IEA INTERNATIONAL ENERGY AGENCY

AUSTRALIAN PV INSTITUTE

IEA-PVPS

National Survey Report of PV Power Applications in AUSTRALIA 2015

With support from

ARENA

Australian Government
Australian Renewable Energy Agency

PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Prepared by the Australian PV Institute

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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, 2015

The Australian PV Institute

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

The 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 International Energy Agency (IEA) Photovoltaic Power Systems (PVPS) and Solar Heating and Cooling (SHC) 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

ACKNOWLEGEMENTS

Front page photo: Broken Hill Utility Scale Solar Facility with Desert Pea, courtesy of AGL

The Institute receives funding from the **Australian Renewable Energy Agency (ARENA: 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, ARENA 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 member countries

The IEA Photovoltaic Power Systems Technology Collaboration 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 participating countries and organisations can be found on the www.iea-pvps.org website.

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

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 objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. 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 2015. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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

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 associated control components. 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 2015 statistics if the PV modules were installed and connected between 1 January and 31 December 2015**, although commissioning may have taken place at a later date.

1.1 Applications for photovoltaics

The Australian market for PV installations experienced significant growth in 2015, and reached a milestone of 5GW of cumulatively installed capacity. In 2015, 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 (ARENA) and the Clean Energy Finance Corporation (CEFC) and a variety of State, Territory and local government support programs. The market for rooftop systems on private residences continued to decline in volume, though it remained the #1 market segment. In 2015, there was modest growth in commercial systems 10-100kW in size, however unlike in 2014, the growth was insufficient to offset the decline in residential volume. The market skyrocketed for systems greater than 100kW, primarily influenced by the installation of three utility-scale systems funded some years prior. Average system size has continued to grow steadily as residential system sizes increase and as a growing number of businesses purchase PV, as shown in Figure 1 and Figure 3.

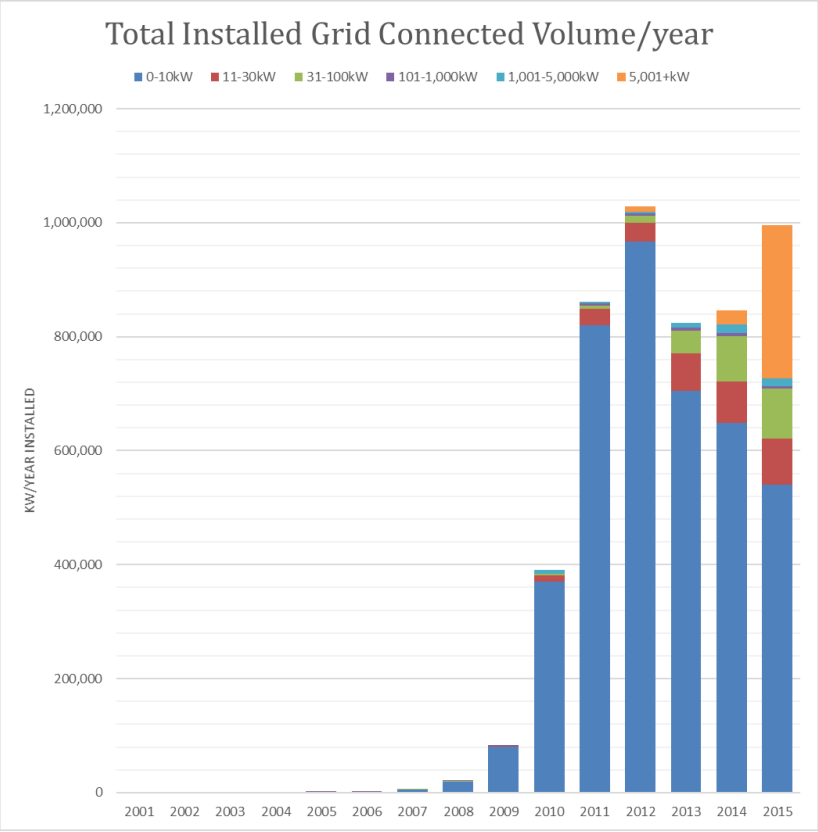


Figure 1: Annual Australian Grid Connected PV installations by Category

1.1.1 *The Grid Market*

Although PV has reached grid parity against retail electricity tariffs in many parts of Australia, electricity prices have stabilised and high market penetration in the residential segment is constraining sales to this sector - Figure 2 illustrates that penetration levels are approaching 40% of suitable dwellings in Brisbane and surrounds. Interest is also surging in grid- connected systems with battery-backup, though installation volumes numbered approximately 500 in 2015.

Three utility-scale projects over 50MW were installed in 2015 that were the culmination of projects shortlisted for Round 1 of the Solar Flagships programme announced in late 2009. Two projects - at Nyngan (106MW) and Broken Hill (53MW) - were the eventual recipients of the Solar Flagships Funding. In addition a further 56 MW was established at the Moree Solar Farm through grant funding from ARENA.

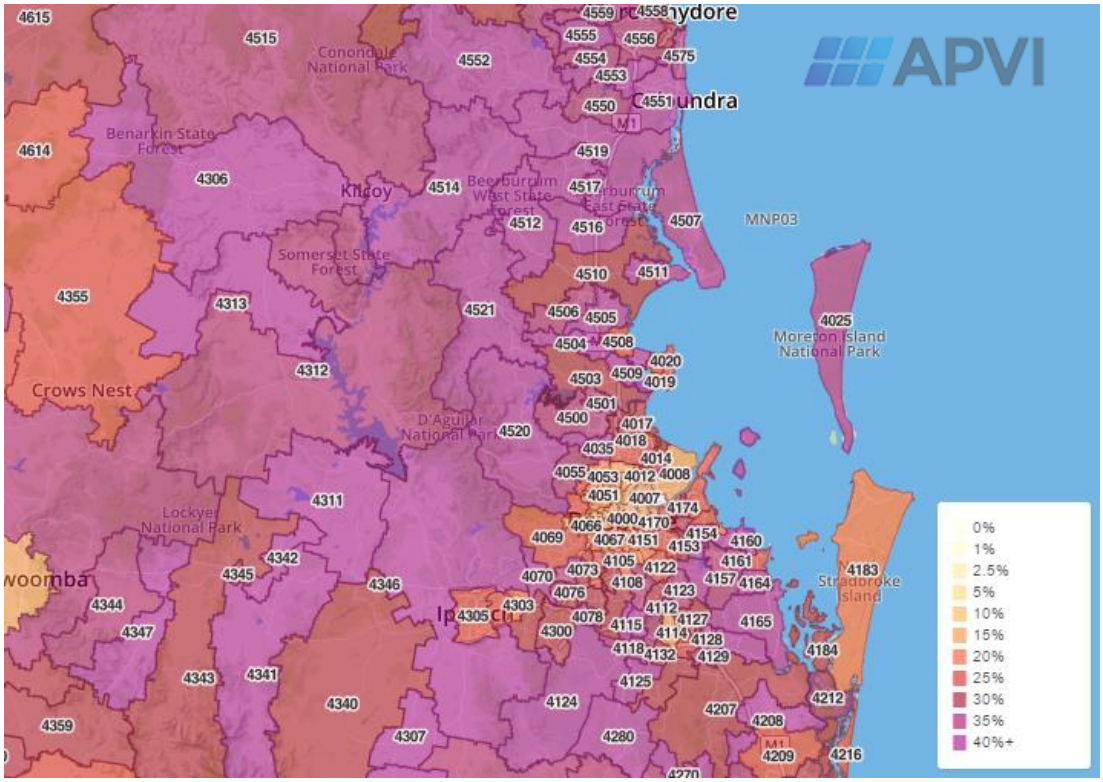


Figure 2: Residential PV penetration levels in Brisbane and surrounding areas of Queensland that exceed 40% of suitable dwellings (Source: APVI Solar Map: http://pv-map.apvi.org.au/)

1.1.1 *The Grid Market*

Australia's long-standing off-grid market continues to be important, particularly in residential applications where PV continues to displace diesel in hybrid power systems. Off-grid industrial and agricultural applications are also an important market. These include power systems for telecommunications, signalling, cathodic protection, water pumping and lighting. The roll-out of the National Broadband Network has presented new opportunities for off-grid solar. Significant markets also exist for fuel saving and peak load reduction on diesel grid systems in remote communities, mine sites and tourist locations. There is also a reasonably significant market for recreational PV applications for caravans, boats and off-road vehicles. Interest is also surging in grid connected systems with battery-backup, though installation volumes numbered approximately 500 in 2015.

1.2 Total photovoltaic power installed

The PV power installed in four sub-markets during 2015 is shown in Table 1. PV data for the tables 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. Data available by the time of publication of this report may not include all 2015 installations, however a projection is been made of historical trends reflecting late registration. 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[1] and may not be correct within ±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. Information on off-grid system installation is based upon an industry survey and has low accuracy. Installations over 100kW typically take longer to register RECs than systems 100kW and under, so the size of this market segment is estimated based upon publically-announced projects.

Table 1: PV power installed during calendar year 2015

			MW installed in 2015 (DC)	**MW installed in 2015 (DC)**
Grid-connected	BAPV	Residential	723 MW	540[2]
		Commercial		168
		Industrial		14
	BIPV	Residential	<1	
		Commercial		
		Industrial		
	Ground-mounted	cSi and TF	273	273[3]
		CPV		
Off-grid		Residential	20	16
		Other		
		Hybrid systems		4
		Total	1016 MW	

[1] Specifically by projecting survey responses based off individual volumes, assuming respondents are representative of the market as a whole.

[2] Market size projected from STC registration after accounting for lag, less off-grid market which is included in this tally.

[3] Uterne 2 plus Weipa, plus Nyngan, Moree, Broken Hill which are typically reported in AC (102, 56, and 53MW respectively).

The off-grid residential and hybrid market sizes were calculated by up-scaling respondents' survey responses under the assumption that respondents' reported grid-connect volumes were representative of the overall market. This assumption correlated well with a figure reported by the Clean Energy Regulator of 472 hybrid systems installed in 2015.

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

MW-GW for capacities and GWh-TWh for energy	2015 numbers	2014 numbers
Total power generation capacities (all technologies)	55.8GW	55.4GW
Total power generation capacities (renewables including hydropower)	14.1GW	12.4GW
Total electricity demand (= consumption)	248.3 TWh[4]	227.5TWh[5] (excl PV)
New power generation capacities installed during the year (all technologies)	390MW (1690MW Renewables, less 1300MW of decommissioned fossil fuel power stations)	1440MW
New power generation capacities installed during the year (renewables including hydropower)	1690MW	1440MW
Total PV electricity production in TWh	7.0TWh	5.6TWh
Total PV electricity production as a % of total electricity consumption	2.8%	2.4%

[4] http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Australian-energy-statistics.aspx

[5] Consumption in the NEM reduced by 5TWh on 2013 figures. Data on the rest of the country is not yet available

Table 3: Other information

	2015 Numbers
Number of PV systems in operation in Australia	**1 500 000:** **<10kW: 1 475 000** **10-100kW: 25 000**
Capacity of decommissioned PV systems during the year in MW	**0**
Total capacity connected to the low voltage distribution grid in MW	**4682MW**
Total capacity connected to the medium voltage distribution grid in MW	**76.2MW**
Total capacity connected to the high voltage transmission grid in MW	**303 MW**

A summary of the cumulative installed PV Power, from 1992-2015, broken down into four sub-markets is shown in Figure 3 and Table 4.

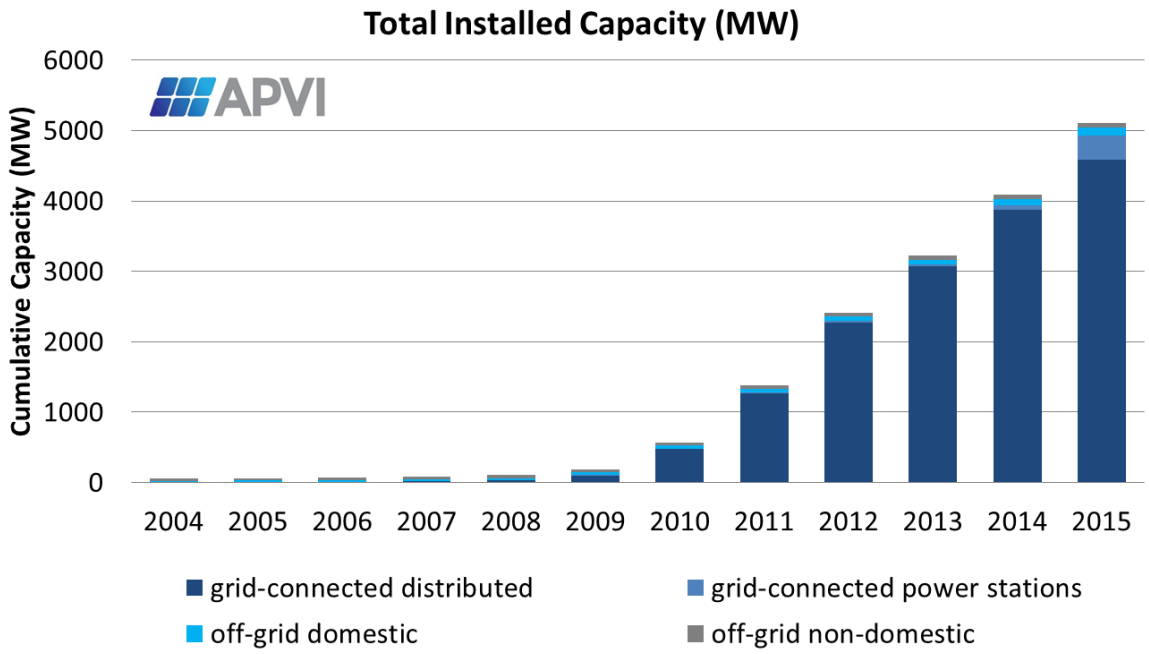


Figure 3: Australian PV Installations by Category 2004-2015.

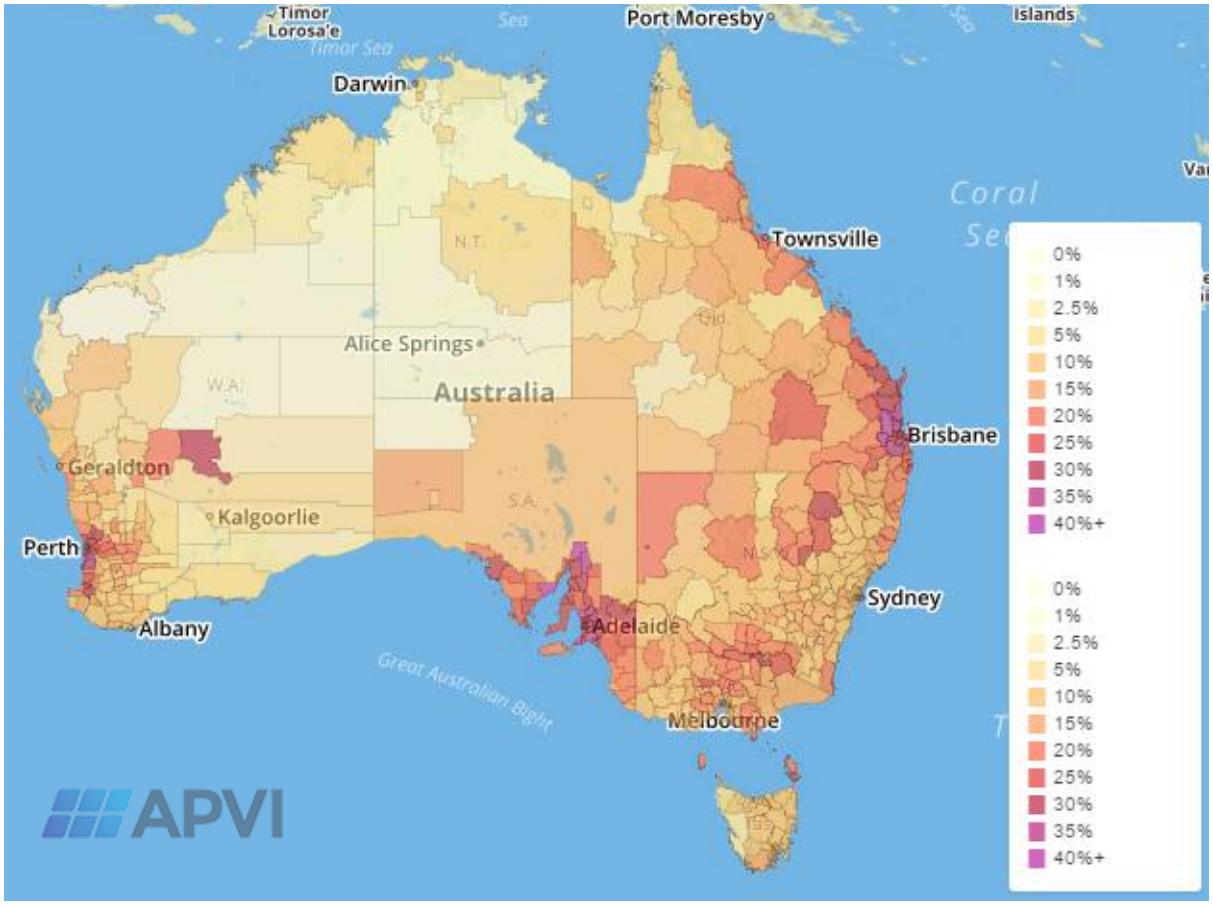


Figure 4: PV Installation Density by Local Government Area (APVI, 2016)

Table 4: 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	2014	2015
Off-Grid domestic	1.6	2.0	2.6	3.3	4.1	5.0	6.1	6.9	9.2	11.1	12.5	14.3	16.6	19.9	23.9	27.7	32.7	40.8	44.2	54.6	64.6	74.0	86.9	102.9
Off-Grid non-domestic	5.8	6.9	8.1	9.4	11.5	13.5	15.1	16.4	17.1	19.2	22.8	26.1	29.6	33.1	36.7	38.7	40.7	43.1	43.6	46.9	53.0	58.0	61.2	70.4
Grid-distributed		0.01	0.02	0.03	0.08	0.20	0.85	1.49	2.39	2.8	3.4	4.6	5.4	6.9	9.0	15.0	29.9	101.2	479.3	1268	2276	3070	3871	4580
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	3.8	7.4	21.5	24	68.5	356
TOTAL (MWp)	**7.30**	**8.90**	**10.70**	**12.70**	**15.70**	**18.70**	**22.52**	**25.32**	**29.21**	**33.58**	**39.13**	**45.63**	**52.30**	**60.58**	**70.30**	**82.49**	**104.5**	**187.6**	**570.9**	**1376.8**	**2415**	**3225**	**4087**	**5109**

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Prices are based upon information drawn from the APVI national survey 2015. The survey reported similar panel prices in 2015 to those reported in 2014, which is quite noteworthy considering the Australian Dollar weakened against the USD by 20% on average over 2015.

Table 5: Typical module prices for a number of years

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Standard module price(s): Typical $ AUD/W	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	0.8	0.8
Best price $ AUD/W														7.5	7	5	3	2	1.2	0.9	0.5	0.62	0.62

2.2 System prices

A summary of typical system prices is provided in the following tables. The prices are exclusive of incentives which reduce the price to consumers by a further AUD 0.6-0.7/Wp, depending on insolation.

Table 6: National trends in system prices (current) for different applications – local currency, prior to subsidy

Price $ AUD/Wp	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Residential PV systems < 10 KW	11	12	12	14	14	13	10	12	12	12.5	12	12	9	6	3.9	3	3.10	2.77	2.37
Commercial and industrial																		2.68	2.19
Ground-mounted																		2.70	2.18

Table 7: Turnkey Prices of Typical Applications – local currency

Category/Size	Typical applications and brief details	Current prices AUD per W
OFF-GRID Up to 1 kW	Water pumps, lighting, remote homes	9 - 15
OFF-GRID >1 kW	Pastoral systems	7.50 - 11
Grid-connected Rooftop up to 10 kW (residential)	Residential	2.37
Grid-connected Rooftop from 10 to 250 kW (commercial)	Commercial rooftop	1.78
Grid-connected Rooftop above 250kW (industrial)	Industrial	N/A
Grid-connected Ground-mounted above 1 MW	Solar Farms	2.18
Other category (hybrid diesel-PV, hybrid with battery…)	Battery Hybrid	4.45

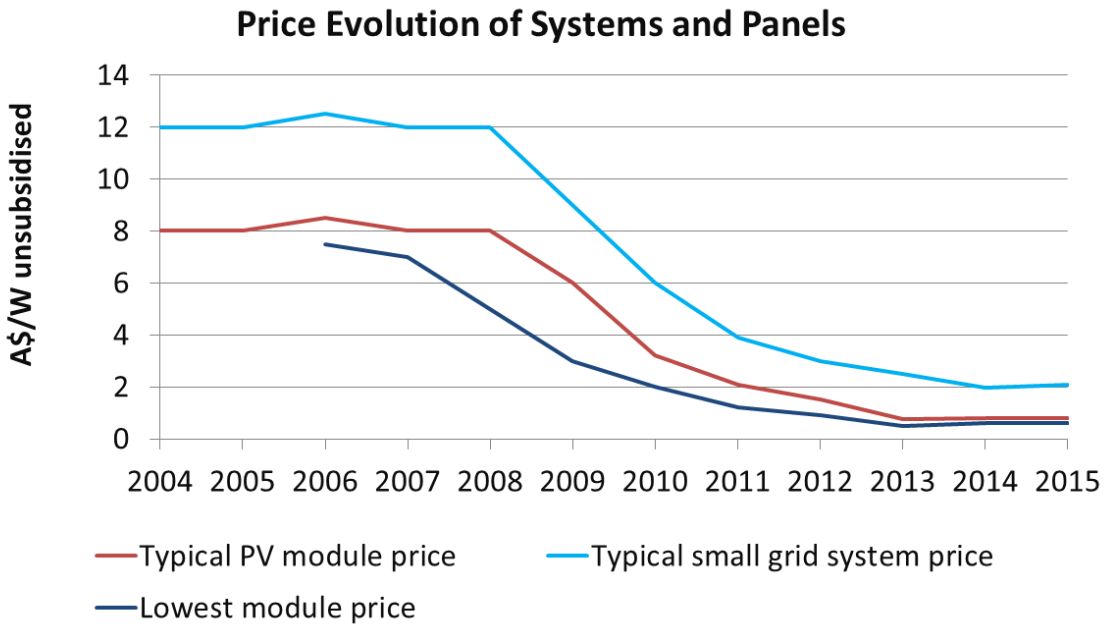


Figure 5: Australian Price evolution of PV Panels and Systems (Current AUD)

2.3 Cost breakdown of PV installations

The cost breakdown for a typical residential PV system shown below in Residential PV System < 10 kW

Table 8 is based upon a small survey of participants, and represents the average of their values at a single point in time. Consequently the breakdown presented here is different to the overall market average shown in Table 7.

2.3.1 *Residential PV System < 10 kW*

Table 8: Indicative Cost breakdown for a residential PV system – Australian Dollars ($)

Cost category	**Average (AUD/W)**
Module	0.80
Inverter	0.25
Other (racking, wiring…)	0.21
Installation	0.35
Customer Acquisition	0.08
Profit	0.36
Other (permitting, contracting, financing…)	0.04
Subtotal Hardware	**1.26**
Subtotal Soft costs	**0.83**
Sales Tax (GST)	**0.20**
Total	**2.29**
Subsidy (STCs)	-0.80
Total Customer Price	1.49

2.3.2 *Utility-scale PV systems > 1 MW*

Table 10: Indicative cost breakdown for an utility-scale PV system – AUD

Cost Category	Average (local currency/W)	Low (local currency/W)	High (local currency/W)
Hardware			
Module			
Inverter			
Other (racking, wiring, etc.)			
Soft cost			
Installation Labor			
Customer acquisition			
Profit			
Other (contracting, permitting, financing etc.)			
Subtotal EPC	2.01	1.97	2.05
Subtotal - Soft cost	0.33	0.16	0.51
Total Installed Cost	2.34	2.13	2.56

2.4 Financial Parameters and specific financing programmes

More finance providers and a broader range of finance options continued to come to the market in 2015, though most residential customers in Australia still purchase their PV systems using cash or a mortgage extension, the latter typically representing the lowest finance cost available.

Despite a flurry of announcements, Power Purchase Agreements (PPAs) have had limited success in the Australian market, largely because metering arrangements create take-or-pay risk for purchasers. PPAs have had greatest success amongst PV-selling electricity retailers and large companies with a primary focus on PPA sales.

Table 9: Financing mechanisms used in Australia

Third Party Ownership (no investment)	Third Party Ownership exists in Australia primarily through Power Purchase Agreements, which have had limited success to date.
Renting	There is only a very small market for solar power rentals in Australia, because of the very competitive pricing and the costs of grid connection and relocation.
Leasing	Leasing is well established as a financing mechanism, particularly in the commercial sector market.
Financing through utilities	Electricity retailers now offer on-bill financing and PPAs
Crowdfunding (investment in PV plants)	Community investment in solar power occurs in small but growing numbers in Australia.
Other (please specify)	10%-20% of the residential market obtains consumer finance to purchase their PV system.

Table 10: PV financing schemes

Average rate of loans – residential installations	5.5% (mortgage finance)
Average rate of loans – commercial installations	10% (commercial finance)
Average cost of capital – industrial and ground-mounted installations	Bank Bill Swap Bid Rate + 250 – 350 basis points (commercial finance)
Leasing	PV customers can lease a system for a set period, typically 5-10 years, paying no up-front cost, with repayments fixed or with a pre-determined annual escalator. Options to renew the lease or to own the system at the end of the lease period are also available
Power Purchase Agreements	PV Customers can enter into an agreement to purchase power directly via solar panels without any upfront capital expense. An external entity will pay for and own the PV system on the customer's premises and will offer a discounted electricity rate to the customer over a fixed period (such as 15 years).

2.5 Additional Australian 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 Australia.

General information is provided in Table 11 and more detail on electricity market operation is provided in Section 7.1.

Table 11: Australian information

Retail Electricity Prices for an household (range)	AUD 0.21 – 0.38 /kWh (flat tariffs)*
Retail Electricity Prices for a small commercial company (range)	AUD 0.23 – 0.35 / kWh
Retail Electricity Prices for a large commercial or industrial company (range)	AUD 0.12 – 0.22 / kWh
Population at the end of 2015 (or latest known)	24 million
Country size (km^2)	7.69 million sq km
Average PV yield (according to the current PV development in the country) in kWh/kWp	1400 kWh/kWp per year
Name and market share of major electric utilities.	• Origin Energy (27%) • AGL (24%) • Energy Australia (19%) • Synergy (7%) • ERM Power Retail (6%) • Ergon Energy (6%) • Aurora Energy (4%) • Others (7%)

3 POLICY FRAMEWORK

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

Table 13: PV support measures

	On-going measures residential	Measures that commenced during 2015 - residential	On-going measures Commercial + industrial	Measures that commenced during 2015 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2015 – ground mounted
Feed-in tariffs	Yes		Yes		No	
Feed-in premium (above market price)	No		No		No	
Capital subsidies	STCs		STCs		No[6]	
Green certificates	STCs		STCs or LGCs[7]		LGCs	
Renewable portfolio standards (RPS) without PV requirements	STCs		STCs or LGCs		LGCs	The RET was reduced in 2015
Income tax credits	No		No		No	
Self-consumption	Yes		Yes		N/A	
Net-metering	Yes (30 minutes)		Yes (30 minutes)		N/A	
Net-billing	No		No		N/A	
Commercial bank activities e.g. green mortgages promoting PV	Yes (through CEFC and some local banks)		Yes (through CEFC)			
Activities of electricity utility businesses	Yes		Yes		Yes	
Sustainable building requirements	Yes		Yes		N/A	
BIPV incentives	No		No		No	
ARENA Grant Funding	No		Yes, Project Specific		Yes, Large Scale Solar Competitive Funding with CEFC support	

[6] Except grant funding for specific projects from ARENA

[7] Small-scale Technology Certificates or Large Scale Generation Certificates

3.1 Self-consumption measures

PV self-consumption	1	Right to self-consume	Yes
	2	Revenues from self-consumed PV	Savings on the electricity bill
	3	Charges to finance Transmission & Distribution grids	Tariff structure changes in some states
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Feed-in Tariff
	5	Maximum timeframe for compensation of fluxes	30 minutes
	6	Geographical compensation	On site only
Other characteristics	7	Regulatory scheme duration	Unlimited but FiTs are revised annually
	8	Third party ownership accepted	Yes (e.g. Solar Leasing)
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	Yes (injection control / ramp-rate control / no DC-injection)
	10	Regulations on enablers of self-consumption (storage, DSM…)	None
	11	PV system size limitations	Yes, in some jurisdictions
	12	Electricity system limitations	None (except additional grid codes)
	13	Additional features	None

3.2 Direct Support measures

3.2.1 *The Renewable Energy Target*

The Renewable Energy Target (RET) consists of two parts – the Large-scale Renewable Energy Target (LRET), which in 2015 was reduced from 41 000 GWh by 2020 to 33 000 GWh, and the Small-scale Renewable Energy Scheme (SRES), with no set amount. 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. The RET is funded by a cross-subsidy leveraged upon all electricity consumption except for certain classes of industrial electricity consumers.

In 2014, the government initiated an independent review of the RET, which found that renewable energy generation was likely to exceed 20% of generation by 2020. This was a result of a projected reduction in electricity demand. The review recommended that the RET be reduced. In 2015 a compromise saw a reduction of the RET to 33 000 GWh.

Large-scale Renewable Energy Target

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, which have been updated in Table 12 to show the reduced target.

Table 12: Annual Generation Targets under the Large-scale Renewable Energy Target (as at end 2015)

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	28 637
2019	31 244
2020	33 850
2021-2030	33 000

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, however each year from then on will receive one year less deeming, in line with the RET completion date of 2030. Installed capacity and system size from 2009 to 2015 are shown in Figure 6.

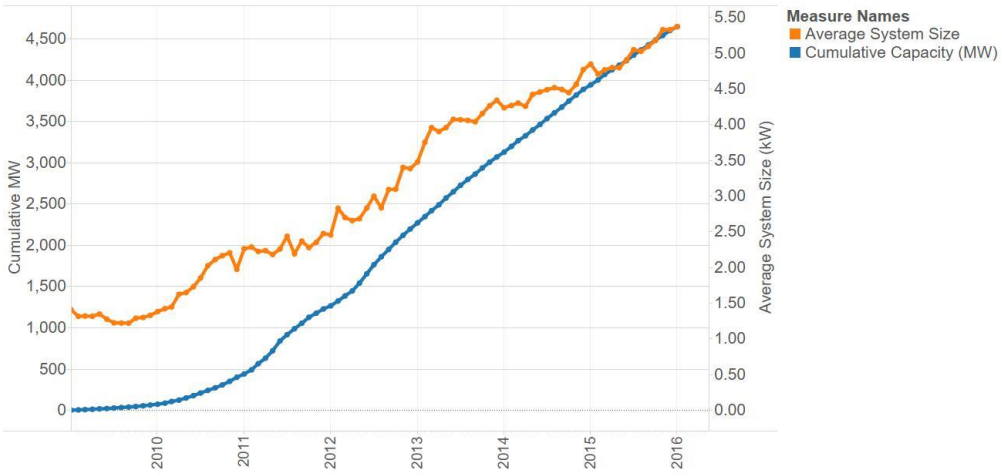


Figure 6: Cumulative installed capacity and average system size for SRES systems 2009-2015 (SunWiz analysis of Clean Energy Regulator data).

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.

3.2.2 *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. 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.

The Australian Government's intention to abolish ARENA was unable to gain sufficient support in the Senate, and in 2016 the government instead announced its intention to cease grant funding for projects and research in renewables and to establish a Clean Energy Innovation Fund (CEIF) within the Clean Energy Finance Corporation (CEFC). The CEIF would provide debt/equity funding to support innovation in renewables. ARENA would continue to manage its existing portfolio of projects and deliver its AUD 100 million Large-Scale Solar PV Competitive Round however after which there will be a shift from a primarily grant based role to more of a debt and equity basis. ARENA and the Clean Energy Finance Corporation (CEFC) will jointly manage the CEIF, allocating up to AUD 100 million each year to commercialize innovative renewable energy projects using equity and debt instruments. Once the fund is established, ARENA will assess project proposals and make recommendations for funding to the CEFC. Any future change to ARENA's funding is subject to a change in the ARENA Act 2011 assented to by the Australian Parliament, which at the time of writing has been dissolved for re-election.

3.2.2.1 Large Scale Solar

The Minister for Resources and Energy referred a number of large scale solar projects to ARENA when it was established in 2012. These projects had been developed for the former Solar Flagships Program. A project by AGL, with First Solar as EPC was selected for a grant in 2012. The project is located across two sites: Nyngan (102 MWac, 134MWdc) and Broken Hill (53 MWac, 64MWdc) in New South Wales with a total nominal capacity of 155 MWac (198MWdc). Details are provided in Figure 7. The system frames were manufactured by IXL in Adelaide. Construction commenced in 2014 and was completed in 2015.

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

ARENA provided AUD 166.7 million in funding to support project implementation, with a further 64.9 million from the NSW State Government. Total capital expenditure for the two solar projects is expected to be approximately AUD 439 million.

Figure 7: 102 MWac Solar Flagship Installation at Nyngan (image courtesy AGL)

Capacity/Generation:	Nyngan	Broken Hill
MW (AC)	102	53
Annual GWh (at plant boundary)	233.4	126
AC Capacity factor (at plant boundary)	26%	27%
Construction:		
Scheduled construction start	Jan 2014	July 2014
Scheduled construction end	June 2015	Nov 2015
Peak Direct construction jobs created	300	150
Design Details:		
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
Environmental Benefits:		
Equivalent NSW homes powered @ 7 MWh/yr	33,300	17,000
Equivalent cars off the street	53,000	29,000

Figure 8: Details of the First Solar / AGL Solar Flagship Projects (Source: First Solar)

In addition to the capital works funding, the University of Queensland and the University of New South Wales were awarded a $40.7 million grant as an Education Investment Fund component of the project. The 3.275 megawatt Gatton Solar Research Facility constructed as part of this research project was switched on in March 2015. The University of New Wales constructed a Power Systems Interface Research Facility to investigate significant areas related to the successful integration of solar PV stations into Australia's electricity grid.

ARENA provided a further $101.7 million to support the construction and operation of the 56MWac (70MWp) Moree Solar Farm which is the first large-scale solar plant in Australia to use a single-axis horizontal tracking system. Construction took place during 2015. The project, valued at approximately $164 million, also received support from the Clean Energy Finance Corporation

3.2.2.2 Regional Australia's Renewables

Some specific funding programmes active in 2015 were ARENA's Regional Australia's Renewables Programme, which provided:

- AUD 20.9 million in finance for a 10.6MW solar power system to meet 20% of the power requirements at diesel-powered copper mine (DeGrussa, WA).
- AUD 2.3 million in finance for a 1MW PV facility with cloud predictive technology at a remote airport in Western Australia, construction in 2016
- AUD 0.45 million in finance for the integration of 1.8MW of PV into the Ayers Rock Resort, for a total project value of AUD 6.5 million, with construction to start in 2016.

- AUD 22.8 million in finance for fringe of grid renewable solar PV in Queensland (Barcaldine, 25MW), construction to commence in 2016
- AUD 5.5 million of grant funding for a containerised high penetration hybrid renewable energy facility located on Flinders Island (Tasmania)
- AUD 4.8 million of finance for a high renewable energy contribution hybrid system integrated with desalination demand management located on Rottnest Island (West Australia)

3.2.3 *Clean Energy Finance Corporation*

The Clean Energy Finance Corporation (CEFC) is a Australian Government initiative that invests using a commercial approach to overcome market barriers and mobilise investment in renewable energy and lower emissions technologies. As with ARENA, Australian government's intention to abolish the CEFC was unable to gain sufficient support in the Senate, and in 2016 the government instead announced its intention to establish a new Clean Energy Innovation Fund (CEIF) to support renewable energy project innovation through debt and equity funding.

The CEFC invested AUD 395 million in Solar PV in 2014-15. CEFC activities in 2014-15[8] include:

- AUD 100 million in finance for solar PV and storage projects across Australia which support an electricity retailer to offer Power Purchase Agreements.
- AUD 4.7 million in finance for a PV Project in the Northern Territory (Ayers Rock Resort, 1.8MW)
- AUD 13 million to expand the Uterne power station in the Northern Territory from 1MW to 4.1MW in size.
- AUD 15 million in finance for remote renewable solar PV and battery storage in Western Australia (Degrussa, 10.6MW with 6MW battery storage)
- The CEFC has also provided AUD 60 million senior debt finance to the 56MW Moree solar farm, which was completed in 2015.

The CEFC is currently running an AUD 250 million Large-Scale Solar Financing Programme providing debt finance to solar PV projects of 10MW or more. The offer of fixed-rate longer-dated senior debt is aimed at sponsors seeking loans of AUD 15 million or more. The programme is open to projects that have, or intend to seek Power Purchase Agreements, as well as projects proposing to take some merchant electricity market exposure. Loans sourced through the programme can be used to complement ARENA's Large-Scale Solar PV Competitive Round funding programme, as well as other large-scale renewable energy development programmes.

3.2.4 *The "Direct Action" Plan*

The Australian Government's Direct Action Plan was brought into legislation after critical support was won in October 2014. Although the Direct Action Plan supports emissions reduction mechanisms, it does not directly support the growth of PV.

3.2.5 *State and Territory Support*

State Governments support a range of research, development and demonstration projects.

[8] http://annualreport2015.cleanenergyfinancecorp.com.au/performance/year-in-review/the-cefcs-new-investments-in-2014-15/

Though the final offer of a premium-feed in Tariff concluded in 2014, historical feed-in tariffs continue to apply in many Australian states for systems less than 30kW, as shown in Table 13. The Australian Capital Territory also provided FiTs via the Large-scale Solar Auction, as discussed below.

3.2.5.1 The Australian Capital Territory (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 20MWac 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 was commissioned in July 2014. OneSun and Zhenfa are expected to be completed in 2016. The auctions are funded from the ACT budget.

The ACT government will follow up with further tenders to reach its goal of 100% renewable energy. In 2016, the ACT government will support 36MW of energy storage to be rolled out across more than 500 Canberra homes and businesses between the years 2016 and 2020.

Figure 9: 20 MWp Royalla Solar Farm

3.2.5.2 Other States

In 2016, the New South Wales Government will tender for renewable energy for its Sydney Metro Northwest rail project.

The Queensland government also intends to provide support in 2016 for up to 60MW worth of ARENA-funded projects through 20 year Power Purchase Agreements.

South Australia's RenewablesSA initiative established a new target of 50% renewable energy production by 2025 through continuing to develop projects in SA and help remove barriers to investment in the renewables sector.

Table 13: Australian State and Territory Feed-in Tariffs in 2015

State	Start Date	Size Limits	Rate AUDc/ kWh	Scheme end	Type	Eligibility
Victoria						
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
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. In 2016 the Victorian Government commenced an investigation into the value of solar power to the network, with the intention of recognising this value in FiT payments.					
South Australia						
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	6.8 (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 was reduced to AUD 0.076/kWh from Jan 2014 and AUD 0.053/kWh from 2015. 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.					
ACT						
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.					
Northern Territory						
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.					
Queensland						
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	6.35	Open ended	Net	Consumers with less than 100MWh/yr
Comments	The SBS net amount was not be mandated for SE Qld after 1 July 2014 – the mandated tariff in regional Queensland for 2015-2016 is shown. Customers may default to the new SBS FiT if they change their system size or move house.					
New South Wales						
Solar Bonus Scheme (SBS)	1 Jan 2010	10 kW	60	31 Dec 2016	Gross	Residential
SBS 60 (closed 27 Oct 2010)						
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 5	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'					
Western Australia						
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	Up to 5kW	dropped to 7.135 from 9.5 on 1 September 2014	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					

3.2.6 *Tenders, auctions & similar schemes*

Solar tenders have come from a mix of state governments, local governments, electricity retailers, and the Australian Renewable Energy Agency (ARENA). Each has its own process with varying funding mechanisms, the most common being PPAs for energy generation or Renewable Energy Certificates or both. Examples include;

- The Australian Capital Territory (ACT) ran two reverse auctions for solar power in recent years. The ACT government will follow up with a storage programme and further tenders to reach its goal of 100% renewable energy.
- Tenders have been announced by three electricity utilities (Ergon, Alinta and Synergy) contracting to purchase their Renewable Energy Certificate requirements.
- In 2016 a consortium of local governments, universities, and private businesses is tendering for renewable energy.
- In 2016, the Queensland Government will support up to 60MW worth of ARENA-funded projects through 20 year Power Purchase Agreements.
- The New South Wales Government will tender for renewable energy for its Sydney Metro Northwest rail project in 2016.
- ARENA shortlisted 22 high-merit large-scale solar projects ranging from 12-108 MW for a total of AUD 100 million of funding in the Large-Scale Solar PV Competitive Round, with projects required to achieve AUD 135/MWh or below.

3.2.7 *BIPV development measures*

ARENA ran a specific call for BIPV technology development projects in 2015, though none have yet been funded. Earlier funding has supported development of roof-integrated BIPV panels by Bluescope steel.

3.2.8 *Rural electrification measures*

Several utilities supplying regional areas are examining renewable energy-based micro-grid systems as an option to grid supply, where the latter is expensive to maintain and where customer density is low. This is expected to reduce the cross-subsidies currently provided for rural grid supply.

3.2.9 *Support for electricity storage and demand response measures*

In 2015, the only known storage incentives were offered by the City of Adelaide and the City of Melbourne. The City of Adelaide provides 50% of the cost of batteries up to a value of ADU 5000, plus up to a further AUD 5000 for 20% of the price of a PV system[9].

In 2016 South Australian electricity network operator SAPN will offer highly subsidised PV-storage systems as part of a trial of 100 houses.

In 2016, the Australian Capital Territory government will support 36MW of energy storage to be rolled out across more than 500 Canberra homes and businesses between the years 2016 and 2020.

[9] http://www.adelaidecitycouncil.com/your-council/funding/sustainable-city-incentives-scheme/

4 HIGHLIGHTS OF R&D

4.1 Highlights of R&D

Australia has a long history of publicly funded support for R&D, market stimulation and demonstration programmes. Photovoltaics research is carried out largely in Australian Universities and Institutes, plus a small number of private companies that carry out research into product development and design as well as research and analysis of the role of PV in the energy market.

Publicly funded PV research is led by the university sector and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and has been funded primarily through government agencies; ARENA and the Australian Research Council (ARC). Private sector research investments are also supported through ARENA, as well as an R&D Tax Incentive.

Publically funded research has been stable for the last few years. Emphasis has shifted toward integration and deployment, with policy research receiving little support.

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

4.2.1 *The Australian Renewable Energy Agency (ARENA)*

ARENA is the main R&D support measure in Australia specific to renewables. ARENA has two objectives: to improve the competitiveness of renewable energy technologies, and to increase the supply of renewable energy in Australia.

ARENA manages a portfolio of solar research initiated under the Australian Solar Institute programmes (ASI). In 2013 this programme was rolled into ARENA. ARENA has since held two R&D funding rounds.

In 2015, there was no competitive R&D funding awarded by ARENA to the research sector, compared with AUD 21.5 million awarded in 2014. However, AUD 0.89 m was allocated to the Commonwealth Scientific and Research Organisation (CSIRO) to establish guidelines for PV testing capabilities plus a total of AUD 6.3 million was awarded to industry to develop a central-receiver concentrating PV technology in addition to the direct funding reported earlier in Section 3.2.2.

The allocation of competitive R&D funding of close to AUD 20.0 million for successful project bids was announced in early 2016. The government has recently removed grant funding for research from future budget allocations and so there is no certainty around future grant funding for solar research via ARENA.

4.2.2 *The Australian Research Council*

The ARC is a statutory agency within the Australian Government. Its mission is to deliver policy and programmes 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 Programme and administers Excellence in Research for Australia (ERA).

Through competitive funding, 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.

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.

In 2015 AUD 3.0m was provided for PV related R&D, compared with AUD 2.6m in 2014.

The Australian budgets for solar research and field testing are shown in Table 14.

Table 14: Australian public budgets for R&D, demonstration/field test programmes and market incentives 2015.

	R & D	Demo/Field test
National/federal	AUD 10.24 million	0
State/regional	0	unknown
Total	AUD 10.24 million	

4.3 Details of Research

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

4.3.1 *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, modules and systems. The group was founded in 1991, and is one of the largest and longest established solar energy research groups in Australia.

Activities span 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 20m. Funding support comes from the Australian Research Council, ARENA, industrial companies and several other sources. In 2015 work continued on the following projects:

- 24-26% efficient Interdigitated Back Contact solar cells
- Nano and Plasmonic materials for solar cells
- Improving conventional silicon solar cells
- Advanced materials for surface passivation and optics
- Defect detection and quenching
- Flexible, light-weight and portable modules
- Improved encapsulation techniques
- Mass storage options for renewable electricity
- Integration of wind and PV into grids

4.3.2 *Charles Darwin University*

PV research at The Centre for Renewable Energy within Charles Darwin University focuses on three main areas: remote area hybrid PV systems, network integration and PV module performance under the unique cyclonic tropical locale of the Northern Territory.

Remote area hybrid PV systems:

- Integration of PVs into existing diesel power systems in remote communities.
- The economics and performance of storage devices in remote areas.
- Development of smart algorithms using artificial intelligence techniques for system optimization.

Network integration:

- The use of intelligent techniques to prevent overvoltage for residential rooftop PVs.
- The economics and effects of implementing demand-side management for residential systems.

PV module performance:

- Performance testing of various PV technologies (CIGS, CdTe and c-Si) under the Northern Territory climate.
- The impact of environmental effects such as soiling, temperatures, fauna, rainfall, etc. on different PV technologies.
- Development of forecasting models for system optimization.

The CRE has five full-time staff, three adjuncts and three post-graduate students working on renewable energy technologies, energy efficiency and policy research. Funding support comes from the Northern Territory Government, ARENA, Department of Industry and Science, Defence Housing Australia, Industry Partners and other sources.

4.3.3 *CSIRO PV Performance Laboratory*

CSIRO continued to operate its IEC 17025 accredited PV cell measurement facilities through 2015 as part of its growing PV Performance Laboratory brand that includes both indoor and outdoor testing of PV modules. The facilities were used to support PV cell research around Australia, as well as consumer advocacy publications, dispute resolution and validation measurements on after-market products such as anti-soiling coatings for modules. They also supported CSIRO's research in Perovskite solar cells, cooling of PV modules in the field and the impact of the solar spectrum on PV output. Activities during the year have led to the solar ground measurement station associated with the PV outdoor facility (BSRN) being accepted as part of the international Baseline Surface Radiation Network – an important collaboration between the world's best solar measurement facilities.

Figure 10: (left) the Solar Ground Measurement Station at the CSIRO Energy centre in Newcastle is now part of the global BSRN network; (right) Dr Chris Fell discusses PV outdoor testing results with Dr Ben Duck

4.3.4 *Monash University*

Monash University is a world leading research organisation in next-generation solar cells that harness the potential of printing methods. The team attracted more than AUD 1m in 2015 from the Australian Research Council and ARENA. The team has published in leading international journals, such as Nature Materials, Nature Photonics and Nature Chemistry, with 66 manuscripts in 2015 alone. The University's target is to work with industrial partners to develop relevant and ground-breaking research towards cost-competitive solar cell technologies.

A research team of five academics and more than 45 postgraduates and research fellows in the Renewable Energy Lab at Monash University focus their research on solution based photovoltaic technologies. These include dye-sensitised solar cells, organic solar cells, inorganic thin film and perovskite solar cells.

A major effort in 2015 was on the development of perovskite solar cells. The team investigated the problems in forming perovskite thin films and developed two novel coating techniques that de-coupled the nucleation and grain growth during the spin coating process, resulting in high quality perovskite films. Planar perovskite solar cells of 17% efficiency were achieved.

Research into solution-processable photovoltaics focuses on understanding the device physics and morphology of high performance devices. A particular strength is the use of advanced synchrotron techniques to characterise thin-film microstructure, with the Australian Synchrotron located adjacent to the university's campus. Polymer based solar cells with efficiency of greater than 9% have been achieved, and the microstructural characteristics of such devices defined. Low-temperature characterisation of cell behaviour is also being carried out with an optical cryostat capable of going down to liquid helium temperatures.

Through the recent recruitment of Associate Professor Jacek Jasieniak, the capabilities in the area of precise thin film coatings for solar cell applications have been extended. Investigations in this area around chemical precursor chemistry and interfacial chemical interactions have shown leading Cu2ZnSn(S,Se)4 thin film solar cell efficiencies from printed devices and have explained a key requirement for the morphological evolution in organic solar cell devices, respectively.

4.3.5 *Murdoch University*

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

Advances in 2015 include:

- Studies on long term degradation of modules in the field for over 15 years
- The characterization and assessment of PV module conditions in the field
- case studies in Indonesia and Western Australia concerned with the effect of dust on the performance of PV modules and the development of modified de-rating factors for soiling
- Coproduction of electricity and biomass from combined PV/microalgae facilities
- The ongoing monitoring of the PV Module and System Fault Reporting Portal (www.surveymonkey.com/s/pvwebportal) which contributes data to the IEA work on PV module reliability.
- Design and installation of a sky-camera network and data acquisition system for intra-hour solar irradiance and photovoltaic system output forecasting.
- PV systems integration studies in remote diesel networks.
- Development of a PV array troubleshooting and educational facility.

Murdoch continues to actively engage with the International Energy Agencies' PVPS Task 13 work on PV reliability and performance. Contributions have been made to reports on electroluminescence testing and the assessment of PV module failures in the field.

4.3.6 *Queensland University of Technology (QUT)*

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, optimisation of battery storage and development of battery storage algorithms. The research is conducted through the Future Energy Systems and Clean Technology Programme of the Institute for Future Environments. Research on solar thermal electricity generation is also being conducted as part of the Australian Solar Thermal Research Initiative consortium.

4.3.7 *University of Melbourne*

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 aims to bring these organic photovoltaic technologies to a level where they can be commercialised, 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 solar cells has been set at 10% PCE for a single junction device.

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 channelled and amplified for collection by high efficiency solar cells at the windows' edge.

4.3.8 *University of New South Wales (UNSW Australia)*

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

The Australian Research Council (ARC) Photovoltaics Centre of Excellence commenced at UNSW Australia in 2003. The Centre now delivers near-term research outcomes with industry-partners leveraged by government funding through to long term research outcomes supported largely by ARENA and international schemes. Significantly, in 2013, UNSW was established as the home for the Australia-US Institute for Advanced Photovoltaics (AUSIAPV) and the Australian Centre for Advanced Photovoltaics (ACAP). These are both ARENA special research initiatives. AUSIAPV aims to significantly accelerate photovoltaic development beyond that achievable by Australia or the US individually, while ACAP is developing the next generations of photovoltaic technology, providing a pipeline of opportunities for performance increase and cost reduction.

UNSW maintains its world-leadership in "first generation" devices, with international records for the highest-performing silicon cells in most major categories. 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 an estimated 10% of the current manufacturing capacity using the UNSW Passivated-Emitter, Rear-Contact (PERC) concepts.

UNSW researchers have pioneered work in second generation photovoltaics with activities in thin silicon layers on glass, organic solar cell research, as well as CZTS (copper-zinc-tin-sulphide) solar cell technology.

UNSW's interest in advanced "third-generation" thin-film solar cells targets significant increases in energy-conversion efficiency. The Centre's experimental programme in this area is concentrating on "all-silicon" tandem solar cells, where high energy-bandgap cells are stacked on top of lower-bandgap devices.

Significant research is also undertaken in the areas of PV and renewable energy systems and policy. During 2015, research has included high PV penetration in electricity grids, continued 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.

4.3.9 *University of Queensland*

Research at the Centre for Organic Photonics and Electronics (COPE) focuses on developing new materials and architectures to improve the efficiency of organic semiconductor based solar cells and thin film perovskite solar cells. COPE is a partner in the ARENA funded Strategic Research Initiative (SRI): Australia-US Institute for Advanced Photovoltaics. Within the SRI, the Centre focuses on applying its core expertise in electro-optics and charge transport physics in organic semiconductors and organohalide perovskites, and the creation of new molecules for advanced photon harvesting concepts.

At the Nanomaterials Centre at the University of Queensland, the team are investigating new types of solid-state solar cells using perovskite sensitisers and solid electrolytes.

The Power & Energy Systems Group (School of ITEE) 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 Energy Economics and Management Group (EEMG) is a national centre for economic research in the field of renewable energy and related environmental questions.

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. The GCI manages the research programme of the UQ MW Array Project and the Gatton Solar Research Facility, where the University of Queensland is the lead research organisation, in partnership with the University of New South Wales, in support of the development of the utility-scale solar industry in Australia. The programme shares learnings with the projects that First Solar is constructing for AGL Energy at Nyngan and Broken Hill that have a combined capacity of 155 MW (AC).

The Gatton Solar Research Facility is located at UQ's Gatton Campus and is one hour west of Brisbane. It was completed and opened in March 2015 and contains 3.275 MW of fixed, single axis tracking and dual axis tracking First Solar CdTe PV panels. In late 2015, a large 760 kWh lithium ion battery was installed at the site, completing the infrastructure package. The Gatton Solar Research Facility is Australia's only commercial-industrial scale PV research facility and is one of the most sophisticated anywhere in the world. This facility brings the total PV plant owned and operated by UQ to > 5 MW.

5 INDUSTRY

5.1 Production of photovoltaic cells and modules (including TF and CPV)

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. Tindo's business model is to both sell panels wholesale and retail PV systems.

Tindo Solar did not provide information on its manufacturing levels in 2015. Small scale technology certificate (STC) registration activity shows that Tindo installed 2.3MW of panels in 2015, meaning its manufacturing volume is certainly higher than this.

Total PV cell and module manufacture together with production capacity information is summarised in Table 16 below.

Table 16: Production and production capacity information for 2015

Cell/Module manufacturer (or total national production)	**Technology** (sc-Si, mc-Si, a-Si, CdTe)	**Total Production (MW)**		**Maximum production capacity (MW/yr)**	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Tindo Solar			>2.3MW		60
TOTALS			**>2.3MW**		**60**

5.2 Manufacturers and suppliers of other components

The balance-of-system component manufacture and supply is an important part of the PV system value chain.

5.2.1 *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. Magellan Power is an Australian based manufacturer of power electronics including PV inverters designed for both residential and commercial applications.

5.2.2 *Storage batteries*

Australian company RedFlow manufactures Zinc Bromine (ZBM) batteries. Its ZBM product delivers up to 3 kW of continuous power (5kW peak) and up to 8 kWh of energy. Redflow has launched a product to serve the residential market.

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 Magellan Power 400kWh lithium polymer battery storage system is in operation at a NSW utility.

Redback Technologies has recently set up offices in Queensland, with a lithium battery technology.

A range of batteries (>70) manufactured by foreign companies are also readily available in Australia. Including the following;

- LG have lithium iron phosphate battery technologies which can be scaled up to 18kWh (2kWh each).
- Samsung have an all-in-one Energy Storage System which can hold 3.6kWh in a compact, slim-line housing weight 95kg.
- Aquion Energy are entering the Australian market with sodium based battery technologies which could promise to be a better fit for utility-scale commercial PV projects than Lithium ion.
- Tesla have made Australia one of their first international markets to release the PowerWall; first installations occurred in January 2016.
- Enphase will launch its energy storage product in Australia in mid 2016
- Australian company 360Storage sold hundreds of systems in 2015, using batteries imported from Pylon.
- AuOptronics and Sunverge batteries are sold by electricity retailer AGL.

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

5.2.3 *Battery charge controllers and DC switchgear*

A range of specialised fuses, switches and charge controllers are made locally. A few examples of charge controllers & switchgear implementations in Australia include:

- Magellan Power have a range of renewable energy battery, control and switching technologies.
- Solari Energy – Solagrid Energy Storage System (ESS) a stand-alone energy storage system suitable for any sized solar energy installation. Also produce solagrid audible alarm safety device in case of faults.

5.2.4 *Supporting structures*

A range of mounting and tracking systems are made in Australia to suit local conditions. IXL have manufactured 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.

5.2.5 *BIPV*

Bluescope steel has manufactured thin-film solar panels that are integrated into Colorbond steel sheet roofing. This building-integrated photovoltaic-thermal (BIPV-T) system is employed for the production of electricity and thermal energy, while an innovative thermal duct system warms and cools air to supplement air conditioning in the home.

Another company, Tractile Solar, combines PV cells with Thermal Hot Water.

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 numbers10.

Table 15: Estimated PV-related labour places in 2016

Research and development (not including companies)	400
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	20
Distributors of PV products	200
System and installation companies	8310
Electricity utility businesses and government	500
Other	3000
Total	12430

6.2 Business value

As Australia predominantly relies upon imported PV modules and inverters, most of the value added in Australia relates to the sales and installation of PV systems.

Table 18: Value of PV business in Australia in 2015 (AUD)

Sub-market	**Capacity installed *in 2015* (MW)**	**Price per W in AUD ($/W)**	**Value AUD**	**Totals**
Off-grid domestic	*16.0*	*8*	*128*	
Off-grid non-domestic	**4.0**	**8**	*32*	
Grid-connected distributed	**709**	**2.37**	*1681*	
Grid-connected centralized	**287**	**2.18**	*626*	
				2467
Import of PV products				*1287*
Value of PV business				***1180***

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

[10] 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 which are 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 National Electricity Market (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, retailers, 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 when calculating retail tariffs, as shown in Table 11.

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 (NWIS). 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.

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 small-scale residential with an average size of 4.5 kW, is connected to the distribution network, and supplies loads directly. This circumvents the incumbent electricity sector and is therefore causing significant problems 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, 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 from incumbents.

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 generation options themselves, even if these may provide more cost effective solutions than grid upgrades or extensions, while third part access to the network is not available.

While some network operators are experimenting with integration of storage, proposed changes to tariff structures that adversely affect the financial attractiveness of PV, or even directly penalise PV pose a threat to increased uptake.

Environmental goals, including greenhouse gas reduction, were initially used to drive policy support for PV, with utilities required to accept PV connections as well as contribute to the Renewable Energy Target. Since 2014, the Australian Government has sought to review, remove or reduce incentives. State governments, which own a significant portion of electricity assets, as well as private owners, are keen to maintain value and/or income. As a result, there is a significant motivation to limit further PV uptake by placing size and installation restrictions and changing connection procedures and tariff structures so as to make PV less attractive.

Despite a lack of positive signals and incentives for new entrants, each of the major electricity retailers sells solar power systems, many offering innovative practices such as on-bill financing, PPAs and energy storage.

7.3 Interest from municipalities and local governments

There is a high and increasing interest in PV implementation from local governments and community organisations around Australia. These groups typically are less well-resourced than utility or large government organisations, and must operate within the electricity market rules described above, however they are backed by a high level of community support for local generation and employment creation. Many local governments install PV on their own buildings, operate bulk-buy initiatives, and are beginning to set their own renewable energy goals and support community-owned solar installations.

Examples of local government solar PV support initiatives include:

- Tenders for PV system installations on council buildings across the nation
- The City of Adelaide provides 50% of the cost of batteries up to a value of AUD 5000, plus up to a further AUD 5000 for 20% of the price of a PV system[11].
- City of Melbourne has a rebate for commercial PV that ranges from AUD 2000 and AUD 4000 and have a minimum system size of 10kW.
- The Melbourne Renewable Energy Project is a consortium of local government, educational institutions, and private companies that aims to purchase 110 GWh worth of energy from new large scale renewable energy facilities.
- Solar Bulk Buy Programmes give households and businesses in these municipalities access to bulk purchase discount deals. Many local government bulk-buy programmes exist.
- The Sunshine Coast Council will commence construction of a 15MW solar farm in 2016, Australia's first Local Government-owned solar farm.
- Many local governments have initiated Environmental Upgrade Agreements to assist in reducing the carbon intensity of energy use. This can include solar PV and is

[11] http://www.adelaidecitycouncil.com/your-council/funding/sustainable-city-incentives-scheme/

implemented by lower than market, fixed interest rate loans over a longer than usual loan term.

- Community solar programmes have gained much popularity in recent years with the formation of many community bulk-buy solar programmes and various initiatives to encourage solar PV investments.

7.4 Interest from state and territory governments

In recent years, PV had fallen out of favour amongst many conservative state governments, in part due to liabilities faced from earlier, generous feed-in tariff programs. Many state governments still own distribution network and generation assets which are facing declining sales volume, due to reduced demand from manufacturing, increased energy efficiency as well as high PV uptake. In 2015, the pendulum swung back in favour of PV as state governments recognised the popularity and inevitability of solar power. Large-scale solar programs were initiated in Queensland, New South Wales and Victoria, and expanded in the ACT; and various State government owned entities announced tenders for purchase of renewable energy.

8 HIGHLIGHTS AND PROSPECTS

The Australian PV market grew again by 19% in 2015, adding a further 1016 MW. This growth occurred despite a 17% contraction in the residential market, which represents the majority of the market for Australian PV. Overall growth was assisted by a 10% increase in the commercial market, plus the addition of three significant utility-scale projects totaling 271 MWdc (215 MWac) (or 20% of the market) an increase from 63 MWdc installed in 2014.

At the end of 2015, installed capacity crossed the 5GW threshold, accounting for 9% of national electricity generation capacity and 2.8% of electrical energy generation. Panel prices were steady in the local currency despite deterioration in the strength of the Australian dollar.

Other benchmarks were set in 2015 – over 1.5 million Australian homes now host a PV system, plus over 25,000 businesses. Residential penetration levels average 19% and are over 50% in some areas. With grid parity for self-consumption, PV is an attractive option for homeowners. The residential market is likely to again decline slightly in 2016, offset by continued growth in commercial PV.

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 coal and gas generation plant closures.

The impact of declining demand on the revenues of incumbent generators and network operators 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. Despite this, PV is returning to favour among some State Governments through large-scale solar tenders. Utilities have started to place significant resources into selling PV systems themselves; electricity retailers Origin and AGL each captured 1.4% of the sub-100kW market; ActewAGL held 12% of its local market, and Synergy began sales of PV systems in 2015.

2015 was Australia's biggest ever year for deployment of utility-scale solar. Three projects that originated out of the Solar Flagships programme were installed – solar farms at Nyngan (102MWac, 134MWdc), Broken Hill (53 MWac, 64MWdc) and Moree (56MWac, 70MWdc). There was also a 3MW upgrade to Uterne, and a 1.7MW power station at Weipa Bauxite Mine. All of these projects were supported by grant funds from the Australian Renewable Energy Agency (ARENA). Leading industry forecasters believe that utility-scale solar will make a strong contribution to meeting the Renewable Energy Target from 2017 onwards, though 2016 will see mostly early stage project development rather than panel deployment. A number of utility-scale projects are likely to arise out of tenders from ARENA and the CEFC, state governments, universities, electricity retailers, and businesses. However, uncertainty around ARENA's ability to provide grant funding will impact future planning in this area.

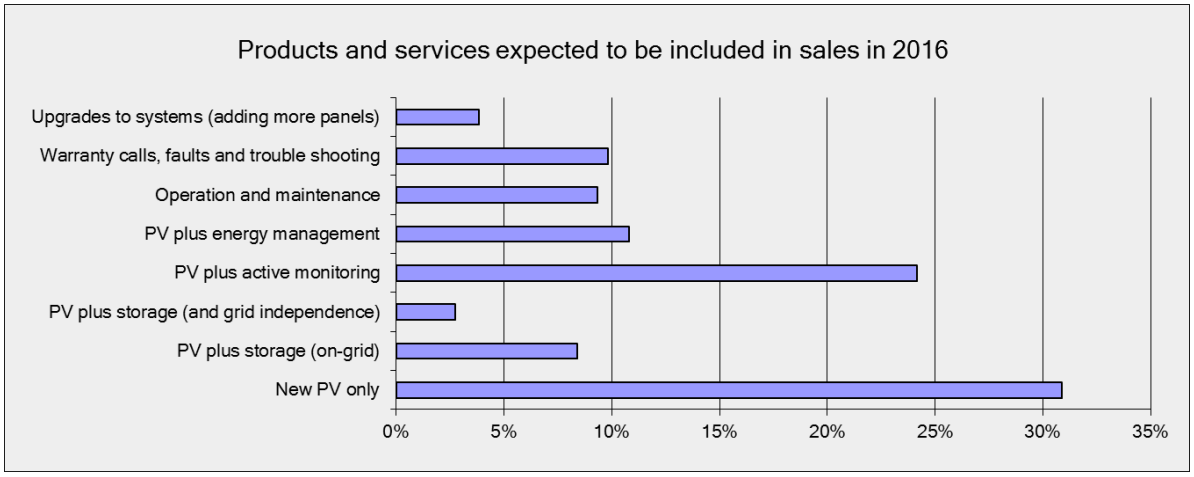
8.1 Storage

The interest in on-site storage technologies has continued to increase and is expected to gain more momentum as products become more cost-effective. With its high electricity tariffs, half-hourly net metering, and low feed-in tariffs, Australia has become a market of particular interest to international battery manufacturers, with many announcing Australian offerings.

The solar storage market is already developing and this can be expected to cause more friction with incumbent electricity sector businesses as customers consider the option of disconnecting from the main grid. It could, however, also offer a means of tackling PV generation intermittency until 'smart' electricity grids are implemented. For the time being, some network operators are conducting trials of energy storage.

According to Clean Energy Regulator data, there were at least 472 installations of grid-connected batteries on new PV systems in 2015. From the APVI survey data, the average size of grid-connected batteries was 9.4kWh, meaning the residential market volume was at least 4.4MWh.

Storage represents a growing opportunity for the Australian market, but the annual APVI survey reveals that PV remains the mainstay of sales, and that more immediate opportunities exist in PV monitoring and maintenance, and on the grid side with demand management and load control. Survey respondents suggested that ~1% of sales enquiries for batteries result in a battery installation, though some respondents had a success rate 10 times higher. However, respondents believe the future for storage is bright, anticipating that their sales rate will double in 2016 and (at least) double again in 2017.



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