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# National Survey Report of PV Power Applications in AUSTRALIA 2013



PHOTOVOLTAIC  
POWER SYSTEMS  
PROGRAMME

**Prepared by the Australian PV Institute**

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PVPS

**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, 2013*

**The Australian PV Institute**

The objective of the APVI is to support the increased development and use of PV via research, analysis and information.

APVI provides:

- Up to date information and analysis of PV developments in Australia and around the world, as well as issues arising.
- A network of PV industry, government and researchers who 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 the IEA SHC and PVPS Programmes, including:
  - PV Information Exchange and Dissemination
  - PV System Performance
  - High Penetration PV in Electricity Grids.

More information on the APVI can be found: [www.apvi.org.au](http://www.apvi.org.au)

**ACKNOWLEDGEMENTS**

**Front page photo:** Murdoch University renewable energy training facilities

The Institute receives funding from the **Australian Renewable Energy Agency (ARENA:** [www.arena.gov.au](http://www.arena.gov.au) ) to assist with the costs of IEA PVPS Programme membership, Task activities and preparation of this report.

This report is prepared on behalf of and with considerable input from members of the Australian PV Institute and the wider Australian PV sector.

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## 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 24 participating countries are Australia (AUS), Austria (AUT), Belgium (BEL), 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), Thailand (THA), 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, the US Solar Energy Industries Association and the Copper Alliance 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](http://www.iea-pvps.org).

Australia's participation in the PVPS is undertaken by the Australian PV Institute and is supported by ARENA. The Australian Executive Committee representative is Dr Muriel Watt, IT Power (Australia). In 2013 Australia participated in:

- Task 1: Leader - Mr Greg Watt, CoB Communications
- Task 13: Leader – Mr Lyndon Frearson, CAT Projects
- 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 promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objective: To enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy 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 2013. Information from this document will be used as input to the annual Trends in Photovoltaic Applications report.

The PVPS website [www.iea-pvps.org](http://www.iea-pvps.org) also plays an important role in disseminating information arising from the programme, including national information.

## 1 INSTALLATION DATA

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. Other applications, such as small mobile devices, are not considered in this report.

For the purposes of this report, PV installations are included in the 2013 statistics if the PV modules were installed and connected between 1 January and 31 December 2013.

### 1.1 Applications for Photovoltaics

The market for PV installations connected to central grids in Australia continues to increase and has represented the largest market for PV since 2009. In 2013, the majority of installations took advantage of incentives under the Australian Government's Renewable Energy Target (RET) mechanisms, with further drivers provided by grants and finance assistance from the Australian Renewable Energy Agency and the Clean Energy Finance Corporation. The largest PV market is for rooftop systems on private residences. Average system size has increased steadily over the past three years, as shown in Figure 1.

With PV having reached grid parity against retail electricity tariffs in many parts of Australia and government support reducing, the market is stabilising but remaining buoyant. The commercial, light industry and utility sectors have grown more slowly than the residential sector to date. Commercial sector interest in using PV to displace purchased power is increasing as electricity tariffs increase. Larger scale plants are being installed via the Australian Government Flagships program and the ACT Government's Feed-In Tariff program.

The second largest installed capacity of PV in Australia is for off-grid residential systems where PV displaces diesel in hybrid power systems. Off-grid industrial and agricultural applications are also an important market. These include power systems for telecommunications, signaling, cathodic protection, water pumping and lighting. Significant markets also exist for fuel saving and peak load reduction on diesel grid systems in communities, mine sites and tourist locations. There is also a reasonably significant market for recreational PV applications for caravans, boats and off-road vehicles.

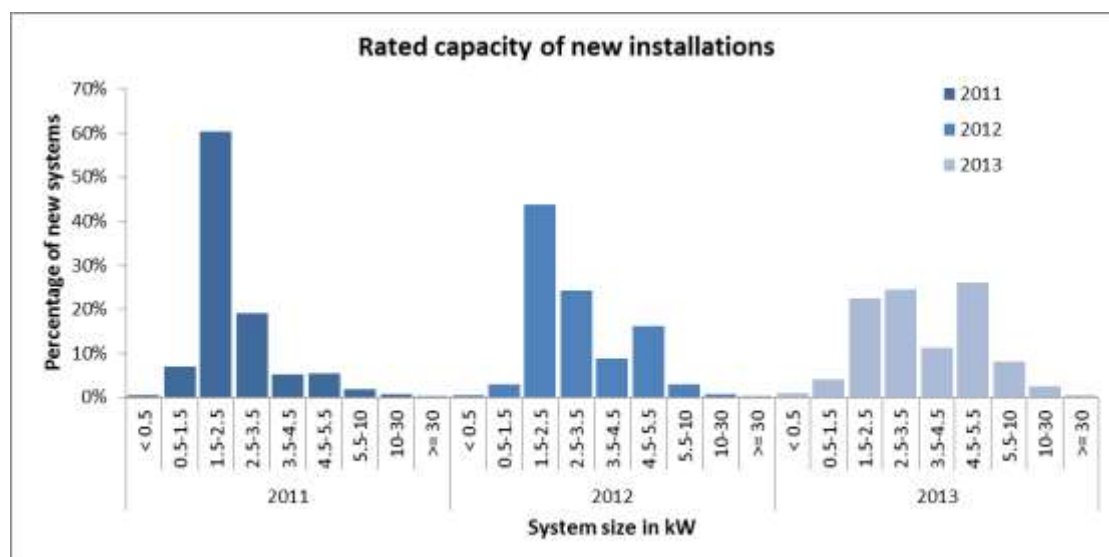
### 1.2 Total photovoltaic power installed

The PV power installed in 4 sub-markets during 2013 is shown in Table 1 and its contribution to the total electricity sector is shown in Table 2. PV data for the tables above are derived from the Renewable Energy Certificate (REC) Registry of the Australian Government's Clean Energy Regulator and information supplied by PV companies. Renewable Energy Certificates can be created up to one year after system installation, hence data available by the time of publication of this report may not include all 2013 installations. In addition, REC data is not broken down by application, so that the separation of domestic and non-domestic markets for the off-grid categories is based on industry survey data and may not be correct within  $\pm 10\%$ . In addition, not all installed PV is registered with the CER. PV output is derived from the REC registry at a weighted average of 1400 GWh/GW.

Overall Australian electricity generation capacity and demand are derived from reports by the Australian Energy Market Operator: [www.aemo.com.au](http://www.aemo.com.au), and includes the National Electricity Market, the WA South West Integrated System and North West Integrated System.

A summary of the cumulative installed PV Power, from 1992-2013, broken down into four sub-markets is shown in Table 3 and Figure 2.





**Figure 1: Trends in PV system size Australia 2011-2013**

**Table 1: PV power installed in Australia during calendar year 2013 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 2013 (MW)	9	5	794	2	810

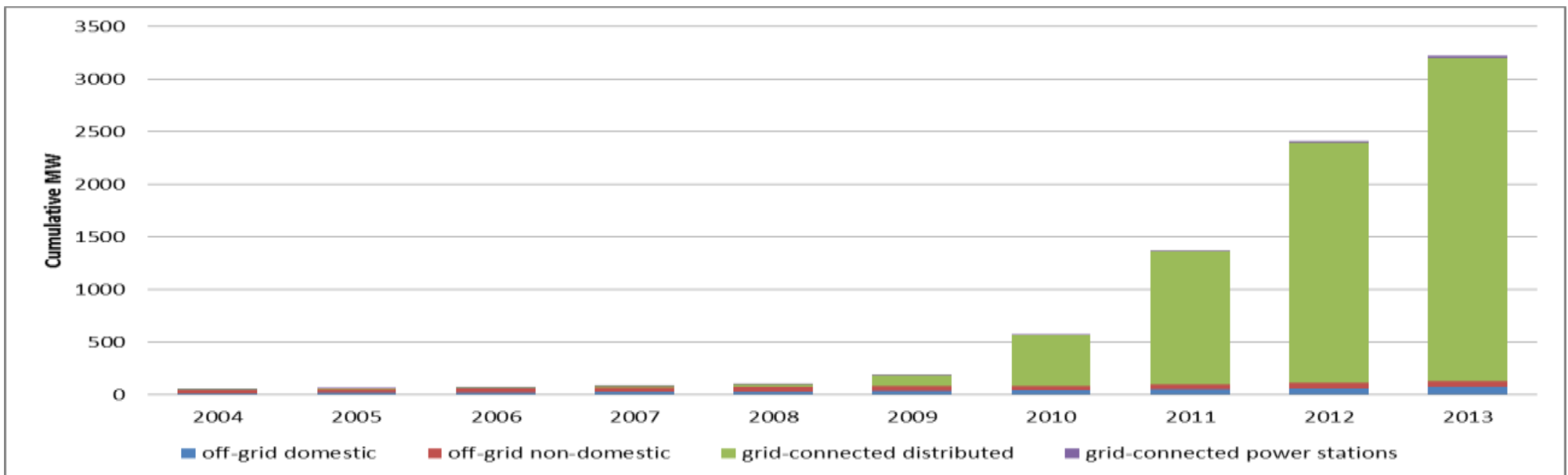
\*including diesel grids

**Table 2: PV power and the broader national energy market.**

<i>Electricity capacities and energy production</i>	2013 numbers	2012 numbers
Total power generation capacities (all technologies)	48 GW	54 GW
Total power generation capacities (renewables including hydropower)	11 GW	
Total electricity demand (= consumption)	199 TWh (excl PV)	207 TWh
New power generation capacities installed during the year (all technologies)	1300 MW	1482 MW
New power generation capacities installed during the year (renewables including hydropower)	1300 MW	
Total PV electricity production	4.5 TWh	3.4 TWh
Total PV electricity production as a % of total electricity consumption	2.3%	1.3%

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

Sub-market	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
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	54,6	64,6	74
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	46,89	53,02	58
Grid-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	1267,9	2275,9	3070
Grid-central				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	7,40	21,5	24
<b>TOTAL (MWp)</b>	<b>7,30</b>	<b>8,90</b>	<b>10,70</b>	<b>12,70</b>	<b>15,70</b>	<b>18,70</b>	<b>22,52</b>	<b>25,32</b>	<b>29,21</b>	<b>33,58</b>	<b>39,13</b>	<b>45,63</b>	<b>52,30</b>	<b>60,58</b>	<b>70,30</b>	<b>82,49</b>	<b>104,5</b>	<b>187,6</b>	<b>570,9</b>	<b>1376,8</b>	<b>2415,0</b>	<b>3225</b>



**Figure 2: Australian PV Installations by Category 2004-2013.**

## 2 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of the Australian PV market. Direct support policies influence PV deployment by incentivizing, simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can drive PV deployment.

### 2.1 Direct support policies

**Table 4: Summary of PV support measures operating in Australia in 2013**

	On-going measures	Measures that commenced during 2013
Feed-in tariffs	✓ (both gross and net, depending on State)	
Capital subsidies for equipment or total cost		✓
Green electricity schemes	✓	
PV-specific green electricity schemes	✓	
Renewable portfolio standards (RPS)	✓	
PV requirement in RPS		
Investment funds for PV	✓	
Income tax credits		
Prosumers' incentives (self-consumption, net-metering, net-billing)	✓ (Depending on State)	
Commercial bank activities e.g. green mortgages promoting PV	✓	
Activities of electricity utility businesses	✓	
Sustainable building requirements	✓	

### 2.2 Direct Support measures

#### 2.2.1 The Renewable Energy Target

The 45 000 GWh Renewable Energy Target (RET) consists of two parts – the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). 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. Although the RET was reviewed in 2012, the new government has initiated a new review in 2014 and so the future settings of the RET are once again uncertain.

##### *Large-scale Renewable Energy Target (LRET)*

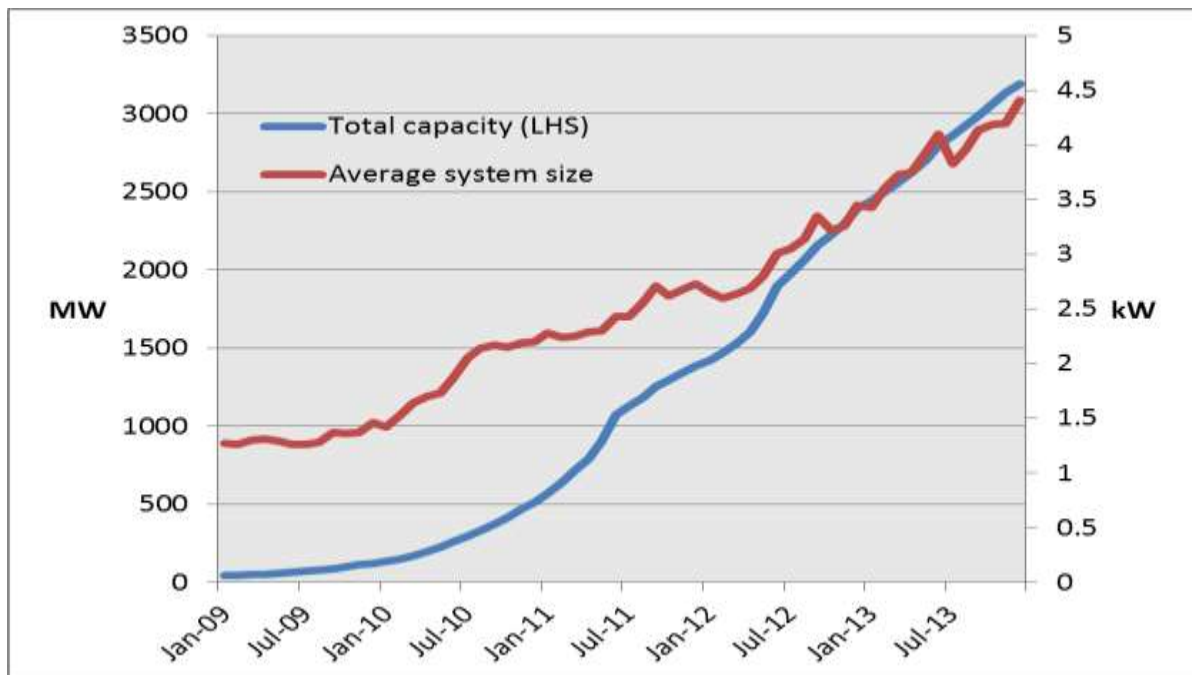
The LRET, covering large-scale renewable energy projects like wind farms, commercial-scale solar and geothermal, will deliver the majority of the 2020 target. The LRET includes legislated annual targets, as shown in Table 5.

**Table 5: Annual Generation Targets under the Large-scale Renewable Energy Target**

Year	Target (GWh)
2011	10 400
2012	16 763
2013	19 088
2014	16 950
2015	18 850
2016	21 431
2017	26 031
2018	30 631
2019	35 231
2020	41 850
2021-2030	41 000

#### *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). Deeming arrangements mean that PV systems up to 100 kWp can claim 15 years' worth of STCs up front up to 2016, but each year from then on will receive one year less deeming. Installed capacity and system size from 2009 to 2013 are shown in Figure 3.



**Figure 3: Cumulative installed capacity and average system size for SRES systems 2009-2013.**

The Clean 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 is no cap on the number of STCs that can be created. A cap applied to the number of Solar Credit multiplier certificates that could be created for off-grid systems between 1.5 and 20kW in size but this mechanism ceased from 1 July 2013.

### **2.2.2 The Australian Renewable Energy Agency (ARENA)**

ARENA has two objectives: to improve the competitiveness of renewable energy technologies, and to increase the supply of renewable energy in Australia. It has an AUD 2.5 billion budget to:

- fund renewable energy projects
- support research and development activities
- support activities to capture and share knowledge.

ARENA is supportive of all renewable energy technologies and projects across the various stages of the innovation chain – from research in the laboratory to large scale technology projects. More details are provided under Section 3.

#### *Solar Flagships*

The Solar Flagship program is now administered by ARENA. A project by AGL/First Solar was selected for a Solar Flagship grant. It will deliver projects with a total nominal capacity of 155 MWac at Nyngan (102 MW) and Broken Hill (53 MW) in New South Wales. Details are provided in Figure 4. The system frames are being manufactured by IXL in Adelaide and construction of both plants is expected to be complete by end 2015.

In addition to supplying the solar modules for the projects, First Solar will provide the engineering, procurement, and construction (EPC) services, as well as operations and maintenance (O&M) support for the first five years of operation.

The Australian Government will provide AUD 129,7 million in funding to support project implementation, and the NSW Government will provide AUD 64,9 million. Total capital expenditure for the two solar projects is expected to be approximately AUD 450 million. An additional AUD 40,7 million has been made available to the Universities of Queensland and NSW for education infrastructure research funding associated with the Flagship, as discussed in Section 3.3.11.

<b>Capacity/Generation:</b>	<b>Nyngan</b>	<b>Broken Hill</b>
MW (AC)	102	53
Annual GWh (at plant boundary)	233.4	126
AC Capacity factor (at plant boundary)	26%	27%
<b>Construction:</b>		
Scheduled construction start	Jan 2014	July 2014
Scheduled construction end	June 2015	Nov 2015
Peak Direct construction jobs created	300	150
<b>Design Details:</b>		
Site area (ha)	460	200
Solar Field area (ha)	250	140
Number of modules (approx)	1,350,000	650,000
Number of posts (approx)	150,000	75,000
Number of inverters	154	80
Number of strings	105,000	55,000
<b>Environmental Benefits:</b>		
Equivalent NSW homes powered @ 7 MWh/yr	33,300	17,000
Equivalent cars off the street	53,000	29,000

**Figure 4: Details of the First Solar / AGL Solar Flagship Projects  
(Source: First Solar)**

### **2.2.3 Clean Energy Finance Corporation**

The Clean Energy Finance Corporation (CEFC) is a Commonwealth Government initiative that invests using a commercial approach to overcome market barriers and mobilise investment in renewable energy and lower emissions technologies. The current government intends to disband the CEFC as soon as it has the balance of power in the Australian senate, which could occur in July 2014.

The CEFC-funded PV projects include the 56MW Solar Farm at Moree and the Australian Agricultural Company's installation of grid-connected PV.

The 56MW Solar Farm at Moree covers 350 hectares and consists of 250,000 single axis tracking solar panels. It is sponsored by Fotowatio Renewable Ventures (FRV) and Pacific Hydro, with the CEFC providing AUD 60 million in senior debt finance.

The AACo project involves the installation of grid-connected PV between 2kW and 99kW at 15 locations throughout Australia. The CEFC and NAB bank are co-financing the project, with the CEFC providing AUD 500 000 of the AUD 990 000 project total. Trina Solar are supplying the panels and SMA Solar Technology are providing the inverters, which will be installed by Infinity Solar.

### **2.2.4 State and Territory Support**

State Governments support a range of research, development and demonstration projects, as summarised in Section 3.4 and highlighted through various case studies cited in this report.

A range of State based feed-in tariffs applied across Australia in 2013 for systems less than 30kW, as shown in Table 6. The Australian Capital Territory also provided FiTs via the Large-scale Solar Auction as discussed below.

### *The ACT Large-scale Solar Auction*

The 40MW ACT Large-scale Solar Auction commenced on 27 January 2012 and closed on 16 April 2013. Three proponents were successful in being awarded a 20 year Grant of Feed-in Tariff Entitlement, namely:

- FRV Royalla Solar Farm Pty Limited for a 20MW proposal, in the Tuggeranong district of the ACT (fixed plate PV);
- OneSun Capital 10MW Operating Pty Ltd for a 7MW proposal to be located in the Coree district of the ACT (fixed plate PV); and
- Zhenfa Canberra Solar Farm One Pty Ltd for a 13MW proposal to be located in the Tuggeranong district (mainly fixed plate PV but including around 0.5MW of ground mounted tracking PV).

The FRV project commenced construction in October 2013, and will be commissioned in July 2014. The Zhenfa project has issued EOs for the construction stage <http://www.mlsolarpark.com.au/default.htm>, while the remaining project is yet to complete the development application process.

The Solar Auction represented the first capacity release under the ACT *Electricity Feed-in (Large-scale Renewable Energy Generation) Act 2011*, which now provides for up to 550MW of renewable energy generation capacity for generators located in the National Electricity Market and connected to that network.

The ACT has also announced a further auction process for proposals incorporating newer solar technologies [http://www.environment.act.gov.au/energy/next\\_generation\\_solar](http://www.environment.act.gov.au/energy/next_generation_solar) and has also allocated a new Community Solar FiT for up to 1MW, which will commence in 2014 [http://www.environment.act.gov.au/energy/community\\_solar](http://www.environment.act.gov.au/energy/community_solar).

A review of the Solar Auction was completed in October 2013 and can be accessed at [http://www.environment.act.gov.au/energy/solar\\_auction](http://www.environment.act.gov.au/energy/solar_auction).

### *NSW Office of Science and Research*

The NSW Government provides funding to support innovation and investment in the State's research and development capacity under the Research Attraction and Acceleration Program (RAAP), formally the Science Leveraging Fund (SLF).

Through the NSW Office of Science and Research, which is responsible to the NSW Chief Scientist and Engineer, annual funding of AUD 5 million is provided to the private and university sectors to advance key research programs and infrastructure, including solar PV, which are important to the NSW Government.

NSW Office of Science and Research has previously provided solar PV funding to Australian Solar Institute (ASI), Australian Research Council (ARC), Education Investment Fund (EIF) and Australian National Fabrication Facility (ANFF) projects, under the SLF. This investment has translated to projects regarding 'hot carrier solar cells', 'overcoming performance limitations of commercial solar cells', and 'improved PV energy conversion' to name but a few.

A strong research and development capability is a critical driver for innovation in the State's economy. Building, supporting and attracting high-technology industry and growing a highly skilled workforce are all factors that underpin productivity growth.

Investment by Government, industry and individuals in R&D has long-term benefits, which include higher standards of living, economic prosperity, improved social and physical infrastructure and the generation of further knowledge, discoveries and services.

By enabling a targeted investment and stronger partner links, the RAAP aims to give NSW a greater role in the future of key national research development and infrastructure and contribute to jobs creation in the State.

**Table 6: Australian State and Territory Feed-in Tariffs in 2013**

State	Start Date	Size Limits	Rate AUDc/kWh	Scheme end	Type	Eligibility
<b>Victoria</b>						
Premium FiT (closed 1 Jan 2012)	1 Nov 2009	5 kW	60	2024	Net	Residential, community, small business
Transitional (closed 30 Sept 2012)	1 Jan 2012	5 kW	25	31 Dec 2016	Net	Residential, community, small business
Standard (closed 30 Sept 2012)	1 Jan 2012	100 kW	Retail rate	31 Dec 2016	Net metering	Residential, community, small business
New Standard	1 Oct 2012	100 kW	8 (updated each year)	Open ended	Net	Residential, community, small business
Comments	Customers lose their FiT and revert to the New Standard FiT if they change their system size or move house. It is compulsory for retailers to offer at least the New Standard FiT rate.					
<b>South Australia</b>						
Groups 1, 2 & 3 (closed 30 Sept 2011)	1 July 2008	10 kVA 1Ø 30 kVA 3Ø	44	30 June 2028	Net	A facility that consumes less than 160MWh/yr
Group 4 (closed 30 Sept 2013)	1 Oct 2011	10 kVA 1Ø 30 kVA 3Ø	16	30 Sept 2016	Net	A facility that consumes less than 160MWh/yr
Group 5	1 Oct 2013	10 kVA 1Ø 30 kVA 3Ø	9,8 (updated each year)	Open ended	Net	A facility that consumes less than 160MWh/yr
Comments	Groups 1, 2 & 3 differ according to the amount of electricity the FiT applies to and when the system was logged with the network operator. The Group 5 FiT is called the 'minimum retailer payment' and customers may receive it in addition to their Group 1-4 FiT. It was originally set at AUD 0,071/kWh for 2011-12, AUD 0,098/kWh for 2012-13, and AUD 0,112/kWh for 2013-14, however was left at AUD 0,098/kWh for July to Dec 2013 and will be reduced to AUD 0,076/kWh from Jan 2014 (and AUD 0,006/kWh of the Australian carbon price legislation is abolished). Group 1-4 customers may convert to Group 5 if they change their system size or move house. They definitely convert to Group 5 if they install storage.					
<b>ACT</b>						
Gross FiT (closed 31 May 2011)	1 March 2009	30 kW	50,05 (<10kW), 40,04 (10-30kW), after 1 July 2010 45,7 (<30kW)	20 years after connection	Gross	Residential, business



Gross FiT (closed 13 July 2011)	1 April 2011	30-200 kW	34,27	20 years after connection	Gross	Residential, business
Net metering (closed 30 June 2013)	14 July 2011	30 kW	Retail tariff	30 June 2020	Net metering	Residential, business
Solar Buyback Scheme	1 July 2013	30 kW	7,5	Open ended	Net	Residential, business
Comments	Although the Gross FiT (30kW) was closed on 31 May 2011, <30kW systems were made eligible for the Gross FiT (30-200kW) from 12 July 2011 to 13 July 2011 to allow these systems to access the cap originally set aside for systems 30kW to 200kW.					
<b>Northern Territory</b>						
Alice Springs Solar City FiT (closed 31 May 2013)	May 2008	2 kW	Ranged 45,76 to 60,40 from 2008/09 to June 2013	30 June 2013?	Gross	Alice Springs residential, business
Net metering	1 June 2013	30 kVA	Retail tariff	Open ended	Net metering	NT wide
Comments	The Alice Springs PV systems were provided as a package, with the largest being 2kW. The FiT consisted of the retail peak rate (increased over time) plus AUD 22,65/kWh.					
<b>Queensland</b>						
Solar Bonus Scheme (closed 10 July 2012)	1 July 2008	10 kVA 1Ø 30 kVA 3Ø	44	1 July 2028	Net	Consumers with less than 100MWh/yr
New SBS	11 July 2012	5 kW	around 8	Open ended	Net	Consumers with less than 100MWh/yr
Comments	The SBS net amount will not be mandated for SE Qld as of 1 July 2014. Customers may default to the new SBS FiT if they change their system size or move house.					
<b>New South Wales</b>						
Solar Bonus Scheme 60 (closed 27 Oct 2010)	1 Jan 2010	10 kW	60	31 Dec 2016	Gross	Residential
SBS 20 (closed 28 April 2011)	28 Oct 2010	10 kW	20	Until 31 Dec 2016	Gross or Net	Residential
Current SBS	28 April 2011	10 kW	around 8 (updated each year)	Open ended	Net	Residential
Comment	Customers may default to the 20 FiT if they change their system size or move house. It is not compulsory for retailers to offer the 'current SBS'					
<b>Western Australia</b>						
Residential FiT scheme (closed 1 Aug 2011)	1 July 2010	5 kW (city) 10 kW 1Ø 30 kW 3Ø (country)	40 to 30 June 2011 20 from 1 July 2011	10 years after installation	Net	Residential
RE Buyback Scheme	2005	5 kW to 1 MW	Currently 8,8529 to 50	Open ended	Net	Residential, Commercial (Horizon Power)

Comments	The amount of the REBS FiT depends on the local cost of generation, the retail tariff and whether residential or commercial					

### **2.2.5 Prosumer development measures**

Self-consumption of electricity is allowed in all jurisdictions in Australia. The schemes through which this occurs are described in Table 6. Currently no additional taxes or grid-support costs must be paid by owners of residential PV systems (apart from costs directly associated with connection and metering of the PV system), although there is significant lobbying from utilities for additional charges to be levied on PV system owners.

### **2.2.6 Rural electrification measures**

#### *Remote Indigenous Energy Program (RIEP)*

The Remote Indigenous Energy Program was established in July 2011, with service delivery commencing July 2012. Similar to the Bushlight program, RIEP will install fit-for-purpose renewable energy systems in up to 50 smaller remote Indigenous communities, provide energy efficiency education, training in basic system maintenance and repair and maintenance of selected existing systems. To date initial community engagement and field and concept design work has been undertaken and the first systems were installed towards the end of 2013.

#### *Regional Australia's Renewables (RAR)*

The Australian Renewable Energy Agency's Regional Australia's Renewables (RAR) initiative supports trials of renewable energy solutions, including hybrid systems, in regional and remote locations with the aim of increasing the use of these technologies for power generation once they become affordable. The initiative has two parts:

#### **1. The RAR Industry Program (I-RAR)**

The RAR Industry Program (I-RAR) aims to build a portfolio of renewable energy solutions in regional and remote Australia, focusing on hybrid and integrated systems in off-grid and fringe-of-grid communities. It will also contribute to knowledge sharing and skills development, especially in regional and remote areas.

#### **2. The Community and Regional Renewable Energy Program (CARRE)**

The RAR Community and Regional Renewable Energy Program (CARRE) aims to demonstrate viability and reliability of renewable energy systems in grids for small communities and islands, grow supporting technologies, show commercial viability and contribute to knowledge sharing.

### **2.2.7 Support measures phased out in 2013**

#### *Feed-in Tariffs*

2013 marked the end of FiTs that actively supported PV. The South Australian AUD 16c FiT and the ACT net metered FiT all changed to a net FiT paid on the assumed avoided cost for the retailer, and the Northern Territory Alice Solar City FiT changed to a net metered FiT. In all other jurisdictions new PV systems receive only the retailer's assumed avoided cost. Some retailers choose not to offer any payment for PV exports.

### *National Solar Schools Program*

The Australian Government's National Solar Schools Program (NSSP) offered eligible primary and secondary schools the opportunity to apply 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 was capped in each financial year and annual funding rounds were held. Applications were assessed against three criteria – value for money, environmental benefit and educational benefit. Additionally, to allow funding to be directed to schools in most need, applications from schools located in remote or low socio-economic areas received additional weighting. The program ran from July 2008 to June 2013.

Schools across Australia responded with great enthusiasm to the NSSP. Since the program commenced, over 8 300 schools registered their interest to participate (88% of all eligible schools). Over the life of the program more than AUD 217 million in funding has been awarded to over 5 300 schools (56% of all eligible schools) for PV and other measures. Around 90% of approved schools have chosen to install a PV system with their NSSP funding. Several State Governments have provided additional funding.

#### **2.2.8 Measures currently discussed but not yet implemented**

The Government proposes to introduce an emissions reduction fund to replace the emissions trading scheme. This will involve an auction for the lowest cost emission reduction projects, with the winners receiving payments for emission reductions reported each year. At this stage, it seems unlikely that PV projects will be eligible.

### **2.3 Indirect policy issues**

Current reviews of electricity tariff structures in many jurisdictions may see restrictions placed on PV above specified penetration levels, and also a reduction in the value of PV electricity via a separation of fixed and network charges from energy charges.

#### **2.3.1 International policies affecting the use of PV Power Systems**

Recent anti-dumping policies implemented in Europe and the US are now being investigated in Australia. Despite very low levels of local manufacture, this could result in PV module price increases.

#### **2.3.2 Taxes on pollution (e.g. carbon tax)**

Australia currently has an emissions trading scheme with a carbon price levied on facilities producing more than 25,000 tCO<sub>2</sub>-e per year. These include electricity generation, stationary energy, landfills, wastewater, industrial processes and fugitive emissions.

At the end of each financial year, liable entities must surrender one carbon unit for every tCO<sub>2</sub>-e that they have produced in that year. There are two stages to the carbon pricing mechanism:

- **Fixed price**—The carbon price is fixed for the first three years. In 2012–13 it was AUD 23 a tonne of carbon, in 2013–14 it is AUD 24,15 a tonne and in 2014–15, it will be AUD 25,40 a tonne. Liable entities can purchase units up to their emissions levels. Purchased units cannot be traded or banked.
- **Flexible price**—From 1 July 2015, if the scheme is still in operation, the price will be set by the market. Most units will be auctioned by the Clean Energy Regulator. The number of units the Government issues each year will be limited by a pollution cap set by regulations.

If a liable entity does not surrender any or enough units, it must pay a 'unit shortfall charge':

- from 2012 to 2015, this charge is set at 130% of the fixed price
- from 2015 onwards, once the carbon pricing mechanism moves to the flexible price period, the unit shortfall charge will be up to 200% of the benchmark average auction price for the relevant period.

The current Australian Government is planning to dismantle the emissions trading scheme and replace it with a Direct Action Plan, with details yet to be established.

### 3 HIGHLIGHTS OF R&D

#### 3.1 The Australian Renewable Energy Agency (ARENA)

ARENA is the main R&D support measure in Australia specific to renewables. ARENA has an AUD 2,5 billion budget and two objectives: to improve the competitiveness of renewable energy technologies, and to increase the supply of renewable energy in Australia. It achieves this by

- funding renewable energy projects
- supporting research and development activities
- supporting activities to capture and share knowledge.

Recent programs have included:

- [Emerging Renewables Program \(ERP\)](#) – supports the development, demonstration and early stage deployment of renewable energy technologies
- Southern Cross Renewable Energy Fund – under the [Renewable Energy Venture Capital Fund](#) – provides management expertise and makes equity investments in early-stage Australian renewable energy companies
- [Supporting High-value Australian Renewable Energy Knowledge \(SHARE\)](#) – increases awareness of renewable energy solutions and shares research knowledge
- [Accelerated Step Change Initiative \(ASCI\)](#) – provides funding for exceptional demonstration, deployment and commercialisation projects not captured by other ARENA programs.
- [Integrating Renewables in the Grid](#) – examines barriers to the integration of renewables into the electricity grid
- [Regional Australia's Renewables](#)
  - [Regional Australia's Renewables – Industry Program \(I-RAR\)](#) – supports the development of renewable energy solutions in off-grid and fringe-of-grid locations
  - [Regional Australia's Renewables – Community and Regional Renewable Energy program \(CARRE\)](#) – supports the demonstration of technologies that can feed more renewable energy into off-grid communities
- [Research and Development Program](#) – supports world-class research and development in priority renewable energy technologies.

In 2013, ARENA provided approximately AUD 168 million towards PV related R&D projects, with a further 78,5 million provided for the Solar Flagship project.

#### 3.2 The Australian Research Council

The ARC is a statutory agency within the Australian Government. Its mission is to deliver policy and programs that advance Australian research and innovation globally and benefit the community. The ARC provides advice to the Government on research matters, manages the National Competitive Grants Program (NCGP), and administers Excellence in Research for Australia (ERA).

Through the NCGP - a significant component of Australia's overall investment in research and development - the ARC supports the highest-quality fundamental and applied research and research training through national competition across all disciplines, with the exception of clinical medicine and dentistry. In 2013 approximately AUD 7,6 million was provided for R&D projects and fellowships related to PV.

ERA assesses research quality within Australia's higher education institutions and gives government, industry, business and the wider community assurance of the excellence of research conducted. It also provides a national stocktake, by research discipline areas, of research strength against international benchmarks.

### **3.3 Details of Research**

Almost every university in Australia undertakes some level of PV research, be it science, engineering or socio-economic. A selection of key research is described below.

#### **3.3.1 *Australian National University***

PV research at the Australian National University (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://sun.anu.edu.au>) at ANU was founded in 1991, and is one of the largest and longest established solar energy research groups in Australia.

Activities in CSES span the range from basic R&D through to technology commercialisation with a focus on silicon. The research is supported by a sophisticated research laboratory and an extensive PV testing and characterisation facility. Current grants and contracts total AUD 20 million. Funding support comes from the Australian Research Council, the Australian Renewable Energy Agency, the Defence Department, industrial companies and several other sources. In 2013 work continued on the following projects:

- >24% efficient Interdigitated Back Contact solar cells
- Next Generation Sliver Solar Cells
- Roof-top solar micro concentrators
- Plasmonics for solar cells
- Flexible portable micro modules
- Improving conventional silicon solar cells
- Defect detection and quenching
- Advanced laser processes

Additionally, ANU offers a popular Renewable Energy Major as part of its undergraduate Engineering degree, as well as a corresponding Masters degree. PV is an integral part of the Master of Energy Change program offered by the ANU Energy Change Institute (<http://energy.anu.edu.au>).

#### **3.3.2 *CSIRO PV Performance Laboratory***

In partnership with ARENA, CSIRO grew its PV performance measurement capability significantly in 2013, with the completion of Stage 1 of a major outdoor research facility at the Energy Centre in Newcastle. The 2500m<sup>2</sup> facility has a present capacity of 60 PV modules for automated I-V testing, with temperature monitoring and high-end measurement of the solar irradiance parameters and solar spectrum as well as sky imaging and detailed logging of weather conditions. It is being used to support CSIRO's (and partners) PV research and also operates commercially as a product testing facility.



**Figure 5: Stage 1 of CSIRO's PV module outdoor research facility at the Energy Centre in Newcastle**

The indoor part of the PV Performance Laboratory is in the final stages of technical accreditation for the qualified measurement of PV cell efficiency to the international standard. This is the culmination of more than five years of hard work and will represent the first such laboratory in the Southern Hemisphere. The lab will perform a key role in standardising cell efficiency claims for Australian PV researchers, in the same way that key laboratories such as NREL and Fraunhofer ISE do for their parts of the world.

CSIRO has also recently procured a Spire 5600SLP flash solar simulator for PV modules, and is in the process of developing procedures that will guarantee the highest level of accuracy for this important measurement.

### **3.3.3 *Dyesol Limited***

Dyesol was established in 2004 to commercialise Dye Solar Cells (DSC). Research is focused on:

1. Developing a suite of DSC chemicals, components and equipment used in the production of DSC cells and modules by researchers and industrialists;
2. Providing turn-key and custom manufacturing facilities for manufacturing Dye Solar Cell photovoltaic modules; and
3. Providing specialist training, consulting and engineering solutions for the manufacture of DSC photovoltaic modules.



### **3.3.4 James Cook University (JCU)**

#### *Research Areas*

The solar PV research activities at JCU are mainly focused on solar PV performance under tropical climate conditions of North Queensland. Three different grid-connected PV systems and technologies are under test, two of which were donated by Q-Cells (4kW out of total 5kW).

A three year project to investigate the impact of high penetration PV on Magnetic Island was completed in 2013. This was part of the Townsville Solar City project and received a total funding of AUD 60,000.

#### *Staff*

The JCU solar research activities are led by Professor Ahmad Zahedi and 4 Postgraduate students are currently involved.



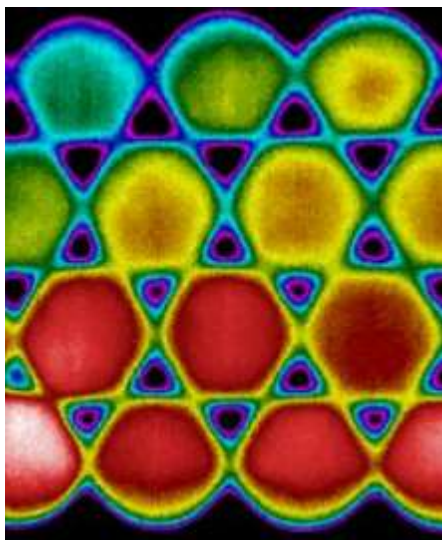
**Figure 6: Q-Cell PV research systems at JCU**

### **3.3.5 Murdoch University**

#### *Research Areas*

PV activities at Murdoch University (MU) are coordinated through the School of Engineering and Information Technology (SEIT) and cover a range of research and educational activities.





**Figure 7: PV module testing:  
Infrared imaging**

The School's **thin film PV devices** group is looking at ways of incorporating silicon nanowires into thin film devices to improve their efficiency and stability. Research in this area continued on the design and optimisation of nanocrystalline silicon solar cells. A variety of suitable catalysts were used to grow the silicon nano wires (SiNWs) in situ and several different designs were tested to determine the best approach.

**Testing and diagnosis of faults** in commercial PV modules is a second key area of expertise. Measurements performed include IV characteristics, minority carrier lifetimes and infrared (IR) photography. Electroluminescence capacity is being developed and the School is in the process of setting up a new solar simulator (SPI-Sun Simulator 5600SLP).

A group of MU researchers is also contributing to joint research project on “Climate Based **Photovoltaic System Performance & Reliability**” coordinated by the Australian PV Institute with the U.S. National Renewable Energy Laboratories (NREL), University of NSW, the Centre for Appropriate Technology in Alice Springs, and the Clean Energy Council. This project contributes to the International Energy Agency Photovoltaic Power Systems Task 13: Performance and Reliability of PV Systems and the International PV Module Quality Assurance Task Force. A key outcome in 2013 was the development of a technical guideline for monitoring and analysing PV systems. Murdoch received AUD 12 000 from ASI/ARENA towards this project. Members of this group are also working on case studies in Indonesia and Western Australia concerned with the effect of dust on the performance of PV modules.

Another key research area within the School is interdisciplinary research on **low emission technologies**: assessing their appropriateness, cost and environmental impacts as well as analyzing the influence of policies and processes on uptake of low emission technologies including PV applications.

### *Education*

Murdoch offers several courses which cover PV principles, applications and system design, including:

- Bachelor of Engineering in Renewable Energy Engineering
- Graduate Certificate in Energy Studies
- Graduate Diploma in Energy Studies
- Graduate Diploma in Energy and the Environment
- Master of Science in Renewable Energy

### *Staff*

Number of staff and students involved in PV research and education (F/T equivalent): 4.2



**Figure 8: Renewable energy training facilities at Murdoch University**

### **3.3.6 Queensland University of Technology (QUT)**

#### *Research Areas*

PV Research at QUT spans the full range of activities from fundamental materials and cell development through to integration of photovoltaics in the electricity system, including issues of network power flows and optimisation of battery storage and development of battery storage algorithms. The research is conducted through the Future Energy Systems and Clean Technology Program of the Institute for Future Environments. Research on solar thermal electricity generation is also being conducted as part of the ASTRI consortium.

The research focusses in three main areas: materials and devices; systems; and network integration (including storage), with details of projects in progress summarised below.



**Figure 9: Three solar trees (18kW) on QUT's new Science and Engineering Centre, part of a 183kW array in the Brisbane CBD.**

## **Materials and Devices**

- Semiconductor absorbers including CZTS, ZnO and perovskite-based materials
- Quantum dot sensitised solar cells for panchromatic light absorption
- Plasmonic absorbers for enhancement of efficiency
- Organic solar cells incorporating carbon nanotubes

## **Systems**

- Optimization of parabolic trough concentrator photovoltaic & thermal solar collector.
- Comparative evaluation of performance of different cells in Brisbane conditions.
- Contribution of PV generated electricity to household demand (field studies).

## **Network Integration**

- Effect of electricity policies and PV installation on network demand (part of a demand-side management statistical model).
- Impact of PV on unbalance of networks and power engineering methods for correction.
- Optimisation of battery storage for improved network utilisation and reduced network investment
- Development of battery control algorithms for effective integration of PV-battery systems in networks

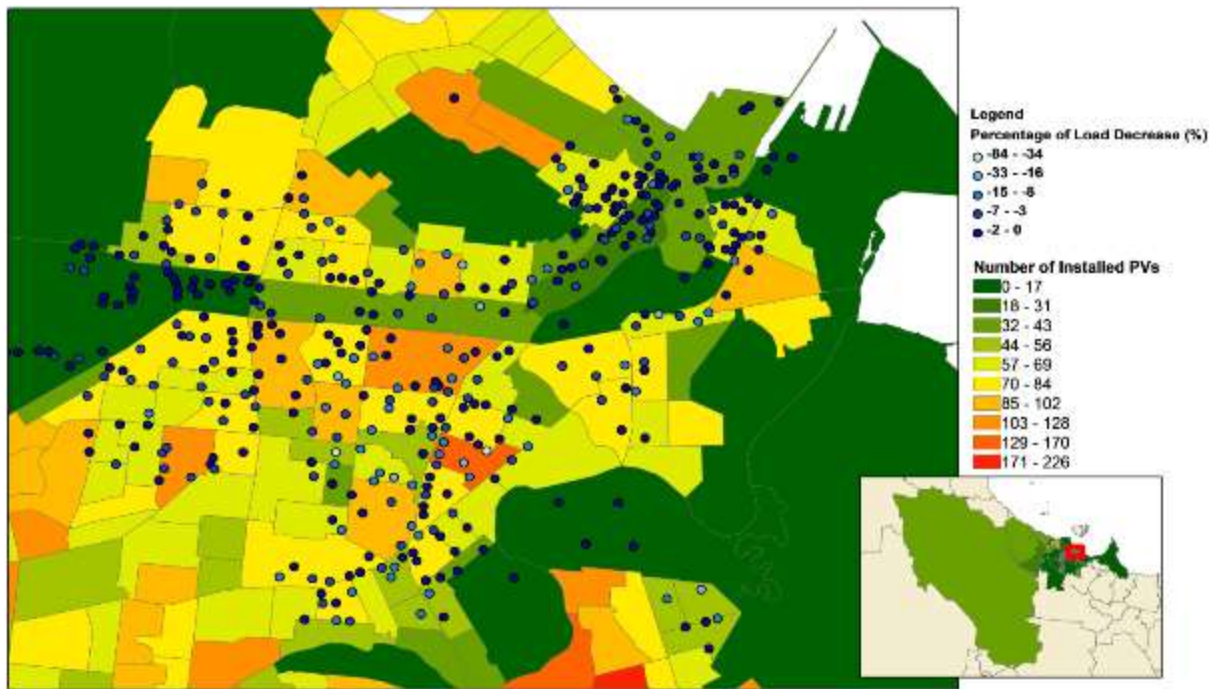
A significant project over the past three years has been an agent-based model platform to assess the impact of different trajectories of electricity consumption at key locations of the electricity distribution network over many years. This enables modelling the impact of greater customer involvement in producing their own electricity and the impact the on the distribution network. As PV installations increase and individual batteries are expected to be more widely taken up with decreasing prices, and their potential to support PV output usage, knowing where, when and how these might impact the load will assist planners in identifying necessary upgrades and modification to the network.

Simulations have been undertaken, modelling the take up of technologies including rooftop solar PV, privately and grid-owned batteries, and electric vehicles. Simulations can be run over many years, for different network areas, capturing variability in space of the technology uptake, and for different usage, capturing people's behaviours and their impact on the time and intensity of the peak load. These simulations can also be used for other purposes, such as greenhouse gas emission calculations and economic impacts on consumers and electricity distributors.

### *Staff and Funding*

There are approximately 16 academic staff involved in PV research (estimated commitment to PV research is 4 EFT), with 13 current higher degree research students primarily focused on PV research.

Current total funding is approximately AUD 1,2 million for PV-related research, from ARC, the Queensland Government, utilities and CSIRO.



**Figure 10: Variation in load at transformer peaks due to rooftop PV – Townsville 2032**

Modelling output from QUT's Agent-based distribution network model showing the impact on transformer loads in the Townsville distribution network in 2032. Each small circle represents a transformer, and the colour represents the reduction in demand compared to current transformer load (see legend). The colours of each region represent the number of installed PV systems in each area (see legend)

### 3.3.7 Solar Systems Pty Ltd

Solar Systems is developing "Dense Array" concentrating PV systems in Victoria using imported concentrator cells and has several trial systems in operation. A 40 dish, 1.5MW CPV array was commissioned in Mildura during 2013, with funding from the Victorian and Australian governments. If trials on the Mildura system are successful, a 100MW system will be constructed.



**Figure 11: 1.5MW Solar Systems CPV system, Mildura, Victoria**  
(Source: solarsystems.com.au)



### **3.3.8 Suntech R&D Australia Pty Ltd**

Suntech R&D Australia employs 15 Australian engineers and scientists in the development of advanced photovoltaic technologies to support the manufacturing and deployment of photovoltaics. Research projects include the development of new processes and tools to enhance outcomes in module manufacturing; by improving power, quality or reducing cost, and Solar Analytics: a software solution for performance monitoring of PV installations.

Suntech R&D Australia works with Australian institutions and organisations on research and applications in PV, including ARENA, Swinburne University of Technology, University of New South Wales, and the Co-operative Research Centre for Low Carbon Living.

### **3.3.9 University of Melbourne**

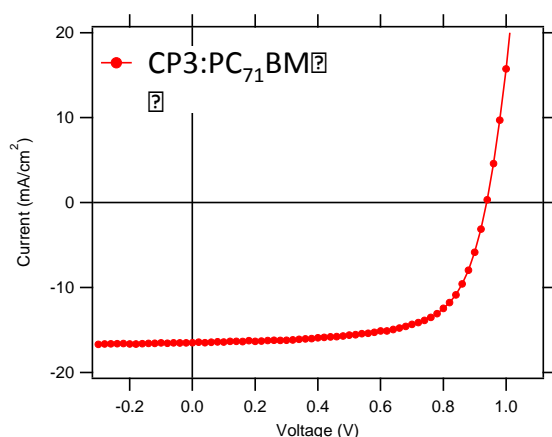
#### *Research Areas*

**Organic photovoltaics** (OPVs) have emerged as a dynamic new technology that promises a low-cost way of mass-producing solar cells through the use of commercial printing presses. Significant developments are required in the performance profile of this exciting new technology to allow commercialisation, with improvement in solar cell efficiency and durability. The University of Melbourne, as lead partner in the Victorian Organic Solar Cell Consortium (VICOSC) has developed a world leading printing capability in the two key emerging technologies, bulk heterojunction solar cells (BHJ) and dye sensitised solar cells (DSC) technologies. The consortium is aiming to bring the technology to a level where it can be commercialised through an iterative process where the printed module performance is matched to product requirements throughout commercialisation, with product development leading to cost competitive products and finally to printed modules rivalling traditional silicon solar cells. The international development goalpost for high efficiency BHJ solar cells has been set at 10% PCE for a single junction device.

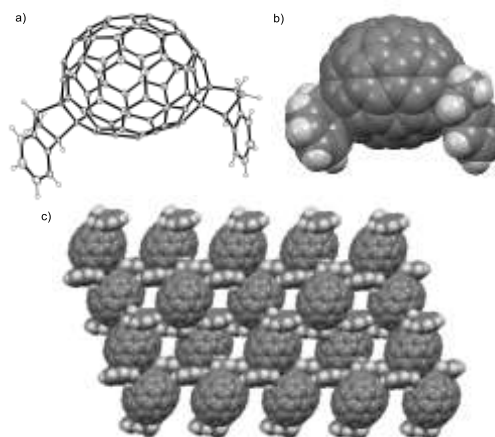
The University of Melbourne has developed with CSIRO, for the consortium, a new *p*-type polymer (CP3), with excellent performance, with the best recorded device efficiency standing at 10.3% PCE (with an average for all material samples of 9.0-9.3% PCE). This will be among the world's best, and only the second of two reported BHJ single junction devices with a reported efficiency of over 10% PCE, as shown in Figure 12.

The University of Melbourne leads the way in understanding the impact of crystal packing on device performance in BHJ solar cells. Isolation of a range of bis-adducts of indene functionalised fullerene (ICBA) has indicated the more crystalline adducts result in devices with higher performance, Figure 13. This understanding is leading to the directed, high yielding synthesis of crystalline bis-adducts of fullerenes.

The University of Melbourne is actively examining new materials classes and device architectures through a fundamental understanding of structure-function and synthesis of organic materials. For example, the University is developing Luminescent Solar Concentrators (LSC) using a new class of aggregation-induced emitters. The aim is to develop highly efficient LSC materials for use on the large glassed areas available in modern buildings where light is channeled and amplified for collection by high efficiency solar cells at the windows' edge, Figure 14.

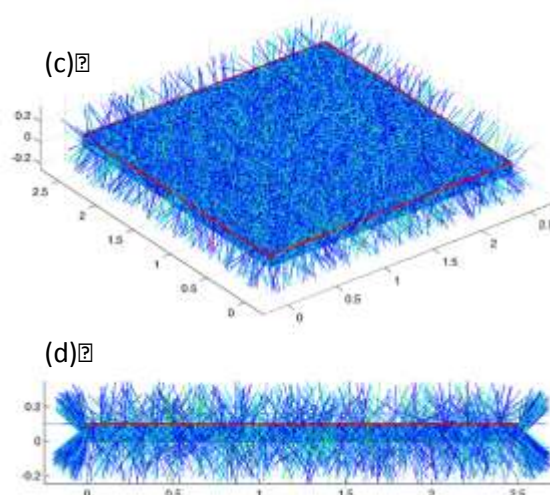
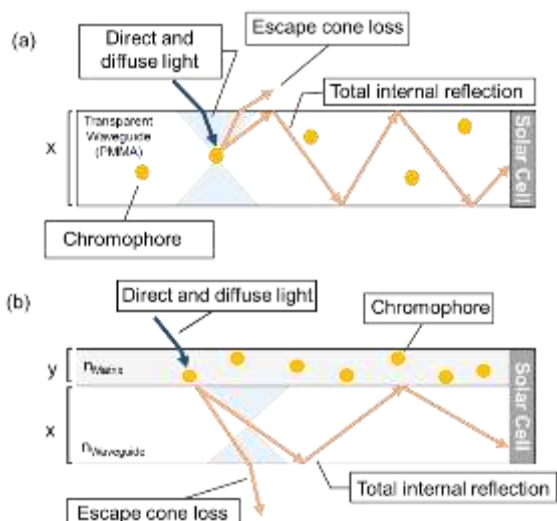


**Figure 12: Device J-V curve for inverted devices with CP3 blended with PC<sub>71</sub>BM acceptor showing a new highest benchmark device efficiency of 10.3% (and a consistent average of between 9.0-9.3%).**



**Figure 13: Structure obtained by X-ray analysis of  $\pm$ -1 crystals grown from chloroform solution of IC<sub>70</sub>BA a) thermal ellipsoid illustration; b) space filling model and c) packing diagram where disordered CHCl<sub>3</sub> solvent molecules have been omitted for clarity.**

On a different thread, the University is the lead institution on an ARENA funded project to produce projections of the **least cost combination of renewable energy technologies** to lead Australia to a low carbon economy. One of the key technologies is PV, and the model simulates how the output of PV varies on hourly timescales and how other technologies co-vary (especially wind power). Results suggest that rooftop PV is the technology of choice up to around 20% penetration of energy supply. Beyond that, wind and dispatchable renewables such as concentrating solar thermal with storage are deployed.



**Figure 14: Conventional structures for LSC applications: (a) millimeter-thick (x) waveguides (typically polymer matrices) infused with fluorescent dyes and (b) micron-thick thin layer matrices (y) cast on top of a waveguide (typically glass). At the University of Melbourne, structure (b) is used with a neat film layer. (n = refractive index). Modelled LSC output with an active fluorescent material in a LSC ( $G=6$ ) – top view (c) and side view (d).**

### *Staff and funding*

The University of Melbourne has 19 staff and 10 post-graduate students working on PV related research.

In 2013, the University received AUD 2,5 million from State and federal governments, industry and internal University funds for PV related R&D.

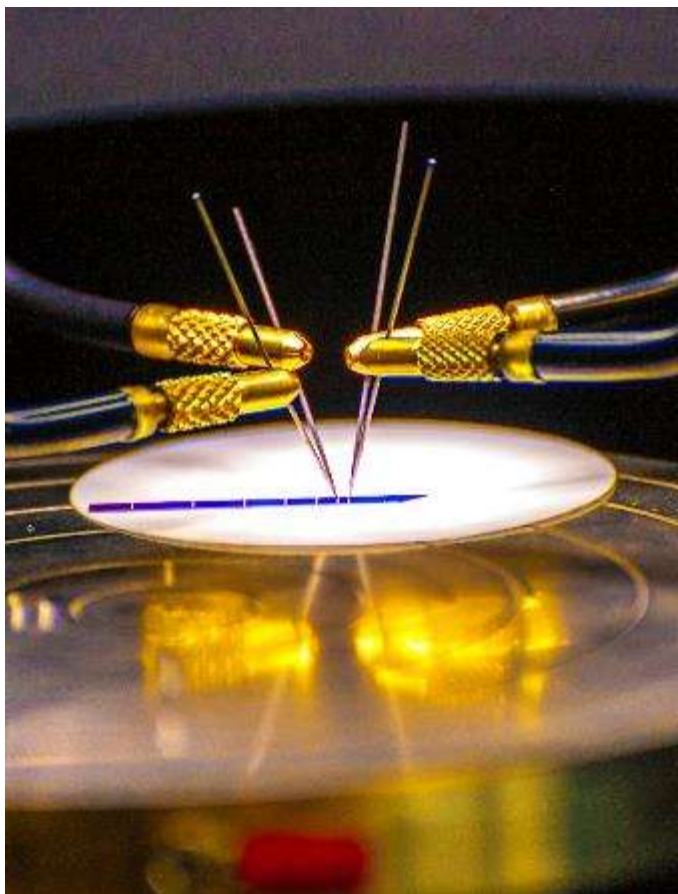
### **3.3.10 University of NSW (UNSW Australia)**

The main UNSW Australia research and educational activities are coordinated through of the School of Photovoltaics and Renewable Energy Engineering. The School hosts 29 academic staff, 60 research and support staff and 140 PhD students.

### *Research Areas*

The Australian Research Council (ARC) Photovoltaics Centre of Excellence commenced at UNSW Australia in 2003. The Centre is now dependent upon industry-related funding for research with near-term outcomes and upon more academically orientated ARC, ARENA and international schemes for its long-term research.

The Centre maintains its world-leadership in “first generation” devices, with international records for the highest-performing silicon cells in most major categories. Centre research addresses the dual challenges of reducing cost and further improving efficiency. The rapid growth of the industry is generating widespread interest in ongoing innovations of the Centre’s first generation technology with several distinct technologies now in large-scale production with annual sales of licensed technology now approaching AUD 1 billion/year.



From a research and development perspective, the Centre remains at the forefront in developing commercially significant technologies, with the latest passivation technology for improving the quality of the silicon material attracting funding from many of the world’s largest cell manufactures with REC, China Sunergy and Suntech already publicly announcing their involvement.

The work is also supported generously by ARENA and is the focus of the 2013 IET A F Harvey Engineering Prize, awarded to UNSW Australia researchers for their pioneering use of lasers for photovoltaic device fabrication and in particular, for the breakthroughs associated with the described passivation technology which appears to have significant relevance to most if not all silicon wafer-based technologies.

**Figure 15: Four Point Probe Transmission Line Measurement**

Centre researchers have pioneered an approach where very thin silicon layers are deposited directly onto a sheet of glass. This “second-generation” approach gives potential cost savings. Not only are the costly processes involved in making wafers no longer required, but also there is an enormous savings in silicon material. Cells also can be made more quickly over the entire area of large glass sheets. The Centre is at the forefront of international research with such “second generation”, silicon based approaches, with the first commercial product from “spin-off”, CSG Solar, several megawatt fields now operating in Europe. The Centre is now investigating electron-beam evaporation of silicon onto the glass substrate, a much quicker process than the plasma-enhanced, chemical deposition processes used to date, and also diode laser processing of the deposited films. A parallel approach involves growing thin layers of single crystal silicon epitaxially by CVD and then transferring such layers onto a supporting substrate such as steel. UNSW Australia has already achieved record performance levels for such devices.

Organic solar cell research, supported by an ARC Discovery Grant, is developing silicon and carbon devices, while ASI funded research is developing CZTS (copper-zinc-tin-sulphide) solar cell technology. By combining these four relatively benign and abundant elements in appropriate proportions, a tetrahedrally co-ordinated “synthetic silicon” compound can be produced with some advantages over silicon, such as stronger light absorption and more potential for bandgap control by alloying with similar compounds.



**Figure 16: PV Teaching resources at UNSW Australia**



The Centre's interest in advanced "third-generation" thin-film solar cells targets significant increases in energy-conversion efficiency. The Centre's experimental program in this area is concentrating on "all-silicon" tandem solar cells, where high energy-bandgap cells are stacked on top of lower-bandgap devices. The silicon bandgap is controlled by quantum-confinement of carriers in small silicon quantum-dots dispersed in an amorphous matrix of silicon oxide, nitride or carbide. Cells based on "hot" carriers are also of great interest since they offer the potential for very high efficiency from simple device structures.

The fourth Centre research strand involves silicon photonics, where the emphasis is upon using our experience with solar cells, using light to produce electricity, to the reverse problem of engineering silicon devices that use electricity to produce light. The Centre holds the international record for the light emission performance from bulk silicon, in both electroluminescent and photoluminescent devices. Emphasis is now upon exploiting our expertise in silicon light emission to develop new techniques for silicon wafer and cell characterisation. A Centre "spin-off" company, BT Imaging, consolidated its position as the premium equipment supplier internationally using this approach.

Significant research is also undertaken in the areas of PV and renewable energy systems and policy. During 2013, research has included high PV penetration in electricity grids, development of a live PV Map for Australia, PV performance analysis, integration of PV and storage, PV/thermal systems, solar forecasting, PV policy and distributed energy market design.

Another significant development during 2013 was the awarding by ARENA of a new Australia/US collaborative Centre, the Australian Centre for Advanced Photovoltaics (ACAP). The primary Australian node for ACAP is UNSW Australia under the Directorship of Professor Martin Green, while the lead US institution with funding from the US DOE, is Arizona State University (ASU) under the Directorship of Professor Christiana Honsberg, formerly from UNSW Australia.

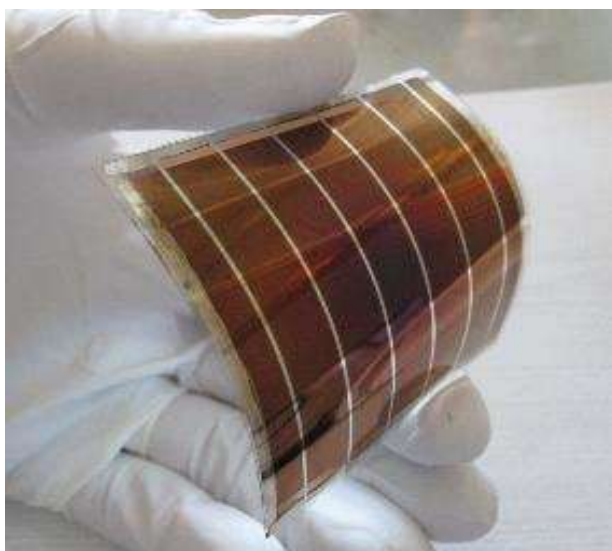
### *Education*

The School of Photovoltaics and Renewable Energy Engineering saw the tenth year of students from the Bachelor of Engineering (Photovoltaics and Solar Energy) program graduated during 2013. This program has been enormously successful, attracting some of the best and brightest students entering the University and providing the human resources to fuel the recent growth of the industry. The eighth year of students have now graduated from the Centre's second undergraduate program, leading to a Bachelor of Engineering (Renewable Energy).

### **3.3.11 University of Queensland**

#### *Research Areas*

Research at the Centre for Organic Photonics and Electronics (COPE) led by Professors Paul Burn and Paul Meredith focuses on developing **new materials and architectures** to improve the efficiency of organic semiconductor based solar cells and thin film perovskite solar cells. This involves the creation of new active light absorbing materials, modification and understanding of perovskite structures, the development of hole and electron transporting materials, transparent conducting electrodes and work function modifiers. COPE also has extensive expertise in the basic **electro-optics and transport physics** of excitonic and non-excitonic solar cells – this includes developing new experimental methods, theory, simulations and advanced photo-physics and spectroscopy. COPE is a partner in the ARENA funded Strategic Research Initiative: Australia-US Institute for Advanced Photovoltaics. Within the SRI, the Centre will focus on applying its core expertise in charge transport physics in organic semiconductors and the creation of new molecules for advanced photon harvesting concepts. COPE also leads a CSIRO Flagships Initiative in collaboration with Flinders University and UTS to develop new **transparent conducting electrodes** for solar cells and other optoelectronic applications.



Professor Lianzhou Wang of the Nanomaterials Centre at the University of Queensland is leading a research team investigating new types of **solid-state solar cells** (SSCs) using perovskite sensitisers and solid electrolytes. Wang's team are investigating less toxic perovskite sensitisers and more stable inorganic hole transporting materials, and optimising the perovskite-based SSCs to improve their efficiency, reproducibility, and stability.

**Figure 17: Plastic Solar Cell 5X5cm<sup>2</sup>**

The Power & Energy Systems Group (School of ITEE) led by Professor Tapan Saha focuses on the **integration of variable energy sources**, in particular wind and solar energy, and other base load (geothermal) renewable energy sources into electricity transmission and distribution networks. The research includes voltage stability and reactive power (VAR) management of electricity networks, such as the placement of switched capacitor banks (SVC) and static compensator devices (STATCOMS); increasing penetration of variable energy sources to distribution grids; design of new coordinated control schemes with energy storage systems and electric vehicles, and transmission of energy from renewable energy sources over long distances.

The Energy Economics and Management Group (EEMG) headed by Professor John Foster and Dr Liam Wagner is a national centre for **economic research in the field of renewable energy** and related environmental questions. To this end, the EEMG has developed two sophisticated models of the national electricity market and other models for policy evaluation and to date has been focusing on solar and wind generation and the impacts of different kinds of carbon mitigation policies on their adoption. The Group is affiliated with the Global Change Institute (GCI) at UQ and played a key role in the development of the very successful UQ Solar Array.

The Global Change Institute (GCI) is a multi-disciplinary, cross-university organisation which seeks to address and answer some of the major questions facing the globe in an era of rapidly changing climate. One area of key focus is Clean Energy in which it focuses upon **opportunities and challenges in the evolving Australian Power System**, Utility-scale PV and CST and concepts around distributed and off-grid power. The Clean Energy Program is led by Professor Paul Meredith and Program Manager, Craig Froome. In particular, the GCI manages the research program of the UQ MW Array Project which is concerned with understanding the economics and integration issues associated with commercial-industrial scale PV (storage, power quality, yield, and systems optimisation).

Other solar projects are being undertaken at the Australian Institute of Bioengineering and Nanotechnology and School of Chemical Engineering focuses on the development of new **semiconducting nanomaterials as photoanodes** for 3<sup>rd</sup> generation dye-sensitized solar cells and quantum dot sensitized solar cells application. This involves the design, synthesis, electronic and structural modification of metal oxides to facilitate the dye/quantum dot absorption capability, light harvesting and electron transfer efficiency. The research also includes the development of a new class of electrode materials that can have higher specific capacity, quicker charging-discharge rates and longer cycling life for new generations of batteries.

### *Gatton Solar Plant*

The Gatton Solar Plant is funded by the Australian Government's Education Infrastructure Fund (EIF). The University of Queensland is the Lead Research Organisation and will partner with the University of New South Wales in an AUD 40.7 million EIF research infrastructure program that will support the development of the utility-scale solar industry in Australia. The program will share learnings with the projects that First Solar is constructing for AGL Energy at Nyngan and Broken Hill that have a combined capacity of 155MW (AC).

The Gatton Solar Plant will be situated on approximately 12.5 hectares of land on the Gatton Campus of the University. The University's Global Change Institute is the hub for the Research Program associated with the EIF Project, the centrepiece of which is a 3.41MW research pilot array and storage system. The Plant will compare the installation and operation of fixed tilt, single-axis and dual-axis tracker technologies. The research will also explore grid integration and implementation of battery storage with utility-scale solar power systems.

The Gatton Plant will be powered by First Solar's advanced thin film PV modules, and will generate approximately 6,400 MWh and displace over 5,600 metric tCO<sub>2</sub>-e per year. Power from the project will be purchased and used on campus to reduce the University's carbon footprint.

This project has commenced construction and will be on-line in early 2015, providing the largest solar research facility in the southern hemisphere.

### **3.3.12 University of South Australia**

#### *Research areas*

The Barbara Hardy Institute (BHI), within the University of South Australia, has been actively **monitoring and analysing the water and energy data for about 60 low-energy houses** located in Australia's leading Green Village, Lochiel Park, situated in South Australia. Each house includes a comprehensive in-home energy monitoring system that records and displays electricity, gas and water consumption, as well as the gross solar photovoltaic (PV) energy generation, import from and export to the grid. Each house has a grid-connected photovoltaic solar system, whose minimum capacity is determined according to the size of the house, i.e. 1kW<sub>p</sub> per 100m<sup>2</sup> habitable floor area.



**Figure 18: Solar installations at South Australia's Lochiel Park Green Village.**

With the expansion of domestic roof top solar PV systems throughout Australia and their potential increasing impact on the energy market, household energy bills and the electricity grid, there has been little evidence base on how a cluster of installed PV systems actually perform and interact with the grid. Research undertaken by members of the BHI has calculated the effectiveness of the installed PV systems for a cluster of low-energy houses within the Lochiel Park Green Village. The data collected from these systems has been compared with theoretical mathematical predictions based on solar system information such as inclination and azimuth angles of the installed panels, the peak power

rating and efficiency of the panels and the inverter, and 5-minute solar irradiation data recorded by the Bureau of Meteorology. This research also shows how monitoring systems can be used to identify solar system installation issues / faults, such as those caused by shading and general inverter failures. This work has also shown the significant improvements to gross energy generated, once system faults have been rectified.

#### *Staff*

The BHI has 4 staff working on PV related activities (about 0.35 FTE) and 2 postgraduate students.

### **3.4 Public budgets for market stimulation, demonstration / field test programmes and R&D**

**Table 7: Public budgets for R&D, demonstration/field test programmes and market incentives (AUD Million).**

	<b>R &amp; D</b>	<b>Demonstration/Field test</b>
<b>National/federal</b>	175,6	78,5
<b>State/regional</b>	0,7	35,5
<b>Total</b>	290,3	

## 4 INDUSTRY

### 4.1 Production of photovoltaic cells and modules

Tindo Solar manufactures solar panels at Technology Park in Adelaide, South Australia. The Tindo Karra is certified with Q cells and STX, with STX providing a better temperature coefficient. Tindo supplies both traditional DC panels and AC panels, the latter with a factory fitted Solarbridge micro inverter. Both panels produce 250 Watt output +/- 2% and are flash tested in Australia.

Total PV cell and module manufacture together with production capacity information is summarised in Table 9 below.

**Table 8: Australian PV cell and module production and production capacity information for 2013**

Cell/Module manufacturer	Technology	Total Production (MW)		Maximum production capacity (MW/yr)	
		Cell	Module	Cell	Module
Wafer-based PV manufacturers					
Tindo	mc-Si		4		60

### 4.2 Manufacturers and suppliers of other components

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

- **PV inverters (for grid-connection and stand-alone systems) and their typical prices**

Australian companies Latronics and Selectronics design and manufacture inverters for use in both grid and off-grid applications. Their long experience with bi-directional inverters is now providing an advantage as grid-connected PV customers begin to explore storage options.

- **Storage batteries**

Australian company RedFlow manufactures Zinc Bromine batteries. Its ZBM product delivers up to 3 kW of continuous power (5kW peak) and up to 8 kWh of energy.

A CSIRO invention called the UltraBattery combines a lead-acid battery and a supercapacitor to provide a fast-charging, long-life battery. The battery is being made commercially by storage company Ecoult.

A range of research programs are underway to develop new types of batteries for utility-scale and residential energy applications.

- **Battery charge controllers and DC switchgear**

A range of specialised fuses, switches and charge controllers are made locally.

- **Supporting structures**

A range of mounting and tracking systems is made in Australia to suit local conditions. IXL will manufacture the support structures for the First Solar / AGL 155MW Solar Flagship systems in NSW and for the UQ Gatton Solar Plant. It previously manufactured the supports for the 10MW First Solar Greenough River solar farm in WA.

## 5 COMPETITIVENESS OF PV ELECTRICITY

Module prices continued to drop from AUD 1,5/Wp in 2012 to around 0,75/Wp in 2013 and installed prices for small residential systems dropped from an average of around AUD 3 to around 2,50/Wp. With continued increases in grid electricity prices, PV is a cost effective option for homeowners across Australia and is of increasing interest to the commercial sector. Over 1 million Australian homes now have a PV system. Residential penetration levels average 15% and are over 30% in some areas.

Typical system prices are provided in Table 9, while trends in module and system prices are shown in Table 10, Table 11 and Table 12.

**Table 9: 2013 Turnkey Prices of Typical PV Applications in Australia (AUD)**

Category/Size	Typical applications and brief details	Current prices AUD per W
OFF-GRID Up to 1 kW	Water pumps, lighting, remote homes	5 - 10
OFF-GRID >1 kW	Telecommunications, pastoral / mining power systems	5 - 15
Grid-connected Rooftop up to 10 kW (residential)	Residential	2,5 – 3,5
Grid-connected Rooftop from 10 to 250 kW (commercial)	Commercial rooftop	2 - 4
Grid-connected Rooftop above 250kW (industrial)	Larger rooftops	2 - 4
Grid-connected Ground-mounted above 1 MW	Solar farms	1,5 – 2,5
Other category existing in your country (hybrid diesel-PV, hybrid with battery...)	Diesel grids	5 - 15

## 5.1 Module and system price trends

**Table 10: Trends in typical module prices in Australia 1993 – 2013 (current AUD)**

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Typical PV module price	9	7	8	8	7	8	8	8	8	7	7	8	8	8.5	8	8	6	3.2	2.1	1.5	0.75
Lowest module price														7.5	7	5	3	2	1.2	0.9	0.5

**Table 11: Trends in typical prices for small residential grid-connected systems in Australia 1997-2013 (current AUD)**

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Typical price	11	12	12	14	14	13	10	12	12	12.5	12	12	9	6	3.9	3	2.5
Balance of System price	4	4	4	6	6	6	3	4	4	4	4	4	3	2.8	1.8	1.5	1.8

**Table 12: Trends in typical prices for small residential off-grid systems in Australia 1993-2013 (current AUD)**

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Typical price	24		22		30	30	30	22	22	20	20	20	20	22	22	22	20	12	11	10	8

## 5.2 Financial Parameters and programs

Most residential customers in Australia purchase their PV systems, using cash or a mortgage extension, the latter typically representing the lowest finance cost available. As more commercial customers enter the market, leasing and other finance options are increasingly on offer. These may become more attractive to residential customers over time.

**Table 13: PV financing scheme**

Cost of capital	Typical mortgage rate: 7%. Typical finance rate: 10%
Description of PV financing schemes available in Australia	PV customers can lease a system for a set period, typically 5-10 years, paying no up-front cost but a fixed electricity price, or one with a pre-determined annual escalator. All operating and maintenance costs are covered by the system supplier. Options to renew the lease are available. Options to own the system at the end of the lease period are also available, although these may place some of the O&M responsibilities onto the customer.

## 5.3 Additional Country information

Electricity prices vary across Australia, by electricity market, by retailer and by end use. Prices across all sectors have increased significantly over recent years, which has made PV electricity cost effective against retail tariffs in most parts of the country.

General information is provided in Table 14 and more detail on electricity market operation is provided in Section 7.1.

**Table 14: Country information**

Retail Electricity Prices for an household (range)	AUD 0,20-0,30 /kWh
Retail Electricity Prices for a commercial company (range)	AUD 0,12 – 0,25 / kWh
Retail Electricity Prices for an industrial company (range)	AUD 0,10 – 0,18 / kWh
Population at the end of 2013 (or latest known)	23 million
Country size (km <sup>2</sup> )	7.6 million sq km
Average PV yield (according to the current PV development in the country) in kWh/kWp	1400 kWh/kWp per year



## 6 PV IN THE ECONOMY

### 6.1 Labour Places

Estimates of direct employment, where the positions are predominantly related to PV, are given in Table 15. Indirect employment would potentially double these numbers<sup>1</sup>.

**Table 15: Estimated PV-related labour places in Australia, 2013**

Research and development (not including companies)	400
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	200
Design, engineering and consulting	2000
System and installation companies	8000
Electricity utility businesses and government	500
Legal, finance, REC trading and industry support	200
Other (EPC, advertising, conferences, media)	400
<b>Total</b>	<b>11,700</b>

### 6.2 Business value

**Table 16: Value of PV business in Australia, 2013 (AUD Million)**

Sub-market	Capacity installed MW	Price per MW	Value AUD million	Totals
Off-grid domestic	9	8000	72	
Off-grid non-domestic	5	10000	50	
Grid-connected distributed	794	2500	1985	
Grid-connected centralized	2	2000	5	
				<b>2112</b>
<i>Import of PV products</i>				<i>-1216</i>
<b>Value of PV business</b>				<b>896</b>

The business value above does not include the value of PV related education, research, media, electricity sector savings or environmental benefits.

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<sup>1</sup> REC Agents Association, Solar Business Services and Greenbank, 2014, Impact of abolishing the Renewable Energy Target on jobs in the Australia solar industry, available [here](#).

## 7 INTEREST FROM ELECTRICITY STAKEHOLDERS

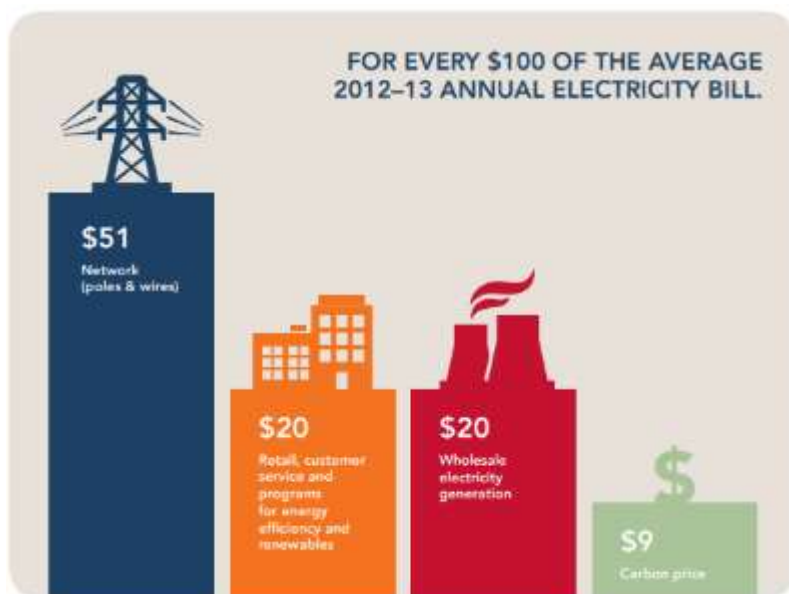
### 7.1 Structure of the electricity system

In most areas of the country on main grids the electricity system is split into generation, transmission, distribution and retail sectors. Smaller grids are typically vertically integrated. There is a mix of public and private ownership across all jurisdictions and sectors.

The NEM spans Australia's eastern and south-eastern coasts and comprises five interconnected states that also act as price regions: Queensland, New South Wales (including the Australian Capital Territory), South Australia, Victoria, and Tasmania, a distance of around 5000 kilometres. There are over 100 registered participants in the NEM, both State government owned and private, including market generators, transmission network service providers, distribution network service providers, and market customers.

The NEM is a wholesale commodity exchange for electricity across the five interconnected states. The market works as a "pool", or spot market, where power supply and demand is matched in real time through a centrally coordinated dispatch process. Generators offer to supply the market with specified amounts of electricity at specified prices for set time periods, and can re-submit the offered amounts at any time. From all the bids offered, the Australian Energy Market Operator (AEMO) decides which generators will be deployed to produce electricity, with the cheapest generator put into operation first. A dispatch price is determined every five minutes, and six dispatch prices are averaged every half-hour to determine the "spot price" for each NEM region. AEMO uses the spot price as its basis for settling the financial transactions for all electricity traded in the NEM. Network, retail and environmental charges are added to the energy price in calculating retail tariffs, as shown in Figure 19.

Western Australia and the Northern Territory are not connected to the NEM. Western Australia operates two separate networks, the South West Interconnected System (SWIS) and the North West Interconnected System. A range of smaller grids also operate in remote areas of the State. The SWIS operates via a short term energy market and a reserve capacity market. Capacity and energy are traded separately. The Northern Territory operates a number of grids, both large and small to service population centres and regional townships.



**Figure 19: Make-up of typical Australian electricity bills (Source: AEMO <http://www.aemo.com.au/About-the-Industry/Energy-Markets> )**

## **7.2 Interest from electricity utility businesses**

The electricity sector in most parts of Australia is organised and regulated to support centralised power generation, distribution and retailing. Most PV installed in Australia to date has been connected to the distribution network, and is supplying loads directly. This circumvents the incumbent electricity sector and is therefore causing significant problems, not necessarily technical, although these may occur as penetration levels rise, but certainly to the income stream of all established generators, networks and retailers. Daytime peak loads are significantly reduced due to PV generation, which has largely displaced gas peaking plant and changed the network load profiles, while overall load has also reduced, partly due to PV, but also due to recent high electricity price rises and increased uptake of energy efficiency measures. Other Distributed Energy options likely to become more common over the next decade include storage, electric vehicles, other solar appliances, such as air conditioners, and energy management systems. All of these will change the ownership structure of energy assets, as well as the usage patterns and, because PV is leading the way, it is bearing the brunt of the initial negative response.

Australian energy regulators, while becoming mindful of the need to change regulatory frameworks in light of these developments, are currently themselves restricted by their own governance arrangements and reporting structures. Nevertheless, it is clear that new regulatory frameworks are needed to cater for rapidly increasing distributed energy options. For instance, network businesses are currently prevented from implementing distributed energy options themselves, even if these may provide more cost effective solutions than grid upgrades or extensions, while third party access to this market is not available.

Some utilities, notably those serving remoter parts of the grid in Queensland and Western Australia, are beginning to explore new business models and tariff structures which might reduce cross subsidies currently operating, while encouraging PV installations and controls which benefit the grid, via intelligent inverters or storage, for instance. Nevertheless, even these relatively innovative utilities are constrained by the regulatory framework under which they operate.

While environmental goals, including greenhouse gas reduction, drove initial policy support for PV, with utilities required to accept PV connections as well as contribute to the Renewable Energy Target (see Section 2.2.1), the Australian government plans to reduce or remove current incentives. State governments, which own a significant portion of electricity assets, as well as private owners, are keen to maintain value and/or income. Hence the current response to high PV uptake levels is to place restrictions on connections and change connection procedures and tariff structures so as to make PV less attractive.

## **7.3 Interest from municipalities and local governments**

While the Australian government and State governments are generally trying to curb PV uptake rates, there is high and increasing interest in PV implementation from local governments and community organisations around Australia. Although these groups typically have little money, and must operate within the electricity market described above, the high level of community support for local generation and employment creation is likely to be a key factor in creating the political will to make the required changes to regulatory frameworks.

## 8 STANDARDS AND CODES

PV system safety remains a top priority in Australia. A new revision of AS/NZS5033: “Installation of PV arrays” will be published later in 2014. The new revision takes account of power optimisers and d.c. to d.c. converters used at a module level and clarifies conditions for micro-inverter and multiple input MPPT inverters.

A major revision of AS/NZS 4777 – Grid connection of energy systems via inverters is still being completed and will be published late in 2014. The revision addresses many issues raised by electricity utilities particularly in the area of power quality and inverter default voltage and frequency settings. This new document will help more uniform acceptance of PV systems connected to the utility grid. This standard looks to the future where local power and VAR control will assist with voltage regulation and where communication options are explored for utility control and where more fault ride-through is provided. AS/NZS 4777 also addresses the issues related to multiple inverter installations, covering issues of phase balancing and protection tripping of multiple inverters.

A major safety issue is the implementation of testing of inverters to IEC 62109-1 and 2 and the need for revision of that IEC standard to address known issues. The Australian committee is involved with IEC working groups to assist in this process.

There is also an urgent need to address safety and quality control of d.c. switches for PV systems as there have been a number of fires caused by failure of d.c. switches both in the quiescent state and during switching under load.

PV-Battery-Grid connected systems are developing rapidly in Australia with the use of lithium ion and lead acid batteries. These systems have potential benefits for the future uptake of PV but there are many issues still to be addressed. There are complex safety implications arising because of the interconnection of PV, the grid and batteries with and without inverter isolation. Other issues of charge control and fire safety of lithium batteries are also important for the future. The industry is working on guidelines initially that will flow through to standards in the future.

## 9 HIGHLIGHTS AND PROSPECTS

The Australian PV market contracted again in 2013, with installation levels reducing from 850 MW in 2012 to around 800 MWp. Installed capacity is now over 3.2 GWp, accounting for 5% of electricity capacity and 2% of electricity generation. Incentives for PV, including feed-in tariffs, have been removed by State Governments and reduced by the Federal Government. Module prices continued to drop from AUD 1,3/Wp in 2012 to around 0,75/Wp and installed prices for small residential systems dropped from an average of around AUD 3 to around 2,50/Wp. With continued increases in grid electricity prices, PV is a cost effective option for homeowners across Australia and is of increasing interest to the commercial sector.

Over 1 million Australian homes now have a PV system. Residential penetration levels average 15% and are over 30% in some areas. Installation restrictions are being imposed by electricity network operators in some areas to cope with potential issues arising from high penetration levels. The major issue arising, however, is economic, not technical. With revenue for electricity networks and retailers dependent largely on kWh sales, PV uptake has contributed to revenue reductions. Large central generators have also been impacted by the overall reductions in energy sales, to which PV has contributed, but is not the only factor, with several plant closures. This has made PV a target for the established electricity sector, as well as State Governments which depend on electricity sector dividends. Various proposals have been put forward to reduce the attractiveness of PV, including imposition of levies, prohibition of net metering, restrictions on system sizes and changing the relative proportion of fixed and variable components in electricity tariffs.

Electricity prices are expected to continue to rise over the next few years in most jurisdictions, despite the newly elected Australian Government committed to removing the carbon price. Hence the market for distributed PV will remain strong, although annual installations are expected to stabilise. Several hundred larger, commercial-scale PV systems were installed in 2013 and construction is now underway on a 20 MW ground-mounted system in the Australian Capital Territory, under its renewables program, and a 50 MW system in NSW, in the first stage of the Australian Government's Solar Flagship program.

The Australian PV Institute, with support from ARENA, has released a solar map of Australia, which tracks installation locations, sizes and PV generation: <http://pv-map.apvi.org.au/>.

There is increasing customer interest in on-site storage. Although not yet cost effective for most customers, a market for storage is already developing. This trend could exacerbate issues faced by incumbent electricity sector businesses, even if it offers a means to manage supply intermittency and peak demand, since it would facilitate the installation of larger PV systems and may also see a trend to self-sufficiency, disconnection of customers from main grids and increased interest in mini-grids to service remote rural communities.

## 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<sup>2</sup>, 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.

CPV: Concentrating PV

Hybrid system: A system combining PV generation with another generation source, such as diesel, hydro, wind.

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 Australian Dollars (AUD).

PV support measures:

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 that may be higher or lower 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
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



Compensation schemes (self-consumption, net-metering, net-billing...)	These schemes allow consumers to reduce their electricity bill thanks to PV production valuation. The schemes must be detailed in order to better understand if we are facing self-consumption schemes (electricity consumed in real-time is not accounted and not invoiced) or net-billing schemes (the electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity account is reconciled over a billing cycle). The compensation for both the electricity self-consumed and injected into the grid should be detailed. Net-metering schemes are specific since they allows PV customers to incur a zero charge when their electricity consumption is exactly balanced by their PV generation, while being charged the applicable retail tariff when their consumption exceeds generation and receiving some remuneration for excess electricity exported to the grid
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

