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*

2001

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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. Eight Tasks have been established, and currently seven are active.

ii Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems. An important deliverable of Task 1 is the annual 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.

The International Survey Report is based on National Survey Reports prepared by all member countries. The International Survey Report and the National Survey Reports are published on the PVPS website.

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 Wp 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 'Peak power').

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

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 Wp 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.

Turn-key price: Price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid system, the prices associated with battery maintenance/replacement should be 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 the interior of Greenland should not be included.)

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.

Please also refer to the internal PVPS report *Writing numerical values, quantities, units and symbols according to International Standards* for guidance.

1 Executive summary

- **Installed PV power**

  Installed PV capacity in Australia rose by 4 370 kWp, or 15%, during 2001, to take the cumulative total to 33 580 kWp. Installations continue to be dominated by the off-grid market for agricultural/industrial use and private dwellings. Important industrial uses include telecommunications systems, shipping, rail and road signalling, water pumping, cathodic protection, billboards and electric fences. While the telecommunications market has been stable for the last few years, major new projects are now beginning to come on stream, which will see this market sector remaining strong over coming years. The water pumping market has been boosted by recent government grants and is now taking off strongly, even where grants are no longer available. Government support for rooftop PV systems has seen an increase in building integrated installations for homes, schools and other community buildings, both on and off-grid. Increased activity is also evident in the medium sized centralised system market for off-grid communities and commercial enterprises. Installations include flat plate and concentrator systems for aboriginal communities and for tourist facilities. Although increasing, the percentage of PV used in grid connected systems is still small, representing 10% of installed PV capacity. With its relatively low electricity tariffs, PV remains an expensive option for grid applications in Australia and with government grants for grid connected systems set to cease within the coming year or so, this market sector may well stall.

- **Costs & prices**

  PV module prices have remained reasonably stable during 2001 at around AUD 8 per Wp, representing a fall of around 10% in real terms over the past decade. System prices for most PV end-use categories also stayed reasonably constant in 2001 and range from AUD 10 to 25 per installed Wp. However, typical prices for rooftop systems in the size range 1 – 3 kWp dropped slightly to AUD 10-12 per Wp, as that market matured. Typical prices for small scale off-grid systems have decreased by 30% in real terms over the past decade.

- **PV production**

  PV cell production in Australia rose 82% in 2001, to 10MWp, compared to a world average increase of 40%, bringing our PV production share up to 2.8% of the international market, against our GDP share of about 1%. Cell production capacity rose to 10.5 MW. Module production also rose slightly to 6 MW with a capacity of 6.5 MW. Two-thirds of Australia's cell production is crystalline silicon, the remainder multi-crystalline silicon. In a world first, pilot production began in 2001 of dye sensitized (TiO2) cells and modules for building integration. Significant expansion of Australia's existing manufacturing capacity is underway, while new thin-film technologies are also expected to begin production over the coming three years.

  While there remains a strong market for special purpose small modules in the agricultural / industrial market, production trends are towards larger modules. Over 60% of Australian product is exported.

- **Budgets for PV**

  Research and development budgets for PV are dominated by Australian government programs aimed at demonstration and market development. These include rebates for rooftop PV systems and for off-grid PV replacing diesel generation. State budgets include additional funding for the above, as well as assistance for PV in schools, Greenpower programs and general promotion. The total public funding for demonstration, field testing and market development was AUD 16.6 million during 2001.

  PV research is undertaken at several universities across Australia, funded by State and federal governments, as well as by private investors, and by all PV companies. Public funding in 2001 was around AUD 1 million. Industry funding for university research and for in-house R&D was around AUD 10 million, largely for new production processes and new products.

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 Wp 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

PV applications in Australia continue to be dominated by off-grid installations for industrial use and private dwellings. Important industrial uses include telecommunications systems, shipping, rail and road signalling, water pumping, cathodic protection, billboards and electric fences. Government support for rooftop PV systems has seen an increase in installations for homes, schools and other community buildings, both on and off-grid. Increased activity is also evident in the medium sized centralised system market for off-grid communities and commercial enterprises. Installations include flat plate and concentrator systems for aboriginal communities and for tourist facilities. The water pumping and small scale industrial markets are both growing strongly. Although increasing, the percentage of PV used in grid connected systems is still small, representing 10% of installed PV capacity.

2.2 Total photovoltaic power installed

Table 1. The cumulative installed PV power in 4 sub-markets.

Sub-market/ application	31 Dec. 1992 kWp	31 Dec. 1993 kWp	31 Dec. 1994 kWp	31 Dec. 1995 kWp	31 Dec. 1996 kWp	31 Dec. 1997 kWp	31 Dec. 1998 kWp	31 Dec. 1999 kWp	31 Dec. 2000 kWp	31 Dec. 2001 kWp
off-grid domestic	1 560	2 030	2 600	3 270	4 080	4 860	5 960	6 820	9 110	10960
off-grid non-domestic	5 760	6 865	8 080	9 380	11 520	13 320	15 080	16 360	17 060	19170
grid-connected distributed		5	20	30	80	200	850	1490	2 390	2800
grid-connected centralized				20	20	320	630	650	650	650
TOTAL	**7 300**	**8 900**	**10 700**	**12 700**	**15 700**	**18 700**	**22 520**	**25 320**	**29 210**	**33 580**

2.3 Major projects, demonstration and field test programmes

Australian Government PV Rebate Program (PVRP)

Aim: To encourage the development and use of building integrated PV.

Funding: Australian Government, with administration by the State Governments. AUD 31 million has been allocated over 4 years. Grants of AUD 5,000 per kWp are provided, to a maximum of AUD 7,500 per residential system and AUD 10,000 per community building system.

Over 1,100 systems were installed in 2001, amounting to 1.3 MWp. 78% of systems, comprising 69% of installed capacity, were on off-grid buildings and AUD 5 million was allocated in grants. Since the start of the programme in 2000, nearly 3000 systems, amounting to 3 MWp, have been installed.

Australian Government Renewable Remote Power Generation Program (RRPGP)

Aims: 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 greenhouse gas emissions.

Each State has established a slightly different program, to meet the specific needs of local off-grid communities. 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. The amount allocated to water pumping is limited to 5% of total funds provided to each State.

Core funding for this program is provided to the States by the Australian government, on the basis of diesel fuel excise collected in the years 2001/02 to 2003/04 from diesel fuel used by public generators not connected to main electricity grids. Grants of up to 50% of the capital cost of renewable energy systems are available for diesel replacement. The program is administered by State governments, with additional funding provided by some States. Up to AUD 264 million is available over the life of the program, which can extend to 2010.

A specific allocation of AUD 8 million has been made to the Aboriginal and Torres Strait Islander Commission (ATSIC) to assist with the development of industry capability and local understanding of renewable energy systems in indigenous communities.

To end 2001, grants of AUD 2.7 million had been paid for 133 installed systems, which included 213 kWp of PV.

Queensland Cool Schools Program

Aim: to increase the use of PV and to educate school children about its use and benefits.

Funding: Queensland Environment Protection Agency will contribute AUD 7 700 for each system. AUD 46,200 was contributed for 6 systems in 2001. Energy utility Stanwell Corporation is undertaking the program.

2kWp of PV will be installed on 17 schools over the next 3 years.

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Table 2: Summary of major projects, demonstration and field test programmes

Project Date plant start up	Technical data/Economic data	Objectives	Main accomplishments until the end of 2001/problems and lessons learned	Funding	Project management	Remarks
Renewable Remote Power Generation Program 2001	Up to AUD 264 million for 4 years, allocated on the basis of diesel fuel excise paid by public generators in each State. Grants up to 50% of costs, for renewable energy components. Funds are able to be carried over until 2010.	• To substitute renewable energy for diesel in off-grid areas and reduce greenhouse gas emissions • To assist the Renewable Energy Industry • To meet infrastructure needs of indigenous communities	Sub-Programs with funding totaling over AUD 98 million are now operational in most States. Some States have been overwhelmed by grant applications, other States may have problems finding sufficient matching funds to utilize their allocations. However, this may be assisted by allocations to several major projects. 133 systems installed to end 2001, including 213 kWp of PV.	Grant funding provided by Australian Greenhouse Office, topped up in some States.	Separate programs operating in each State and managed by the State governments.	Start-up delays have caused major problems in the industry, with customers delaying purchases for several years. Some States are attempting to achieve standardization and quality control over systems installed, to reduce on-site problems later on. Some funding is also being made available to assist the industry in training and accreditation.
Full commercialisation of Plug&Power™ 2001	AUD 1 million (RECP – AUD 0.5 million) Balance of systems (BoS) hardware to be configured for mass production & sale.	• To develop new packages & hard tooling for BoS components • To develop Plug&Power™ for cyclonic regions • To develop sales & marketing tools • To monitor six Plug&Power™	Project commenced in August 2001 & is running to program.	Pacific Solar Pty Ltd Australian Govt RECP	Pacific Solar Pty Ltd	Project proceeding smoothing to achieve first milestone before mid 2002.

		sites				
Titania Dye Sensitised Solar Tile and Wall Panel manufacturing facility 2000	AUD 2.5million (RECP-AUD 1 million) The facilities will be capable of producing 10,000 sq.m of Solar Wall Panels annually.	• To validate manufacturing processes • To enable the first phase (500kWp) start-up	World's first DSC manufacturing facilities installed in Queanbeyan.	Sustainable Technologies International Pty Ltd, Australian Govt - RECP	Sustainable Technologies International	Commercial exploitation of the facilities to commence in 2002
BIPV cladding of the Melbourne School of Energy and Environment building 2000	AUD 755,000 RECP grant + University funding.	To demonstrate the application of building-integrated PV power generation on a large scale.	Systems design completed by STI. A combination of crystalline and thin film technology used.	Australian Govt RECP Melbourne University Private Ltd	Melbourne University Private	Contractual issues concerning project interfaces required extensive effort. The project will be commissioned by STI in 2002.
PV Rebate Programme 2000	Grants of AUD 5 000 per kWp, up to AUD 7,500 for households and AUD 10,000 for community buildings. To date, 3 MWp installed on 3 000 systems with AUD 19 Million provided in grants	To stimulate the use of PV on residential and community buildings	81% of installations, comprising 73% of installed PV capacity, have been on off-grid buildings.	Australian Government funded, with State Government administration	Australian Greenhouse Office	Some specific BIPV products are emerging. Demand in the grid-connect market is still slow.
Wetlands Project - Homebush Bay	64kWp PV grid-connected and battery backup system sited on the Homebush Bay wetlands area in the	To pump water from 40 ponds once every three days during the summer and less frequently in the winter to mitigate mosquito infestations and the build up of	Positioned slightly east of north, a carefully constructed galvanised steel custom-made frame was designed on a 45	Waste Services and Olympic Co-ordination Authority	Waste Services and Olympic Co-ordination Authority (OCA) and completed	System operational.

64kWp 2000	grounds of an old Royal Australian Navy armaments depot. The PV system comprises 800 SX80 Solarex modules three 20 KVa AES stringed inverters and a 240 volt DC 1000Ampère battery backup supply.	algae blooms. The tilt of the array is 15 degrees, to maximise summer output.	degree slope without detracting from the historic munitions building.	(OCA)	by Advanced Energy Systems (AES) of Perth and the Sydney based company, Solar Technology Australia (SOLARTECH).	
Citipower Solar Pioneers Programme 2000	$60,000 REIP grant plus contributions from customers and Citipower.	To help accelerate the commercialisation and uptake of PV, assist in increasing sales of Australian made equipment and to enable participating customers to make their own contribution to the reduction in Australia's greenhouse emissions.	50 systems, with a capacity of 57.6 kW, are installed. Most of the systems are rated at 1 kWp. One system is installed on a secondary school, the remainder on residential properties.	Citipower, customers, Australian Govt - Renewable Energy Industry Program	Citipower	Difficulties with sourcing small inverters, need for electronic meters, unfamiliarity of electrical inspection authorities and lack of established work practices.
GreenGel battery 2000	AUD 1 Million RECP grant + funding from the companies involved	Commercialisation of a long life deep cycle lead acid battery for off-grid renewable energy systems.		Australian Govt RECP BP Solar Battery Energy South Pacific CSIRO	BP Solar	
1MW PV concentrator power station, Broken Hill, NSW 2000	AUD 1 million RECP grant, AUD 250,000 from NSW SEDA + funding from the companies involved.	42 x 24kWp dishes, delivering 3-phase AC power to the main electricity grid.		Australian Govt RECP Australian Inland Energy NSW SEDA	Solar Systems	

				Solar Systems Pty Ltd		
200 kWp Diesel Grid Feed Sun Farm for the Anangu Pitjantjatjara Lands, South Australia. 2000	AUD 1 million RECP grant + funding from the Pitjantjatjara Council and SA Government 10 x 20kWp PV concentrator dishes, which operate and feed power directly into the local grid, supplying 20% of the daily load	- To reduce diesel consumption and greenhouse gas emissions. - To develop an air-cooled concentrator dish technology particularly suited to remote and arid locations where cooling water is in limited supply.	Site preparations completed with installation planned for 2002.	Australian Govt RECP Pitjantjatjara Council Inc South Australian Division of State Aboriginal Affairs	Pitjantjatjara Council	
Peak lopping in off-grid diesel systems using PV. 2000	AUD 0.5 million RECP grant + 1.25 million via the RRPGP program and funding from NT PAWA Flat-plate PV panels at Bulman Aboriginal community (55kWp) and Kings Canyon tourist site (225kWp), connected to diesel-powered grids via inverters.	- To demonstrate the large scale commercial viability of PV peak lopping in remote diesel grid systems - To lower operating costs and reduce greenhouse gas emissions - To reduce diesel consumption.	Early studies have shown good correlation between peak load and solar insolation, which will allow maximum benefit to be gained by addition of PV.	Australian Govt. RECP Power and Water Authority of the Northern Territory. NT Centre for Energy Research	PAWA	The first stage of the project is expected to be commissioned during the 3rd quarter of 2002.
All-plastic PV roof tile 2000	AUD 135,000 RECP grant, AUD 20,000 from NSW SEDA + funding from the companies involved.	- To develop an extruded frame for PV laminates and a low cost pluggable PV junction box. - To market and promote	The new Solar Tile is already being used in Sydney, using BP Solar's 85 Wp Saturn cell PV laminates, under a	Australian Govt RECP NSW SEDA PV Solar	PV Solar Energy	

		the product to architects, BIPV installers, home renovators and financiers.	contract to developer MIRVAC for the Newington Solar Village stage 2. 79 homes are now being built, each with 12 tiles, making a 1 kWp PV system.	Energy Pty Ltd, Utilux Pty Ltd and BP Solar Australia		
Solar Sailor 2000	AUD 1 million RECP grant + company funding. 108-seat multi-purpose catamaran capable of running on solar and wind energy with CNG or LPG back-up	- To construct, test and demonstrate commercial viability - To showcase the solar wing, a solid-aerofoil sail with an embedded array of PV cells that utilises solar and wind energy separately or in combination	Solar Sailor is operated commercially on Sydney Harbour and is in high demand.	RECP Solar Sailor Holdings Ltd	Solar Sailor	Orders for additional vessels have been received.
Commercialisation of an efficient solar electric charge controller 2000	AUD 125,000 RECP grant + company funding.	- To repackaging the technology in a more commercial form, lower unit costs and develop effective marketing strategies and materials.		RECP Plasmatronics Pty Ltd	Plasmatronics	
Solar Kogarah 2000	AUD 1 million RECP grant, AUD 200,000 from NSW SEDA + Council funding for 160 kWp of BIPV	- To establish a major building demonstration site for specific solar energy products and BIPV in an inner city town centre. - On-site marketing and promotion of solar energy in urban environments - Renewable energy	Design and tendering for the PV systems been completed. Sydney based electricity utility EnergyAustralia will undertake the PV component of the building. 148 kWp of UniSolar PV	Australian Govt RECP NSW SEDA Kogarah Council	Kogarah Council	Some delays have been experienced in manufacture of the PV framing systems.

		training services.	modules will be used for the roof and 12 kWp glass/glass BP Solar modules over the entrance and lobby areas. 59 SunPower 1.5 – 2.5 kW inverters will also be used.			
BIPV system for the heritage-listed Queen Victoria Market, Melbourne 2000	AUD 1 million RECP grant + Council funds. 3800m^2 PV installed so as not to detract from the heritage buildings 350,000kWh of green electricity per year	- First PV array for market-type buildings - Long term performance monitoring by the University of Melbourne's Green Building Research Group - Educational purposes		RECP Melbourne City Council		
NSW Solar in Schools Programme 1999	AUD 0.5 million provided jointly by NSW SEDA, the Department of Education and Training and Integral Energy	To increase awareness and knowledge of PV systems.	18 schools were provided with 1 to 1.5 kWp roof mounted PV systems.	NSW SEDA Dept of Education & Training Integral Energy	Integral Energy	
20kWp grid-connected solar PV trough concentrator 1999	AUD 300,000 REIP grant + University and company funds Parabolic trough-shaped mirror to concentrate the sun's energy onto a line of high efficiency PV cells.	To demonstrate and evaluate the commercial potential of PV concentrator technology, especially for use in diesel powered mini-grids in rural and remote areas.	System commissioned.	ANUTECH	Australian Govt. REIP, ANUTECH Pty Ltd, Solahart Industries Pty Ltd and Western Power Corporation	

Sydney Superdome Solar System 1999	70 kWp a-Si roof integrated array, comprising 1176 X 77 Wp modules on a steel frame with an 8º tilt, 19 X 4 kW inverters and optic fibre monitoring link.	To demonstrate a large roof-integrated array and supply 1000 of EnergyAustralia's *Pure**Energy*** customers.		EnergyAustralia, via contributions from *Pure**Energy*** customers	EnergyAustralia in conjunction with SEDA, Abi Millenium, Olympic Co-odinating Authority	Saves 85 t of greenhouse gas emissions per year.
Olympic Boulevard PV Lights 1999	1520 laser grooved c-Si modules on 19 towers. Grid connected.	To provide lights, signage, shelter and shade, plus a high profile demonstration of PV power.	Won the Inst of Eng 1999 Eng Excellence Award for Project Development. Provides 160 000 kWh/an	Australian Olympic Co-ordinating Authority	EnergyAustralia	Very high visibility site, with innovative design features.
Newington Solar Village 1998-2000	629 X 1 kWp grid connected rooftop systems (c-Si cells) in a high density residential estate.	To develop and demonstrate standardised, easy to install BIPV systems in commercial housing. To investigate network issues involved with a high density of small PV arrays.	Valuable trade and professional experience, understanding and skill development.	PV costs included in house prices.	Pacific Power, BP Solar.	High profile site for international demonstration of BIPV during the 2000 Olympic Games.
Western Plains Zoo 1998	Grid connected 50 kWp mc-Si array.	To demonstrate PV for its Green Power customers and gain installation & operational experience.	Trees surrounding site.	Advance Energy via its Green Power customers, SEDA.	Advance Energy	High profile tourist site.
Queanbeyan Energy Depot 1998	Grid connected 50 kWp mc-Si array, comprising 720 X 77 Wp modules.	To gain installation & operational experience with larger scale PV systems.	Difficult sloping site, with non-ideal orientation.	Great Southern Energy via its Earth Saver customers and SEDA.	Great Southern Energy	
White Cliffs	Grid connected 42	To refurbish a concentrating solar	Produces 70 000	Advance		Popular tourist site.

Solar Power Station. 1998	kWp concentrating array with 14 X 20 m^2 tracking dishes.	thermal system with PV.	kWh/an.	Energy & Solar Research Corporation, with contributions from Advance Energy's Solar Fund green power scheme.		The PV system operates at 55 ºC.
Wilpena Pound Solar Power Station. 1998	100 kWp ground mounted mc-Si array in hybrid configuration with 440 kW diesels, 400 kWh battery bank, 125 kVA inverter /charger plus innovative remote monitoring & controls	To gain experience with and demonstrate a stand-alone community sized PV based power system.	The PV/battery system typically supplies all daytime load.	South Australian government, Electricity Trust of SA.	ETSA Power	Remote monitoring & control via modem link using a Hybrid Station Control Module, to allow integration of renewable & conventional energy sources
Singleton Solar Farm 1997-98	Grid connected 400 kWp array of 3312 a-Si and 3456 mc-Si panels on steel frames at 30º N tilt. 5 X 50 kW and 36 X 4 kW inverters are used.	To gain experience with large grid connected arrays and system components.	Largest central PV power station in Australia. Produces 500 000 kWh/an, supplies 6000 PureEnergy customers.	EnergyAustralia, via contributions from PureEnergy customers, SEDA, Singleton Shire Council.	EnergyAustralia	Avoids 500t greenhouse gases/an.
Homebush Business Park PV Power Station	11.2 kWp c-Si array, comprising 140 X 80 Wp panels and a 10 kW inverter.			EnergyAustralia via its PureEnergy customers.	EnergyAustralia	

1997						
Foreshore Park PV Power Station, Newcastle 1996	6.5 kWp array on a historic railway shed, comprising 80 X 83 Wp and 16 X 64 Wp mc-Si modules with a 5 kVA inverter.	To demonstrate a grid connected building integrated PV system.	Very careful design required to fit heritage listed building requirements.	EnergyAustralia via its PureEnergy customers.	EnergyAustralia	High visibility tourist area, in a heritage listed building.
National Innovation Centre PV Power Station 1996	10 kWp array at Australian Technology Park.	120 X 83 W mc-Si modules and 10 kVA inverter.		EnergyAustralia via its PureEnergy customers.	EnergyAustralia	System used to analyse PV system maintenance requirements.

2.4 Highlights of R&D

PV research is undertaken at several universities across Australia and by a number of PV companies.

The Centre for PV Engineering, University of NSW, is undertaking research into improved crystalline and thin-film silicon cell efficiencies, as well as theoretical research into so-called 'third generation photovoltaics' which is expected to provide the basis for significant increases in PV device conversion efficiency over the next decade. Work is also undertaken in conjunction with industry licensees on improved manufacturing processes for its "Saturn" laser grooved cell technology.

The Centre for Sustainable Energy Systems at the Australian National University (ANU), in conjunction with energy utility Origin Energy, is developing a new thin film PV technology, using the *epilift* process. This allows high efficiency cells to be produced at low cost by depositing a thin, removable layer of silicon onto a silicon substrate. The ANU is also developing parabolic trough and paraboloidal dish PV concentrator systems, and a Combined Heat And Power Solar System, *CHAPS*, which integrates PV electricity generation and solar hot water production using 25X concentrating troughs.

Murdoch University is developing methods of producing low cost silicon from a number of new sources for both wafer based and thin-film silicon solar cells. The process will provide options for the PV industry if the price of conventional silicon wafers increases.

Pacific Solar, a company set up by Pacific Power and Unisearch Ltd, the commercial arm of the University of NSW, is developing a thin-film crystalline silicon on glass (CSG) technology. The cells will be used in their ac *Plug & Power*™ PV modules, which are already on the market using conventional PV cells, and are especially designed for rooftop installations. Eurosolare, a 26% shareholder in Pacific Solar, will distribute Plug&Power™ in Europe. During 2001, the company spent AUD 8.5 million on PV and inverter R&D. Their thin-film CSG modules (0.3m X 0.4m) have now achieved over 7 % efficiency and are estimated to more than halve manufacturing costs compared with wafer technologies when in full production.

Sustainable Technologies International (STI) has commenced the world's first pilot production of titania dye sensitized solar tiles and panels at its 0.5 MW Queanbeyan, New South Wales, plant. R&D efforts are directed towards improvement of manufacturing processes and development of new, low cost designs.

Solar Systems Ltd continues development and demonstration of its *SS20* PV tracking concentrator dishes. System efficiencies of 20% 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% efficiency. Both air and water cooling systems are being developed.

PV Solar Energy Pty Ltd is developing a new all-plastic PV roof tile. The tile will use a new low cost pluggable PV junction box, developed by Utilux Pty Ltd and monocrystalline solar cell laminates produced by BP Solar Australia.

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

Table 3 gives figures for the year on public sector budgets for R&D, demonstration/field test programmes and market incentives for PV.

Table 3. Public budgets (in National Currency) for R&D, demonstration/field test programmes and market incentives.

AUD million	R & D	Demo/ Field test	Market Development
National	1.0	4.1	11.6
State		0.2	0.7
Total	**1.0**	**4.3**	**12.3**

3 Industry and growth

3.1 Production of photovoltaic cells and modules

Cell and module production and manufacturing capacity for 2001 is listed in Table 4. PV cell production in Australia rose 82% in 2001, to 10MWp, compared to a world average increase of 40%, bringing our PV production share up to 2.8% of the international market, against our GDP share of about 1%.

Table 4: Production and production capacity information for 2001 for each Australian manufacturer

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MWp)*		Maximum production capacity (MWp)	
		Cell	Module	Cell	Module
BP Solar	Sc-Si	4	2.5	4	2.5
	mc-Si	6	3.7	6	3.7
STI	TiO2	0.01	0.01	0.5	0.5
TOTALS		**10**	**6**	**10.5**	**6.5**

*Note that modules were largely produced from the cells and are not totally additional.

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. Some modules are fabricated from imported cells.

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).

b) Whether the manufacturer produces their own cells in-house or whether they are purchased on the international market, or both.

BP Solar: Cells manufactured in-house, some from internal company imports.

STI: Cells manufactured in-house.

c) The quantity of PV cell production sold as cells on the international market to other module manufacturers.

BP Solar: 4 MW, most inter-company.

STI: nil.

d) Technical characteristics of standard commercial modules, cell material, typical module output power range, type of encapsulation, length of typical warranty.

BP Solar: All commercially produced modules use sc-Si or mc-Si. Modules range in size from 2 - 150 Wp. There is increasing emphasis on large area (72 cell / 1.6m X 0.7m) high power modules (120Wp+). Almost all have front glass / EVA internal encapsulant / PVF back sheet, with fabrication by high temperature vacuum lamination. However, special glass/glass modules are supplied for navigation aids and some industrial and building applications, eg. for hazardous areas, small area / low power systems or for building cladding purposes.

Warranties range from 10-20 years, depending on the application, as well as on the level of manufacturer involvement in system design.

STI: The DSC tiles are interconnected and laminated into Solar Wall Panels (typically 600X900mm) to suit end-user requirements, primarily for façade integration. Most of the materials and components are manufactured at STI.

e) Certification of modules to IEC 61215 or IEC 61646 or equivalent. Certification to ISO 9000, ISO 14000.

BP Solar: Fabrication facilities are accredited to ISO 9000 Quality Standards, Underwriter Laboratories (UL) and ISO 14000 Environmental Standards. Modules are certified to Australian standards, plus international standards via US (IEC, Arizona State University) and European (ESTI 503, Ispra, Italy) testing.

f) Availability of modules specially designed for utility applications (large size modules, high insulation modules, facade and roof top modules, etc.) and their characteristics.

BP Solar: Special modules are manufactured to specification for Telstra, Australia's telecommunications utility company.

g) New developments and new products.

Several new thin-film products are also under development, in addition to the STI product now on the market:

- Pacific Solar – thin-film crystalline silicon on glass (CSG) modules;
- Australian National University – thin film c-Si using the Epilift process;
- STI – "parallel" titania dye sensitised tiles with improved current output.

STI developed extensive testing facilities specifically designed to address thin-film photoelectrochemical cells. Their in-house built equipment is capable of testing and monitoring more than 100 devices simultaneously.

Pacific Solar has introduced a new "Plug & Power" AC module based system (Plug&Power™), using imported and locally manufactured crystalline Si cells in 2001, but eventually to use their new thin-film CSG product. Four demonstration systems will be built in 2002 using pilot-line cells, prior to construction starting in 2003 of a full production line for operation in 2005.

A number of new concentrator systems are under development and demonstration:

- Solar Systems are testing and demonstrating a new concentrator system at White Cliffs Solar Power station. A 200kWp plant is now under construction for the Pitjantjatjara Aboriginal community and a 1 MWp plant is planned for Broken Hill. The systems are currently based on Si cells, but work is continuing on development of non-silicon devices.
- The Australian National University (ANU) is developing parabolic trough and paraboloidal dish concentrator systems. A research system is being operated and monitored near Canberra and a 20 kWp system has been built in Rockingham, WA.
- The ANU is also developing a Combined Heat And Power Solar System which integrates PV electricity generation and solar hot water production.

h) Details of module production capacity under construction at end of 2001 but not yet in production.

BP Solar: Module production will be expanded to 8 MW by end 2002.

i) Trends in manufacturing and products for each manufacturer.

BP Solar is partway through an expansion of its cell and module production facilities at Homebush Bay, Sydney with emphasis on high volume world class manufacturing methodology and a technology move to higher performance screen printed processing. Both mono and poly crystalline cells and modules are produced. Output from the plant is expected to reach 20 MWp runrate capacity by end 2002. The facility will have the capacity to expand final cell production volume to around 40 MWp.

Sustainable Technologies International opened the world's first Titania Dye Sensitised Solar Tile and Wall Panel manufacturing facilities in 2001. The first phase has a capacity of 500 kWp. The company is working on up-scaling the manufacturing facilities and on the next generation designs for the Dye Sensitised Tile.

Pacific Solar continues the development of its thin-film CSG product. Pilot production is already underway and construction of a full scale production facility is scheduled to begin in 2003. It continues to develop and market its Plug&Power™ ac module

system for grid-connected rooftop applications and now has nationwide sales and distribution.

In addition to their cell development work, all manufacturers are developing new types of modules to suit different market niches, especially the building integrated PV market.

j) A description of year 2001 module prices.

Module prices for silicon products have remained stable over the past year and are not expected to change substantially in the coming year. Retail prices are typically around AUD 7 to 9 per Wp.

The STI DSC modules are 5% efficient, with panels priced at around $1000 per m^2.

k) Module prices in current and constant Australian dollars for the period 1992-2001 are shown in Table 4a.

Table 4a: Indicative PV module prices (AUD) 1992-2001

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Module price(s) Current AUD			7		8			8	8	8
Constant (AUD 2001)			9		9			9	8	8

3.2 Manufacturers and suppliers of other components

Table 5 summarises typical grid connect inverter prices in Australia during 2001.

Table 5: Price of inverters for grid-connected PV applications.

Size of Inverter	<1 KVA	1-10 KVA	10-100 KVA	>100 KVA
Average Price per kVA (AUD)		950-1 400	~ 1 000	

Business activities, trends and strategies for balance of system components:

- PV inverters and regulators

A number of Australian inverter manufacturers continue to supply inverters for both the grid and off-grid markets. These include Advanced Energy Systems, Enertec, Latronic Sunpower, Plasmatronics, Powercor Australia, Power Solutions Australia and Selectronics. Typical sizes are in the 1 – 10 kW range, although larger systems are also made. Some of these companies, as well as a number of others, also manufacture charge controllers and regulators for PV systems.

PV company Pacific Solar has developed its own module inverter, the IPC-1, for use in its Plug&Power ac module systems. It is now commercially produced in Sydney, with 1000 units manufactured in 2001, its first year of full production. Its IPC-2 model, currently going through international certification, will be suitable for both 50 and 60 Hz and 110V and 240V operation.

- Storage batteries and charge controllers

Development work continues on four main storage types:

- the Green Gel lead acid battery, being designed by BP Solar, Battery Energy and CSIRO specifically for PV applications, with improved charging regimes, lower maintenance, extended cycles and better temperature tolerance, as well as an integrated regulator and electronic controls.
- the Vanadium Redox battery, which is aimed at the electric vehicle and UPS markets and expects higher efficiencies and energy densities than lead acid batteries, as well as rapid charge and discharge capability.
- the Zinc Bromine battery which is being developed by the ZBB Energy Corporation for utility load management, larger scale remote power applications, UPS systems and electric vehicles.
- The cap-XX supercapacitor, which is being developed by cap-XX Pty Ltd and CSIRO as a short term storage / quick charge device for computers, PV systems and electric vehicles.

Century Yuasa is developing a remote electrolyte sensor for batteries in off-grid PV systems.

- Supporting structures

Support structures for ground mounted PV systems are usually manufactured for PV installers in their local area. Some standard structures are available through PV manufacturers.

A specific roof mounting frame developed by Pacific Solar for its Plug&Power™ modules is locally manufactured for domestic use and export.

Sydney based company PV Solar Energy is developing a plastic extruded frame for solar tiles, based on a Swiss design. The tiles are being installed on 79 homes in the second stage of the Newington Solar Village, using BP Solar's 85 Wp "Saturn" cell laminates.

Special frame systems are also being developed for use in the Solar Kogarah project.

3.3 System prices

Table 6 provides a summary of turnkey prices (excluding GST) for the various categories of PV installation. Prices do not include recurring charges after installation, such as battery replacement or operation and maintenance, nor do they include additional costs incurred due to the remoteness of the site or special installation requirements.

Table 6: Turnkey Prices in 2001 of Typical PV Applications

Category/Size	Typical applications and brief details	Current price per Wp in AUD
OFF-GRID Up to 1 kWp	Household and remote industrial uses	20-25
OFF-GRID >1 kWp	Pastoral properties and remote agricultural and industrial uses	17-20
GRID-CONNECTED Specific case	1-3 kWp residential roof-mounted systems	10-12
GRID-CONNECTED Up to 10 kWp	Commercial and institutional buildings	14
GRID-CONNECTED >10 kWp	Power stations, light industrial applications	12-13

Table 6a provides an indication of Australian trends in turnkey prices of selected PV applications.

Table 6a: Australian trends in system prices (current and constant AUD) for off-grid applications up to 1 kWp (Average)

YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Price AUD/Wp - Current		24		22		30	30	30	22	22
Constant (AUD 2001)		32		27		36	35	34	23	22

Table 6b: Australian trends in system prices (current and constant AUD) for grid connected applications up to 10 kWp (Average)

YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Price AUD/Wp - Current						11	12	12	14	14
Constant (AUD 2001)						13	14	14	14	14

3.4 Labour places

Estimated labour places (where these are mainly involved with PV) during 2001 were as follows:

a) Research and development (not including companies);

30

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

320

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

c1) Distributors;

40

c2) System and installation companies;

190

c3) Utilities and government.

20

Total labour places: 600.

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

- Promotional initiatives

  The off-grid PV market is set to boom with the commencement of the Renewable Remote Power Program. The Program varies by State, but in general provides a 50% rebate for renewable energy components when used to replace diesel fuel based power generation. Activities in some States have already increased ten fold, with the majority of systems approved using PV.

- Utility perception of PV

  Although maintaining a general interest in PV, few electricity retailers are currently installing PV systems, although some own and operate systems installed during the 1990's. The biggest current utility program is the Northern Territory Power and Water Authority program aimed at installing 225 kWp and 55 kWp systems for peak load reduction in its diesel power stations. If successful, more such systems are planned.

  Sydney based utility EnergyAustralia successfully tendered for the installation of 148 kWp of roof integrated PV as part of the Solar Kogarah urban development project. Imported Unisolar thin-film amorphous product will be laminated on a spandek roof base. A translucent polycrystalline PV foyer design increases capacity to 160kWp.

  Brisbane based energy retailer Energex promotes and sells PV to its franchise customers and also offers a high buy-back rate for PV generation in excess of the user's load.

- Changes in public perceptions of PV

  The public is generally supportive of PV and interested in its use, if affordable. This is clearly evidenced by the large number of grant applications received for both the PV Rooftop Program and the Renewable Remote Power Generation Program. Both programs have had to put in place stricter prioritization and grant limits than initially proposed, in order to cope with the overwhelming demand. Even with the grants, PV is still an expensive option for grid-connected households, so that the high public interest is indicative of environmental concerns.

- Major new projects or initiatives

  In NSW a new Solar Schools program will begin in 2002, involving the installation of 1.5 kWp systems on 25 schools around the State. This will add to the 18 school systems previously installed under a NSW Government / Integral Energy program.

- Planned developments

  Several new commercial building projects are expected to come on line in 2002, including the Kogarah Council building, the Melbourne University building and the Edwards Street building in Brisbane. Plans are also underway for an innovative solar building as part of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Distributed Generation Research Centre in Newcastle, NSW. The building is expected to be completed in 2003 and will include PV systems manufactured by all Australian PV companies. These buildings will provide valuable

and highly visible demonstrations of building integrated PV, which may increase interest in building applications.

In the off-grid market, the PV concentrator systems being installed by Solar Systems, if successful, may significantly increase interest in PV use in diesel power stations.

4.2 Indirect policy issues

In line with the Australian Government's requirement that the implications of any new international agreements are rigorously assessed, Australia will be conducting a Treaty Impact Analysis of the Kyoto Protocol which will include consultations with all levels of government and other stakeholders.

Following from the US decision not to ratify the Kyoto Protocol, it seems unlikely that Australia will do so. This means that government interest in greenhouse gas reduction strategies in Australia and as part of Australia's trade and overseas aid programs is likely also to be reduced. Funding for the Australian Greenhouse Office, which has been the focus of much of Australia's renewable energy policy development, is likely to be reduced as current programs finish. Of particular relevance to PV is the conclusion of the AGO PV Rooftop Program, which provided assistance for grid connected as well as off-grid rooftop PV systems, and which accounted for 30% of all PV sales in Australia in 2001. The program concludes in 2002/03, although some funding is expected to carry over until 2003/04, after which there may be a slump in the BIPV market.

Nevertheless, at State level, interest in and support for renewable energy is growing, driven by prospects of employment creation and industry development. Sustainable energy development offices have now been set up in 5 states and proposed for another one. This is focussing a range of policy mechanisms, from planning guidelines, through industry development, waste management, transport and energy to assessment of sustainable options and is likely to have a strong longer term influence on government policy frameworks.

4.3 Standards and codes

Work continued in 2001 on converting the 1997 guidelines for grid-connection of inverters (largely for small PV systems) into an Australian Standard (numbered AS 4777).

There is interest in the development of standardized net metering for small systems and for inclusion of PV in energy efficient building codes. The development of straightforward grid connection agreements for small systems is also being examined.

5 The Future

Renewable Energy Action Agenda

The Sustainable Energy Industry Association of Australia developed a Renewable Energy Technology Roadmap in 2001, as an outcome of the Renewable Energy Action Agenda. This agenda was developed in conjunction with renewable energy and related industry groups and aims to increase the size of the industry to one with a turnover of $4 billion by 2010 with five key strategies:

- developing the market
- building community commitment
- building industry capability
- setting the policy framework and
- encouraging a culture of innovation.

The Action Agenda sets out to; leverage government support to develop business opportunities, promote renewable transport fuels, implement an export strategy, increase community commitment, improve the reliability and quality of renewable energy products and services, ensure skilled people are available to support industry growth, improve access to finance, establish a renewable energy peak industry forum and implement a renewable energy industry innovation strategy.

The Technology Roadmap examines each renewable energy technology and its application areas and identifies developments required in order for Australian industry to increase its market. Specific Roadmaps for each technology have been recommended.

Mandatory Renewable Energy Target (MRET)

The Australian MRET, which aims for an additional 9,500 GWh of renewable energy based electricity by 2010 (between 1 and 2% of total electricity used), has now been operating for one year and liable parties, which are electricity retailers and large users, are beginning to get a feel for the technologies, prices and issues involved with obtaining Renewable Energy Certificates (RECs) from the various energy sources. Whilst PV had not initially been expected to capture any significant portion of the RECs market due to its relatively high capital cost, delays and problems emerging with siting of wind generators, with fuel sources and emissions from bioenergy plants and with technical development of solar thermal systems, may well see PV systems emerge as a realistic option, with significantly lower externalities and hence up-front project development costs than some of the other renewable energy options. However, the current value of RECs being traded is around 5% of the typical cost of PV, so that MRET is not yet a strong driver.

Energy Market Review

A current review of the Australian energy market may see some changes to MRET, with several submissions calling for the target to be increased to 10% of electricity used by 2010. A portfolio approach has also been suggested, which may see a specific target set for PV, and hence make MRET of more relevance to PV. Calls for greater market action on the demand side may also provide better market signals for distribution generation, including PV.

The Review may also result in changes to the operation of the National Electricity Market, including access for renewable energy systems. There is also a strong push for the Review to lead to the development of a longer term Energy Strategy for Australia.

Annex A Method and accuracy of data

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

   Data was collected directly from individual companies, utilities and government departments and from web pages and other published material.

b) An estimate of the accuracy of the data if this is worse than 10 %. The accuracy can be given as a tolerance (either 20kWp ± 20% or 20kWp ± 4 kWp) or as a range (e.g. 16kWp to 24kWp).

   Most within ±10%.