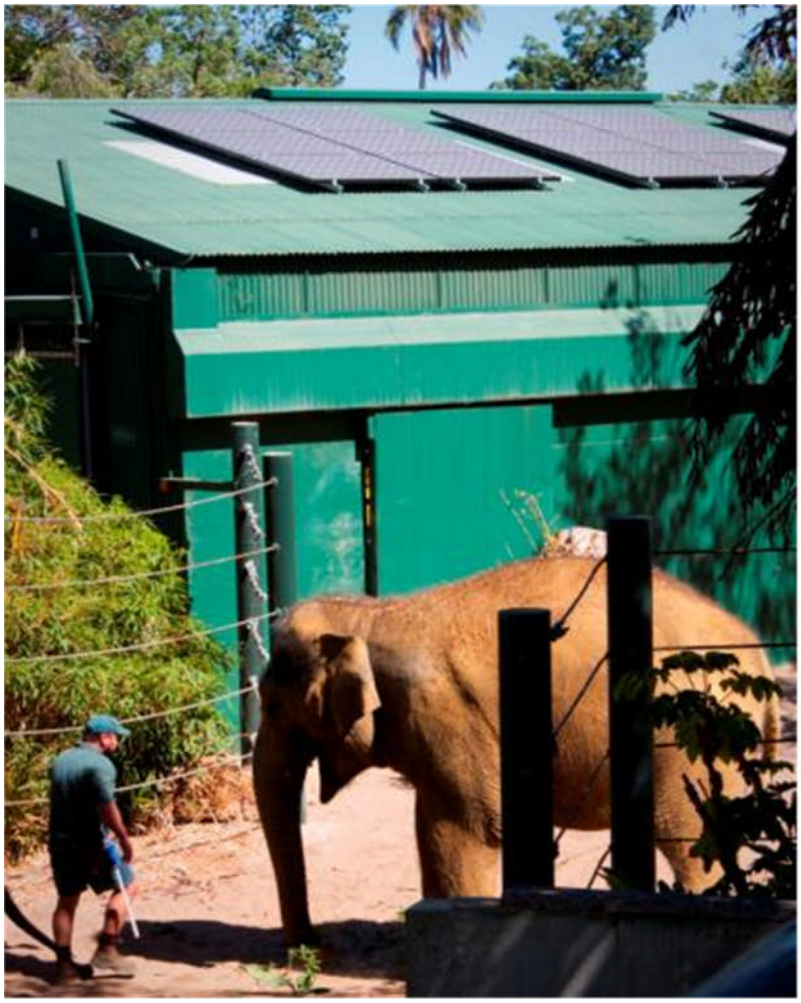


Figure 5: PV Array at Perth Zoo (Photo: Solar Cities)

1.3.5 Solar Schools

The Australian Government's National Solar Schools Program (NSSP) assists schools to take practical action in the fight against climate change. It offers eligible primary and secondary schools the opportunity to compete for grants of up to AUD 50 000 to install solar and other renewable power systems, solar hot water systems, rainwater tanks and a range of energy efficiency measures. Funding is capped in each financial year and annual funding rounds are held. Applications are assessed against three criteria – value for money, environmental benefit and educational benefit. This merit-based, competitive assessment process is used to determine which applications best meet these criteria and will be offered funding.

Schools across Australia have responded with great enthusiasm to the NSSP. Since the program commenced on 1 July 2008, over 7 000 schools have registered their interest to participate. By April 2011, more than AUD 128 million in funding had been paid to over 2 800 schools for PV and other measures, with almost 2 000 schools reporting that their installations were complete.

Figure 6: Portland Primary School (Photo: Heather Atchison)

Around 90 per cent of approved schools have chosen to install a PV system with their NSSP funding. In the 2010-11 funding round, over 1 200 schools have shared in AUD 51 million. Approximately 8,2 MW of PV and other eligible items will be installed. Over 2 000 applications were received in the 2010-11 funding round. Almost AUD 50 million in funding is available under the program for the remaining two rounds. In early 2011, it was announced that the program will be restricted and will end earlier than planned, on 30 June 2013.

1.3.6 Solar Flagships

In May 2009 the Australian Government announced a call for 1 GW of solar generation via 4 solar power stations (solar thermal and PV). The Solar Flagships program is split over two funding rounds with the first round to target 400MW of electricity generation.

The Department of Resources, Energy and Tourism received 52 proposals for funding in Round 1 of the Solar Flagships Program. From these proposals, the Solar Flagships Council recommended that the projects proposed by eight applicants be shortlisted for further assessment. These eight applicants include four applicants with PV projects: AGL, BP Solar, Infigen-Suntech and TRUenergy. All shortlisted applicants were eligible to claim up to $1.875 million for the preparation of feasibility and design studies to be submitted as part of their full applications on 15 December 2010. Seven of the eight shortlisted applicants submitted full applications on 15 December 2010; one applicant with a solar thermal project withdrew just before the closing date for full applications.

The Solar Flagships Council has undertaken a comprehensive assessment of the seven shortlisted projects and provided its report to the Government for consideration. The Government plans to announce the projects that will be offered funding in Round 1 of the Solar Flagships Program around the middle of 2011.

1.3.7 Bushlight

Bushlight (www.bushlight.org.au) is an Australian Government-funded national, non-profit project that installs renewable energy systems in remote Indigenous communities (known as homelands) throughout central and northern Australia. Each system installation is preceded by, and carried out in conjunction with, a comprehensive program of community engagement, education and training. Bushlight is mainly funded by the Australian Government through the Department of Families, Housing, Community Services and Indigenous Affairs, and the Department of Climate Change and Energy Efficiency. It also receives funding from a range of other sources, including fee-for-service work for discrete projects.

In 2010, Bushlight installed 9 new renewable energy systems, with a combined total output of 121,6kWp of PV. Bushlight upgraded one system with an additional 2.7kWp. The total installed capacity is 124.3kWp. Bushlight's maintenance program provided ongoing support 265 renewable energy systems, located in 220 communities during 2010.

1.3.8 Renewable Remote Power Generation Program (RRPGP)

RRPGP provided rebates of up to 50% of the capital cost of renewable energy and related components used for diesel displacement in stand-alone power systems. Typical applications included off-grid households, indigenous communities, community organisations, retail/roadhouses, tourism sites, pastoral stations and other off-grid business and government facilities. Components eligible for the rebate included renewable generation equipment, inverters, battery banks, enclosures, other supporting equipment and installations costs. For water pumping, only the renewable energy components were eligible (not pumps, pipe, concrete footings etc). Stand-alone power systems varied from 100% renewable to less than 50% renewable, with the diesel generator providing the majority of the load. Some systems included both PV and wind. System upgrades were also funded.

In 2010 a total of 3 378 kWp of PV was installed in remote areas of Australia under the RRPGP. This includes 500 kWp of tracking PV at Nullagine and Marble Bar in Western Australia and 235 kWp of concentrating solar at Alice Springs Airport. In addition there was 36,9 kW of wind installed. A total of AUD 22,1 Million was provided in rebates.

Galaxy Resources has been funded for AUD446 250 under the Western Australian component of the RRPGP to install 100 kW of wind and tracking solar generation capacity at its Mt Cattlin lithium mine, near Ravensthorpe. Galaxy is the first miner to use solar tracking technology, which can boost power output by up to 15%.

The RRPGP program has now closed.

1.3.9 Northern Territory PV Programs

Alice Solar City **capital subsidies for residential and commercial PV**: The Northern Territory Government is providing funding of AUD3,49 million to the Alice Solar City project. The Residential and Commercial programs administered under the project provide capital subsidies to participants for the installation of PV as one of a suite of measures.

Solar Champions: The Northern Territory Government is providing AUD230 000 for the supply and installation of solar photovoltaic panels for up to five not-for-profit, non-government-organisations in regional and urban centres of the Territory to demonstrate innovations in solar power.

PV for the Arts: The Northern Territory government funding of AUD1.138 million will be provided for the supply and installation of a PV system for the Araluen Arts Centre. The Northern Territory government has also provided AUD12 000 for installation of a PV system at the Red Hot Arts centre.

Alice Springs Solar City **enhanced feed-in tariff**: Where participants install solar PV and sign up to cost reflective tariff arrangements they receive an AUD 0,5128/kWh feed-in tariff.

Net metering: Under current arrangements (excluding Alice Springs Solar city participants as per enhanced feed-in tariff above), all the electricity generated is sold to Power Water Corporation at AUD 0,1923/kWh (this is equivalent to the standard tariff rate for consumption).

Research and Development: The Northern Territory Government provided land for the development of the solar centre that is part of the Desert Knowledge precinct in Alice Springs. The Solar Centre is a resource for the rapidly expanding solar industry in Central Australia and provides the industry with long-term system level data. It promotes understanding and confidence in solar technologies, and helps prove the reliability of solar generators in an Australian context.

1.3.10 Queensland PV Initiatives

Hervey Bay Solar Farm: The Queensland Government is investing around AUD 2 million to build a PV solar farm in Hervey Bay. The government has partnered with Wide Bay Water Corporation (WBWC), a Fraser Coast Council owned water utility, to build the solar farm at an arboretum (tree park) being developed by WBWC. The electricity generated by the solar farm will offset the power used in water and wastewater treatment in Hervey Bay and the arboretum project. It is estimated the solar farm will be greater than 350kW in size.

Hervey Bay Queensland Health Solar System: The Queensland Government is also investing up to AUD 2 million to install a solar power system at Hervey Bay Hospital. The electricity produced by the solar system will be used within the hospital helping reduce its electricity bill and demonstrate the benefits of PV to Queensland's businesses that consume large amounts of energy.

The Solar Sport and Community Grant Initiative: The Gambling Community Benefit Fund (GCBF) is Queensland's largest one-off grants program, distributing approximately AUD 39 million per year. The Solar Sport and Community Group Grant program prioritises AUD 10 million over three years from the GCBF to fund the purchase of solar items. Community and sporting organisations can apply for funding to purchase a 1,5kW solar power system, a solar (or heat pump) hot water system or both.

The AUD 5,8 million **Solar Kindergartens program** will install 1,5 kW solar power systems in up to 420 kindergartens over four years.

As part of the Queensland Government's *Toward Q2* early childhood education initiative, up to 240 new Queensland kindergarten services are planned across the State in areas of need. The objective is to install a roof-top solar panel system, as appropriate, at each of these sites. In addition, the AUD 5.8 million includes a competitive funding round of AUD 2 million that will enable solar power to be installed on up to 180 existing not-for-profit community kindergartens.

The Queensland Government is developing a **solar atlas** - a comprehensive and up-to-date map of solar energy to help identify the best potential sites to develop large-scale commercial solar energy plants. The Atlas will also include information such as electricity and natural gas transmission infrastructure, land and water resources and meteorological information. The Solar Atlas will be a valuable tool for industry and companies looking to invest in solar power projects in Queensland.

Solar Stadium: Queensland's redeveloped Carrara Stadium on the Gold Coast is the first in Australia to integrate solar power into its design, creating a solar stadium (See Figure 12). The Queensland Government invested AUD 4,4 million to build a solar roof on the new AUD

142 million facility. The 200kW solar roof consists of high-efficiency solar panels that are five meters deep and are positioned on the inner edge of the roof, delivering around 20 per cent of the stadium's annual energy use.

Cloncurry Solar Farm: Cloncurry in northwest Queensland is blessed with some of the best solar resources in the state and the Queensland Government is investing AUD 5,7 million to build a solar farm in the region. The government has opened a Request for Proposal to market looking for joint private sector investment to build, own and operate a one megawatt plus PV solar farm in Cloncurry Shire. Dependent on the location of the facility, energy produced by the solar farm could be fed into Ergon Energy's Mount Isa-Cloncurry electricity network that supplies Cloncurry. The solar farm will provide valuable insights to the benefits of solar power in Queensland's remote and off-grid regions.

Further details of the Queensland Government's solar initiatives are available at website www.brightthing.energy.qld.gov.au.

1.3.11 South Australian PV Programs

The South Australian **Renewable Energy Fund** was open for applications in 2010. It is aimed at supporting investment in renewable energy in SA. No funding was provided to PV solar projects in 2010. More information is available from:
http://www.renewablessa.sa.gov.au/files/110308-grants-policies-and-procedures.pdf

Figure 7: 112kW First Solar PV arrays on Monash University (Photo: First Solar)

SA introduced a **Payroll Tax Rebate** for the on-site labour of renewable energy projects. The Rebate commenced on 1 July 2010 and will continue to 30 June 2014. The rebate available for solar is up to AUD5 million. For details see:
http://www.renewablessa.sa.gov.au/files/2009dec16_payroll_tax.pdf

Grants: In December, the Premier announced that AUD1 million will be available from 2011 for grants to community owned and run solar farms. A grant of AUD100 000 was made to Solar Shop and HydraGate for the development of an affordable solar tracking unit.
http://www.renewablessa.sa.gov.au/files/cancun-end-release-(2).pdf

1.3.12 Tasmanian PV Programs

The Tasmanian **Renewable Energy Loan Scheme** (RELS) will assist eligible businesses to purchase and install renewable energy generation facilities or manufacture renewable energy technology in Tasmania.

The loan scheme includes low-interest loans under the AUD30 million Renewable Energy Loan Fund announced in the 2010-11 Tasmanian State Budget and associated top-up grants (capped at AUD 100 000) to assist with the commercial viability of eligible projects. The scheme will be open until 30 June 2014 and is subject to an annual review.

1.3.13 Victorian Government Solar Hubs Program

The Victorian Government has supported five communities across regional Victoria to carry out solar PV bulk buys. With nearly AUD2,2 million in funding support from the government, 8.45MW of community-based solar power is to be installed by January 2013 across 19 Victorian municipalities. The bulk buys, being run by local governments and community groups in the Bendigo and Mt Alexander region, south-west Gippsland, Shepparton area, Mildura, and north east Victoria, aim to install solar PV systems on residential, local government and commercial buildings. Once installed, the PV systems are likely to generate in excess of 12 GWh of energy per annum and result in the avoidance of over 250 000 tonnes of greenhouse gases over the life of the systems. Additionally, the bulk buys will contribute directly to the strengthening of the renewable energy sector in regional Victoria through dedicated use of local installers for PV systems.

1.3.14 Western Australian PV Programs

The **Renewable Energy Buy-back Scheme** (REBS) operates in Western Australia, and under this scheme, PV systems are paid a tariff in addition to the relevant feed-in tariff for electricity exported to the grid. The details of the scheme differ between retailers. Horizon Power allow systems up to 10 kW (single phase) and 30 kW (three phase) and pay the relevant retail tariff minus GST (unless the system owner is registered for GST, in which case it is not deducted). Synergy only allows systems up to 5 kW (single phase) and only pay AUD 0,7/kWh, unless the system owner is an educational or not-for-profit organisation, in which case the relevant retail tariff applies.

The **WA Feed-in Tariff** is paid through consolidated revenue – AUD 114,4 million over next 4 years and AUD 127 million in total.

Demonstration: The Western Australian Government has provided AUD 20 million to Verve Energy to demonstrate utility-scale solar photovoltaic generation in the State's Mid West Region

Solar Schools: Approximately 141kWp of PV has been installed under the WA Government's AUD 6,5 million Solar Schools program

1.4 Highlights of R&D

The following provides a brief overview of selected R&D activities in 2010. Most Australian universities now undertake some type of PV research, whether technical, economic or social, however, not all are reported on below.

1.4.1 The Australian Solar Institute (ASI)

The ASI is an AUD 150 million commitment from the Australian Government's Clean Energy Initiative to keep Australia at the forefront of solar research and development. Its primary role is to invest in research & development projects that will accelerate innovation in

photovoltaic and concentrating solar thermal technologies, which have the potential to significantly reduce the cost of solar energy compared to other existing energy sources. The ASI is committed to skills development, knowledge building, retaining local expertise and strengthening collaboration between Australian and international solar research and industry expertise.

In 2010 the ASI announced AUD 43 million for PV research and development projects and awarded PhD scholarships and post-doctoral fellowships to six students in PV research at Australian institutions as part of its inaugural Skills Development program. As part of its knowledge and capacity building efforts, the ASI established initiatives with similar entities in other countries including a Memorandum of Understanding with the Fraunhofer Institute in Germany, a leading European PV research body. In late 2010, the United States - Australia Solar Energy Collaboration was established to drive collaboration between Australian and US participants through research scholarships, laboratory exchanges, and information exchange on R&D as well as funding for joint research projects. The ASI is managing the Australian Government's AUD 50 million contribution to the initiative.

1.4.2 The Australian Centre for Renewable Energy (ACRE)

ACRE was established in 2010 with the aims of delivering programs and providing relevant policy advice to move promising renewable energy technologies, products and services through their innovation cycles to commercial competitiveness nationally and internationally for the benefit of Australia.

It has two complementary roles:

- to develop Australian technology and ventures by exploiting identified opportunities in national or global markets, through venture capital and funding of strategic R&D; and
- to develop Australian renewable energy resources by leveraging the best available technology, finance and management capacity to lower the costs of commercial deployment of renewable energy in Australia, through support for piloting, demonstration and early stage commercialisation.

For PV, ACRE's priority will be on enabling technologies, including storage, grid connection technologies and hybrid systems.

1.4.3 Australian National University

PV research at ANU involves a group of 60 researchers, research students and support staff who undertake work in the areas of photovoltaic solar cells, solar thermal and combined heat and power systems. The Centre for Sustainable Energy Systems (CSES: http://.cses.anu.edu.au) at ANU was founded in 1991, and is one of the largest and longest established solar energy research groups in Australia. ANU is a core member of the ASI and in 2010 the Centre benefited from an AUD 5 million ASI foundation grant to greatly extend and enhance their research facilities. Work also commenced on the following projects funded by the ASI and commercial partners:

- Advanced Sliver Solar Cells
- Next Generation Sliver Solar Cells
- Plasmon solar cells

Work in CSES spans the range from basic R&D through to technology commercialisation. Current grants and contracts total AUD 30 million. CSES works with Government and with private companies. Commercialisation of SLIVER solar cells and roof-top hybrid PV/thermal concentrators are in progress.

Research activities include defect detection and surface passivation in silicon wafers; high performance silicon solar cells, including SLIVER solar cells; modelling; plasmons and nano PV technology; PV modules, hybrid PV/thermal parabolic trough concentrator systems; and solar cooling. The research conducted at the state-of-the-art fabrication laboratory spans the spectrum from the fundamental to the applied. The research is supported by extensive PV testing and characterisation facilities.

Funding support for CSES comes from the Australian Research Council, the Australian Solar Institute, the Defence Department, the Asia Pacific Partnership program, DIISR, private companies and several other sources.

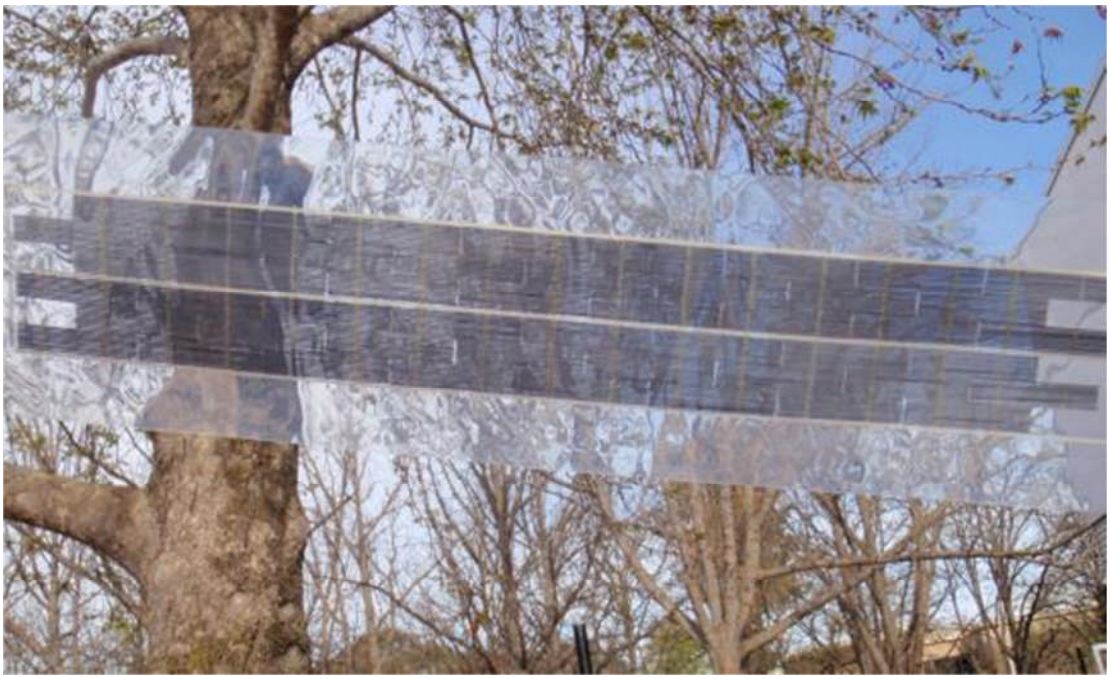


Figure 8: SLIVER bifacial flexible lightweight solar module

1.4.4 Murdoch University.

The PV devices group at Murdoch University is continuing its research on new device designs based on amorphous and nanocrystalline silicon. Current projects are focussed on the incorporation of quantum dots and silicon nanowires into thin film solar cells with the aim of producing stable, low-cost devices. Some work is underway on new testing procedures for prototype devices.

At the end of 2010, Murdoch University received a grant from the WA Office of Energy to undertake measurements on PV arrays which had been installed as part of the RRPGP rebate program. This project will be undertaken in 2011 and will involve measuring the IV characteristics of a number of PV arrays in the field to try and determine the level, if any, of degradation in the performance of these arrays.

With support from the WA Department of Education, Murdoch University will continue its research activities in the area of safety in grid-connected PV installations and will conduct a PV safety audit in early 2011 of 20 PV systems installed as part of the National Solar Schools Program in WA schools.

1.4.5 The University of Queensland (UQ)

UQ has a broad portfolio of solar PV research, the main components of which are as follows:

Next Generation Organic Solar Cells (Professor Paul Meredith and Professor Paul Burn, Centre for Organic Photonics and Electronics - COPE): This large program with ~ 15 research students and staff focuses on several elements of next generation organic solar cell development including new acceptor / donor materials, fundamental understanding of basic physical and chemical processes in OPV, new architectures to break through the single junction Shockley-Queisser limit (multiple and structured junction approaches), new transparent conducting electrodes and architectures for large area devices. The program is funded by three separate grants from the Australian Solar Institute, the Australian Research Council and the Queensland Government (National and International Research Alliances Program). The COPE group were also part of the International Organic Solar Cell Alliance led by Professor Andrew Holmes from the University of Melbourne and funded by the Federal Government (DIISR International Science Linkages). Key collaborators for the COPE program are the CSIRO in Australia, James Cook University, SolarSells Pty Ltd, Imperial College London and The National Renewable Energy Laboratory in the USA.

The UQ 1.22MW Array (Professor Paul Meredith, Professor Tapan Saha, Mr Craig Froome, Professor John Foster, University of Queensland Properties & Facilities, The University of Queensland Renewable Energy Technology Advisory Committee): UQ is building Australia's largest flat panel PV array at the Brisbane St Lucia Campus. It will cover 4 roofs and will also contain an 8kW SolFocus CPV 2-axis tracking array. The array installation was started in 2010 and will be complete by mid-2011. It will house a number of major experiments including: new inverter technology trials; smart-modules with integrated mpp tracking; a 400kW h Zn-Br commercial-industrial scale storage battery trial; new solar coatings; power quality and yield analysis. The project not only provides UQ with ~ 5% of its peak power consumption but is a flexible test bed for experiments aimed at understanding how to deploy and optimize MW-scale PV arrays in an urban grid environment. Furthermore, the array will be integrated into UQ teaching programs and provides a powerful vehicle for public engagement in solar PV. To this end, the array output will be fully monitored and the information made available to schools, government, industry and the general public through a dedicated web interface. Viewing platforms and a public visitor centre will also be constructed to facilitate this engagement. The project involves major research groups across UQ with external partners Trina Solar, Ingenero, Redflow, Energex and AUD 1,5 million from the Queensland State Government.

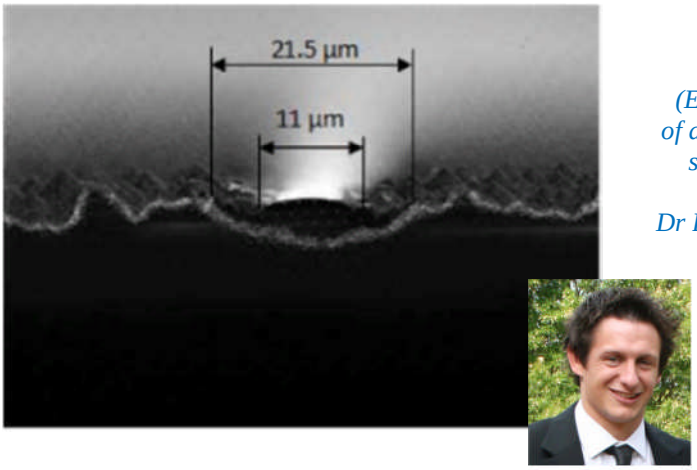
Power Systems and Network Engineering (Professor Tapan Saha)*:* UQ has a large and internationally respected effort on power systems with particular emphasis on embedded and distributed solar PV energy, adaptive and smart grids, frequency and voltage stability and new inverter technologies. This work is funded by the Australian Research Council (Linkage Program) and national and international energy companies and utilities. The UQ Power Systems group is also part of the national i-Grid effort led by CSIRO. Key collaborators include Ergon, Energex, Powerlink and an array of national and international power companies.

Energy Economics (Professor John Foster): The UQ Energy Economics group is focussed on understanding the value and impact of solar power generation (particularly distributed PV) in the Australian grid and electricity market (NEM). In particular, its work focuses on the impact of supply stability and pricing in the context of carbon pricing. The work is funded by the Australian Research Council through the Linkage Program and the National i-Grid Initiative led by CSIRO. Key collaborators include AGL.

1.4.6 University of New South Wales (UNSW)

Cell Efficiencies

A new solar cell efficiency record of 19.3% has been set by UNSW researchers for a large area (157 cm^2) laser doped, selective emitter (LDSE) cell using cells largely processed on a standard Centrotherm screen-printing production line. With further optimisation of the cell design, the laser doped solar cell is expected to become the first low-cost cell capable of energy conversion efficiency above 20% to enter full-scale production.



An electron beam induced current (EBIC) image of the laser doped region of a LDSE solar cell superimposed upon a scanning electron micrograph (SEM) of the same region. The inset shows Dr Brett Hallam, a key member of the team producing the new result.

The UNSW Pluto technology is now in commercial production by Chinese/Australian PV manufacturer Suntech, which uses a low cost approach to fabricate 17% efficient modules.

ASI Grants

The University of NSW is a Core Institution of the ASI and has also received a number of competitive research grants from the ASI in 2010:

- Development and Commercialisation of High Efficiency Silicon Solar Cell Technology. AUD 3,972 million funding from ASI as core funding to support an AUD 12,75million project.
- Overcoming the Fundamental Performance Limitations of Commercial Solar Cells, with industry partners Suntech Power and Silex Solar. ASI funding AUD5.0m, total project value AUD 24,156 million. The project aims to significantly build on the UNSW Laser Doped Selective Emitter (LDSE) process by addressing the remaining major source of cell performance limitation – recombination of photo-generated current carriers at the rear surface. The NSW Government is providing an additional AUD 500 000 through its Science Leveraging Fund to support an extension to this project for research towards a 26% efficient silicon solar cell.
- Forecasting and Characterising Grid Connected Solar Energy and Developing Synergies with Wind, with project partners University of South Australia, APVA, Epuron and the Bureau of Meteorology. ASI Funding: AUD 470 284; Project value: AUD 832 537. This project combines forecasting with strategies to manage high levels of solar and wind penetration. The value of the energy technology to the National Electricity Market will be improved by forecasting, which in turn will lead to improved cost effectiveness within the timeframe of the project.

New Photovoltaic Buildings:

During 2010, construction began on two new buildings on the UNSW Kensington campus destined for the Centre's future use.

The first of these is the Solar Industrial Research Facility (SIRF) on the upper campus, due to be completed in mid-2011. This impressive, stylish building will house a full-scale, state-of-the-art solar cell production line, although not with the level of automation required for commercial throughputs. A special area is also set aside for applying new processing steps to cells otherwise processed on the main line. The SIRF facility will be used to demonstrate the next generation of the Centre's wafer-based technology at large scale, accelerating the transfer of this technology into production and increasing the scope and effectiveness of licensing to the rapidly growing industry. The facility will also play a key role in Centre research and in the training of Centre students as well as, via short courses, the huge numbers of external engineers and technicians entering this industry.

The second new Centre building is the Tyree Energy Technology Building (ETB) being purpose-built on the lower campus to house the Centre's main laboratories. The new AUD 155 million building is supported by Sir William Tyree as well as by a grant of AUD 75 million from the Australian Government's Education Investment Fund. Co-located in the building will be other UNSW energy-related activities such as the Centre for Energy Research and Policy Analysis.

1.4.7 Commonwealth Scientific and Industrial Research Organisation (CSIRO)

National Solar Energy Centre

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Energy Centre in Newcastle is home to the National Solar Energy Centre, a suite of research capability in both solar thermal and photovoltaics technology that includes a team of 30 specialist scientists and engineers. CSIRO conducts projects aligned with Australia's national research priorities and engages with government, universities and industry in both co-investment and fee-for-service arrangements.

Major projects

For major projects, CSIRO draws on expertise across the organisation. As part of the Victorian Organic Solar Cell Consortium, CSIRO's Flexible Electronics Team are working to develop new materials and processes to enable high throughput, low cost, reel-to-reel printable solar cells. Other major engagements in photovoltaics include Dyesol and the University of Newcastle.

Performance evaluation

Development is also underway for an integrated photovoltaics performance facility. The facility will provide an ISO17025-accredited measurement laboratory for qualified measurement of the efficiency of research-scale photovoltaic devices to international standards. It will also include infrastructure for long-term outdoor evaluation of photovoltaic technologies, including independent assessment of the durability and annual energy yield, critical factors for determining the true value of any new development in photovoltaics.

PV integration

CSIRO opened a new AUD 2 million Renewable Energy Integration facility in 2010; an experimental facility specifically designed to study the integration of renewable energy generation sources and energy storage into electricity grids. This project is already generating results showing challenges around large numbers of inverters operating in the grid, and working to develop control solutions to address these challenges.

CSIRO was successful in securing a project with the Australian Solar Institute investigating the impact of high-penetration solar generation on Australia's distribution grids. This project will include a survey of relevant research around the world and how this is applicable to Australia, as well as the development of models aimed at helping predict the impact of high penetration PV operation in particular types of grid.

Figure 9: CSIRO Renewable Energy Integration Facility opening, showing the research team at the opening ceremony (Photo: CSIRO)

1.4.8 Victorian Organic Solar Cell Consortium (VICOSC)

The Victorian Organic Solar Cell Consortium (VICOSC) was established in 2007 and brings together over 40 researchers from the University of Melbourne, Monash University and CSIRO's Future Manufacturing Flagship. The consortium is developing new technologies for roll-to-roll printing of both bulk heterojunction and dye-sensitised solar cells. The consortium's industrial partners are BlueScope Steel, Securency, Innovia Films and Robert Bosch SE Asia. The consortium has obtained funding from the Victorian Government's Victoria's Science Agenda, the Victorian Department of Business and Innovation and the Australian Solar Institute.

The consortium is working on the advanced materials and platform technologies needed for the development of a sustainable organic and large-area electronics capability in Australia. Specifically, the project will deliver new materials and device architectures that promise to enhance the overall efficiency and durability of printed solar cells. This will be enabled by a rapid feedback loop to ensure the new materials are rapidly optimised and matched to new device architectures. This project will help to de-risk the technology allowing the project partners to make a decision on the timing of carrying the technology forward to pilot plant scale. The consortium has a strong focus on developing existing printing techniques to manufacture the next generation of thin-film solar cells.

Recently, scientists from the consortium led Australia's involvement in the first ever international study of the outdoor performance of Organic Photovoltaic devices. Testing was conducted at 27 laboratories around the world. CSIRO's laboratories in both Newcastle and Melbourne were the only labs in the southern hemisphere to participate in the study.

Figure 10: Printing the active layer of a bulk heterojunction (BHJ) solar cell (P3HT supplied by Merck) on the Securency proofing press (Photo: CSIRO)

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

Table 6 and **Figure 11** give values for the year on budgets from the public authorities for R&D, demonstration/field test programmes and market incentives (public subsidies, fiscal incentives). Much of this support is matched by private investment. Further support is provided by local governments.

Table 6: Public budgets for PV R&D, demonstration/field test programmes and market incentives in Australia in 2010 (AUD Million).

	R & D	Demo/Field test	Market incentives
National	61,9	5,5	521,8
State/Territory	0,9	38,6	12,6
Total	641,35		

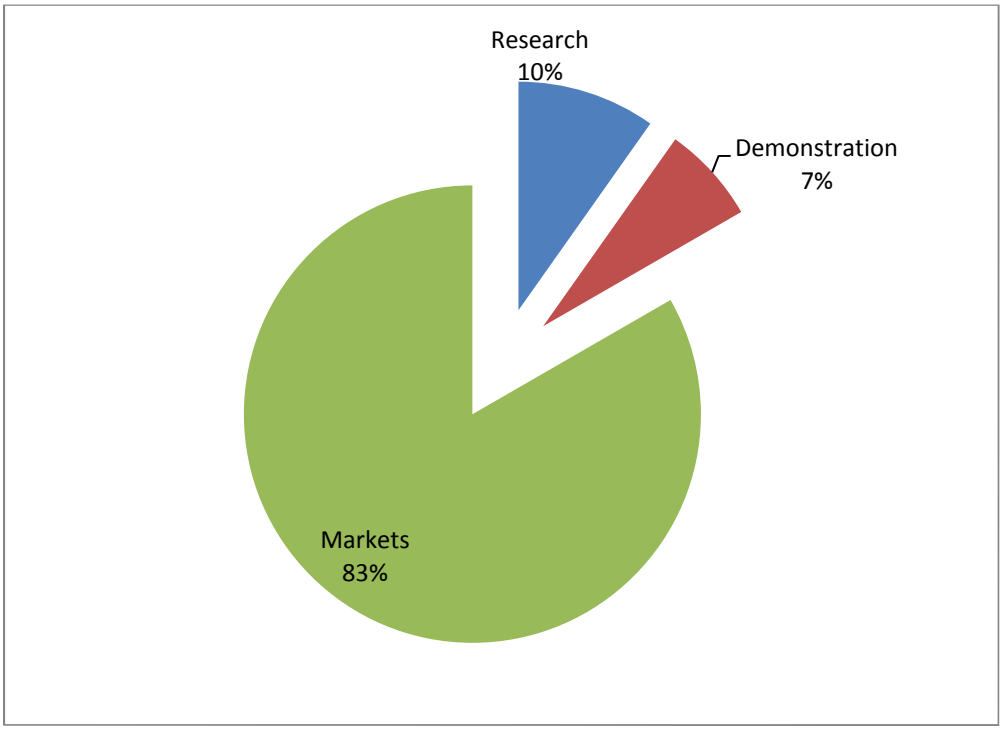


Figure 11: Allocation of Australian Commonwealth and State Government Budgets for PV R&D, Demonstration and Market Development in 2010.

2 INDUSTRY AND GROWTH

2.1 Production of photovoltaic cells and modules

Australia has only one commercial-scale flat-plate cell and module manufacturer, Silex Solar, with a second module manufacturer preparing to begin production in 2011.

Another Australian company, Solar Systems from Melbourne, is manufacturing Concentrating PV, capable of producing the CPV module and receiver in-house. The concentrating factor is 500 suns and the company imports the III/V multi-junction cells from various suppliers.

Total PV cell and module manufacture together with production capacity information in 2010 is summarised in Table 7 below.

Table 7: Australian PV production and production capacity information for 2010

Cell/Module manufacturer	Technology	Total Production (MW)		Maximum production capacity (MW/yr)	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Silex Solar	Mono-Si	8	8	50	35
Cells for Concentration					
Solar Systems	CPV (III/V)	0	0.05 (trial)	0	3

2.1.1 Local manufacture

Silex Solar produces its own cells and modules using imported wafers.

Solar Systems produces the CPV modules using imported III/V multi-junction cells from various suppliers.

2.1.2 Exports

With high local demand, exports from Australia were limited in 2010. Approximately 20 kW of cells and 200 kW of modules were exported, the latter typically as part of systems installed in the Pacific region.

2.2 Module prices

Table 8 summarises typical module prices in Australia during 2010. It should be noted that prices changed during the year and the range of prices on offer increased.

Table 8: Typical module prices in Australia (Current AUD/Wp)

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Typical module price	9	7	8	8	7	8	8	8	8	7	7	8	8	8,5	8	8	6	3,2
Best price														7,5	7	5	3	2,0

2.3 Manufacturers and suppliers of other components

Balance of system (BOS) component manufacture and supply is an important part of the PV system value chain and is accounting for an increasing portion of system costs as PV module prices fall. The following summarises some of the developments in BOS components during 2010:

2.3.1 PV inverters

PV inverters for both grid and off-grid applications are manufactured in Australia, especially to suit Australian conditions, particularly heat, dust, humidity and vermin. However, most of inverters used in 2010 were imported. Inverter shortages world-wide caused installation delays for many systems during 2010.

While residential grid-connected systems continued to dominate the market in 2010, system sizes have been increasing, in part because of the transition from rebates capped to 1kWp to the Solar Credit multiplier capped at 1,5kWp, but also because of reduced system prices. This has resulted in increased use of larger inverters. Typical retail prices are AUD 1,10 per kW for 1,5kW inverters, falling to AUD 1 per kW for 2 and 3 kW and to 0,8 per kW for 5 kW.

With Australian policy settings favouring 1.5kW systems, both Chinese and German inverter manufacturers now offer 1,5kW-focussed inverters in the Australian market.

2.3.1 Storage batteries

Most off-grid PV systems use lead-acid batteries. Zinc Bromine flow batteries, manufactured in Australia, continue to be used for trial applications with PV systems and for demand management.

2.3.2 Battery charge controllers and DC switchgear

Battery charge controllers and both AC and DC switchgear are manufactured in Australia.

2.3.3 Supporting structures

A range of support structures are manufactured in Australia, especially for off-grid stand-alone applications, including water pumping, but also for grid systems.

2.4 System prices

Table 9 shows indicative turnkey prices (excluding GST) per W for the 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.

Additional information showing national trends in the turnkey prices of selected applications is provided in Table 10 and Table 11.

Table 9: Turnkey Prices of Typical PV Applications in Australia in 2010

Category/Size	Typical applications and brief details	Current prices per W (AUD)
OFF-GRID Up to 1 kW	Remote homes, water pumps, lights	6-15
OFF-GRID >1 kW	Telecommunications, pastoral/mining power systems	7-20
ON-GRID Specific case	1-3 kW roof-mounted systems	5-7
ON-GRID up to 10 kW	Larger roof mounted systems on homes, public buildings	6-7
ON-GRID >10 kW	Larger roof mounted systems on public and commercial buildings	6-7
GRID – CONNECTED (centralized, if relevant)	Larger roof mounted systems on commercial buildings.	7-9

Table 10: Australian trends in typical system prices (current AUD excluding GST) for off-grid applications up to 5 kWp

YEAR	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
AUD /Wp:	24		22		30	30	30	22	22	20	20	20	20	22	22	22	20	12

Table 11: Australian trends in typical system prices (current AUD, excluding GST) for grid applications up to 5 kWp

YEAR	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
AUD /Wp:	11	12	12	14	14	13	10	12	12	12,5	12	12	9	6

2.5 Labour places

Table 12 shows PV-related employment in Australia during 2010. There has been a large increase in accredited installers over the past 2 years, as the grid connect market has grown rapidly. Along with this, especially as interest has grown in the potential for development of a larger-scale system market, has been an increase in consulting, legal and financial sector interest in PV. With the major government support mechanism now operating through the renewable energy certificate (REC) market, there has also been an increase in numbers of REC traders and market analysts covering PV.

Table 12: Estimated PV-related labour places in Australia, 2010

Research and development (not including companies)	300
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	300
Distributors of PV products	600
System and installation companies	6 000
Electricity utility businesses and government	200
Other (financial, legal, market analysts, consultants, REC traders, education and training etc.)	2 000
Total	9 400

2.6 Business value

Table 13 provides an estimate of the value of PV business in Australia in 2010.

Table 13: Value of PV business in Australia 2010 (AUD Million)

Sub-market	**Capacity installed *in 2010* (kW)**	**Price per W**	**Value AUD million**	**Totals**
Off-grid domestic	3 465	10	35	
Off-grid non-domestic	431	15	6	
Grid-connected distributed	378 128	6.5	2 269	
Grid-connected centralized	1 265	8	10	
				2 320
Export of PV products				*2*
Import of PV products				*-1055*
Value of PV business				***1 267***

3 FRAMEWORK FOR DEPLOYMENT (NON-TECHNICAL FACTORS)

Table 14 lists the main support measures for PV during 2010. Definitions are provided in the Definitions, Symbols and Abbreviations section at the beginning of this report. Further details on some of these follow.

Table 14: PV support measures in 2010

	On-going measures	Measures that commenced during 2010
Enhanced feed-in tariffs (gross / net?)	SA: AUD 0,44/kWh net Qld; AUD 0,44/kWh net Alice Springs Solar City: AUD 0,45/kWh gross ACT: AUD 0,5005/kWh then AUD 0,457 from 1 July gross Vic: AUD 0,60/kWh net WA: REBS net	NSW: AUD 0,60/kWh from 1 Jan then AUD 0,20 from 27 Oct gross WA: AUD 0,40/kWh net from 1 Aug 2010 then AUD 0,20/kWh from 1 July 2011
Capital subsidies for equipment or total cost	Solar Homes & Communities: AUD 8/W ended June 2009 but still driving a backlog of installations in 2010 RRPGP: 50% ended June 2009 but continued with some installations in 2010 WA Household Renewable Energy Scheme, provides 3 annual payments for residential systems installed between 6 September 2008 and 2 June 2009.	
Green electricity schemes	GreenPower	
PV-specific green electricity schemes		
Renewable portfolio standards (RPS)	Small-scale Renewable Energy Scheme (SRES) that includes Solar Credits: 5 times multiplier for STC creation for small generation units	
PV requirement in RPS		
Investment funds for PV		
Income tax credits		
Net metering	Available to the majority of residential customers if they choose not to have a FiT, although rates for exported electricity vary	
Net billing		
Commercial bank activities e.g. green mortgages promoting PV	Bendigo Bank: 0.5% reduction in mortgage rate for sustainable energy inclusion	
Activities of electricity utility businesses	Via GreenPower, SRES, Solar Cities, REBS	
Sustainable building requirements	NSW BASIX NABERS GreenStar ratings	

3.1 Description of changes to support measures in 2010

3.1.1 The Renewable Energy Target

In June 2010, the 45 000 GWh Renewable Energy Target (RET) was separated into two parts, to commence on 1 January 2011 – the Large–scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). In December 2010 the Solar Credits multiplier for the 2011-2012 period was reduced from 4 to 3, with multipliers in subsequent years also reduced by 1. See Section 2.3.3 for more detail.

3.1.2 State and Territory Feed-in Tariffs

A range of State based feed-in tariffs applied across Australia in 2010, as shown in Table 5. The changes that occurred in 2010 are:

- The ACT feed-in tariff for systems up to 30 kW decreased to AUD 0,457/kWh for systems installed as of the 1 July 2010.
- The New South Wales AUD 0,60/kWh gross feed-in tariff commenced on the 1 Jan 2010 (although system owners only received the tariff once appropriate meters had been installed), then dropped to AUD 0,20 from 27 Oct 2010.
- The Western Australian AUD 0,40/kWh net feed-in tariff commenced on the 1 Aug 2010. This feed-in tariff is paid in addition to the rate paid by retailers under the Renewable Energy Buyback Scheme.

The changes that will occur in 2011 are:

- The South Australian FiT will be increased to AUD 0,54/kWh for households that, after the 31 Aug 2010, received permission to connect their systems. The AUD 0,54/kWh will be paid from the 6 April 2011. The current proposal is that the FiT will apply only to the first 45 kWh exported each day and the scheme will be closed to new entrants from 1 Oct 2011.
- The ACT feed-in tariff for systems up to 30 kW will end as of the 31 May 2011 as the 15MW cap will be reached. The feed-in tariff for systems from 30 kW up to 200 kW will be AUD 0,3427/kWh as of April 2011. It will also be capped at 15MW.
- The Qld feed-in tariff will only be available to systems up to 5 kW as of the 7 June 2011. Existing connections will not be impacted.
- The New South Wales AUD 0,60/kWh gross feed-in tariff will, as of 1 July 2011, be retrospectively reduced to AUD 0,40/kWh for all systems eligible for this tariff. The AUD 0,20/kWh gross feed-in tariff will be closed to new entrants as of midnight the 28 April 2011. These may have changed since the time this report went to print.
- The Western Australian feed-in tariff will reduce from AUD 0,40/kWh to AUD 0,20/kWh from 1 July 2011.

3.2 Indirect policy issues

3.2.1 International policies affecting the use of PV Power Systems

Increased international climate change and PV development activities continue to set the benchmark for Australian policies. In addition, Australian PV prices are impacted by the large support programs for PV internationally.

3.2.2 Taxation Measures

The South Australian Government introduced a Payroll Tax Rebate for the on-site labour of renewable energy projects. The Rebate commenced on 1 July 2010 and will continue to 30 June 2014. The rebate available for solar is up to AUD5 million.
http://www.renewablessa.sa.gov.au/files/2009dec16_payroll_tax.pdf

During 2010 no concrete progress was made at the national level regarding placing a price on greenhouse gas emissions. This is currently flagged to occur in July 2012 through a scheme that firstly places a fixed price on emissions for 3 years then converts to an emissions trading scheme after that. However, there are a number of political and scheme design issues yet to be addressed. Even when a price is placed on greenhouse emissions, it will only have a significant impact on the PV market as the levelised cost of PV electricity approaches grid parity – this could occur in many Australian jurisdictions in the period 2015 to 2020.

3.3 Interest from electricity utility businesses

In the past, electricity utilities were heavily involved in PV demonstration programs through their own R&D arms. More recently, utility interest has largely been driven by government programs, such as the Solar Cities and, to a lesser extent, Smart Grids programs, as discussed below. The Electricity Networks Association has begun to examine issues of high PV penetration and is preparing guidelines and protocols for utilities.

All electricity retailers are liable under the Renewable Energy Target and some have installed their own PV systems to contribute to meeting their liability. Some utilities have also established solar businesses and retail PV systems to their customers.

The Northern Territory Power Water Corporation recently purchased the concentrating solar PV power stations at Lajamanu, Hermannsburg and Yuendumu and operates them to provide power at those communities. It has also begun construction of a solar / wind / diesel hybrid power station at Lake Nash, and PV / diesel power stations at Ti Tree and Kalkarindji.

3.3.1 Solar Cities

As discussed in more detail in Section 1.3.4, Solar Cities is a demonstration program, where each Solar City consortium trials a unique combination of energy options such as energy efficiency measures for homes and businesses, the use of solar technologies, cost reflective pricing trials to reward people who use energy wisely, and community education. The Solar Cities are Adelaide, Alice Springs, Blacktown, Central Victoria, Moreland, Perth and Townsville. Each consortium includes an electricity retailer and by the end of 2010, the Solar Cities Consortia had collectively installed 4 687 kW PV, 20 167 smart meters and conducted 9 370 home energy assessments.

3.3.2 Smart Grid/Smart City Program

The Australian Government has committed up to AUD 100 million to develop the Smart Grid, Smart City demonstration project in partnership with the energy sector. This initiative will gather robust information about the costs and benefits of smart grids to inform future decisions by government, electricity providers, technology suppliers and consumers across Australia.

The electricity retailer EnergyAustralia will demonstrate Australia's first commercial-scale smart grid, based in Newcastle, New South Wales, under the Australian Government's National Energy Efficiency Initiative - Smart Grid, Smart City. EnergyAustralia, working with

their consortium partners IBM Australia, GE Energy Australia, AGL Energy, Sydney Water, Hunter Water Australia, and Newcastle City Council, will deploy a commercial scale project that will lead to Australia-wide advances in energy management.

3.4 Standards and codes

3.4.1 AS/NZS 4509 - Stand-alone power systems

Part 1: - Safety and installation (2009)

Revised and now incorporating old parts 1 and 3. Part 1 and 3 have been updated considerably to fix minor problems. It now covers the connection to the house via the equivalent of a "consumers mains" making sure it dovetails with AS/NZS3000. It also has new sections and diagrams addressing housing and ventilation of batteries.

Part 2: - System design guidelines Completed in 2010

Revised and now published. Minor revisions to fix small problems and make sure again it links accurately with AS/NZS3000 and a section has been added to include the use of a.c. buss systems. This new section is aimed at specifically not excluding a.c. buss systems but not covering designs where time of use loads are important. It does not cover every method of designing systems but gives a solid conservative approach.

3.4.2 AS/NZS 5033 – Installation of PV arrays

The new draft of AS/NZS 5033 will be released at the end of May 2011 for public comment. The revised standard is based on a new draft international standard (IEC) which is also out for international public comment.

The revision includes:

- Scope expanded >30kW and up to 1000V
- Modules will no longer be classed as double insulated (Class II).
- Reinforcing of AS/NZS3000 cable protection and support requirements
- Earthing – if LV …EARTH the FRAMES
- Fusing
- New calculations based on Max O/C protection rating of modules
- Use gPV category fuses
- Voltage ratings based on lowest temperature at site.
- Connectors
- PV dc isolator clarification
- Reworking of windloading and structural sections
- Signs
- Other minor corrections

3.4.3 AS 4777 – Grid connection of energy systems via inverters

AS4777.1 has been extensively revised and AS4777.2 and .3 are being combined into one standard.

AS 4777-1 Revision

The revision of AS/NZS4777.1 includes:

- Expanded Scope for larger systems
- Require a.c. isolation adjacent to inverter if switchboard is not within line of sight of main switchboard and not more than 3m away.
- RCDs on inverter circuits
- Segregation of ac and dc wiring

- DC isolation & wiring restraint particularly near inverter.
- Alignment with amended AS/NZS3000
- Updated labelling and signage requirements.
- Recommendations of very low Voltage drop from inverter- point of connection.

The new draft AS/NZS4777.1 should be available for public comment in June 2011.

AS 4777-2&3 Revision

Parts 2 and 3 will be combined to simplify product testing and to make sure inverters meet both requirements. Other issues include:

- Important utility safety and quality of supply issues which are arising out of higher penetration levels of PV in the electricity network
- Revision of voltage and frequency settings to line up with regulators requirements.
- Two averaging times and trip settings
- Recommended default settings for Australia and NZ
- Possible revised anti-islanding requirements.

ASNZS4777.2 is still under discussion but will be released for public comment later in 2011.

3.4.4 AS/NZS 3000 – Wiring Rules

The focus is on making sure that any inconsistencies are removed between standards, ensuring that the diagrams line up, and ensuring that the language is clear.

3.4.5 New Signs

A new consistent set of signs have been developed across the whole range of standards for PV. They have been incorporated into AS/NZS 4509, AS/NZS 5033 & AS/NZS 4777. Where possible the set of signs has been reduced and simplified.

4 HIGHLIGHTS AND PROSPECTS

The grid connected PV market in Australia grew more than 480% in 2010, from 73 MW to 379 MW. This was driven by a combination of support via the Solar Homes and Communities program, Solar Credits and feed-in tariffs, bolstered by rapid international PV price drops, a high Australian dollar exchange rate and streamlining of local PV system delivery chains. Such streamlining was achieved most notably by reduced reliance on PV distributors, as well as by sales of standardised systems, without individual designs for the site. Government support for PV will begin to wind down in 2011 and discussion now focuses on how best to regulate an unsubsidized market as it approaches grid parity. Issues of high PV penetration in sections of the electricity network are also of increasing interest for researchers and electricity utilities.

To date most of the PV incentives have focussed on small-scale, residential PV systems. Interest in larger systems has been raised by the Australian Government's Solar Flagship program, with winners of the first stage, for 150 MW of PV, to be announced in 2011. State Governments have also shown interest in developing commercial-scale PV markets. These will provide better economies of scale for the industry, as well as better matching electricity load profiles.

Research funding from the Australian Solar Institute will begin to see enhanced research outcomes, encompassing a range of PV technologies. The new Australian Centre for Renewable Energy will also begin to provide venture capital and product development support from 2011.

There are no specific PV targets for Australia, although each State-based feed-in tariff program has had its own target, as shown in Table 5. Australia has an overall renewable energy target of 45 000 GWh (approximately 20% of electricity use) by 2020.

Figure 12: Carrara Stadium, Gold Cost. 215kW BIPV system (Photo: SunWiz)

ANNEX A: 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.

1) retail electricity prices vary between retailers and also have different fixed supply charges and step rates. Typical flat tariffs range from AUD 0,13 to 0,23 per kWh for households, with higher summer tariffs in some jurisdictions and off-peak hot water tariffs or around AUD 0,04 – 0,12 per kWh also available.

   Time of use tariffs vary, but for residential customers, can be as high as 0,40/kWh between 2pm and 8pm on weekdays.

   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 respectively. However, various standing and peak power 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) typical household electricity consumption ~ 8 000 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 – an increasing number of residential consumers in Australia, including most households with PV systems, have interval meters. They are being introduced progressively, accompanied by Time-of-Use tariffs.

4) average household income – AUD 44 200 per year

5) typical mortgage interest rate – 7.5%

6) voltage – 240 volts

7) The electricity sector has separate retail, distribution, transmission and generation businesses. Some States have privatised sections of their electricity industry, but most remain publicly owned. The Australian Energy Market Commission (AEMC) is 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 to 1,6 per litre in capital cities, retail prices in rural and remote areas are higher. Price includes the Diesel Fuel Excise of AUD 0,38143 and a 10% GST which some consumers are eligible for rebates on.

9) typical values of kWh / kW for PV systems in Australia: 1200 to 1800 kWh/kW per year depending on location.