IEA INTERNATIONAL ENERGY AGENCY

AUSTRALIAN PV INSTITUTE

IEA-PVPS

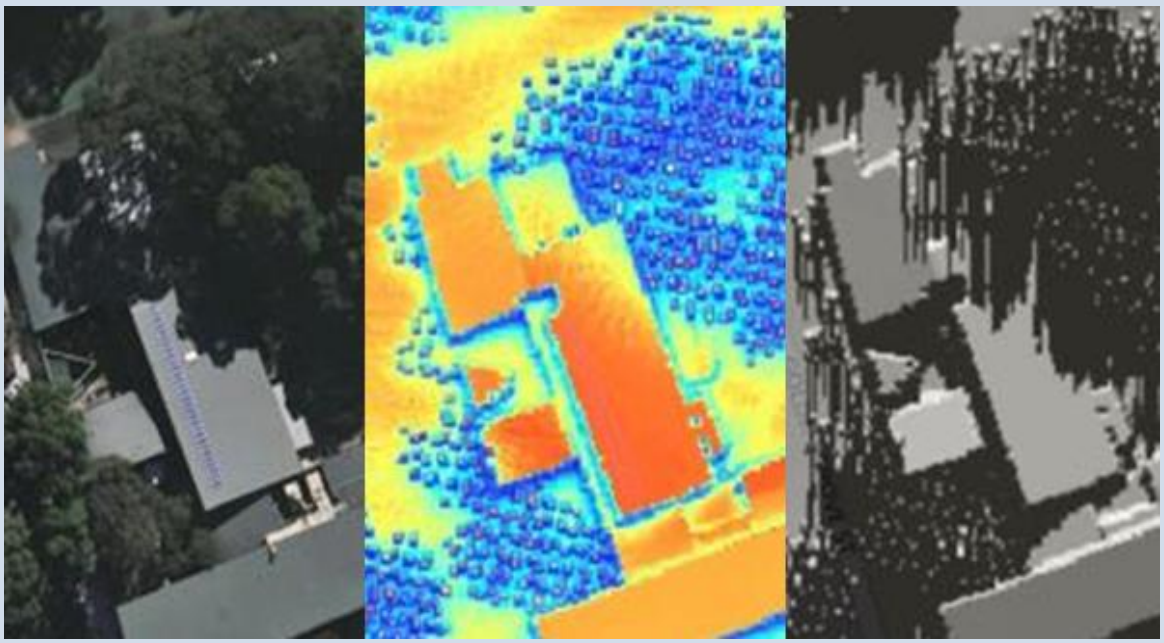
National Survey Report of PV Power Applications in AUSTRALIA 2016

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, 2016

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
    - Solar Resource Assessment.

More information on the APVI can be found: www.apvi.org.au

ACKNOWLEGEMENTS

Front page photo: APVI Solar Potential (SunSPoT) insolation heat map and shadow layers, courtesy of APVI.

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 country 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 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 2016 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2016, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

The Australian market for PV installations in 2016 fell 16% below the capacity installed in the previous year, to 866MW. The reduction was largely owing to the near-complete absence of utility-scale project commissioning in 2016; the rest of the market grew substantially. The market for rooftop systems on private residences stabilised and remained the #1 market segment. In 2016, there was significant growth in commercial systems in the 30-100kW size range, complemented by a growing volume of industrial rooftop systems in the 101-5000kW range. 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 6.

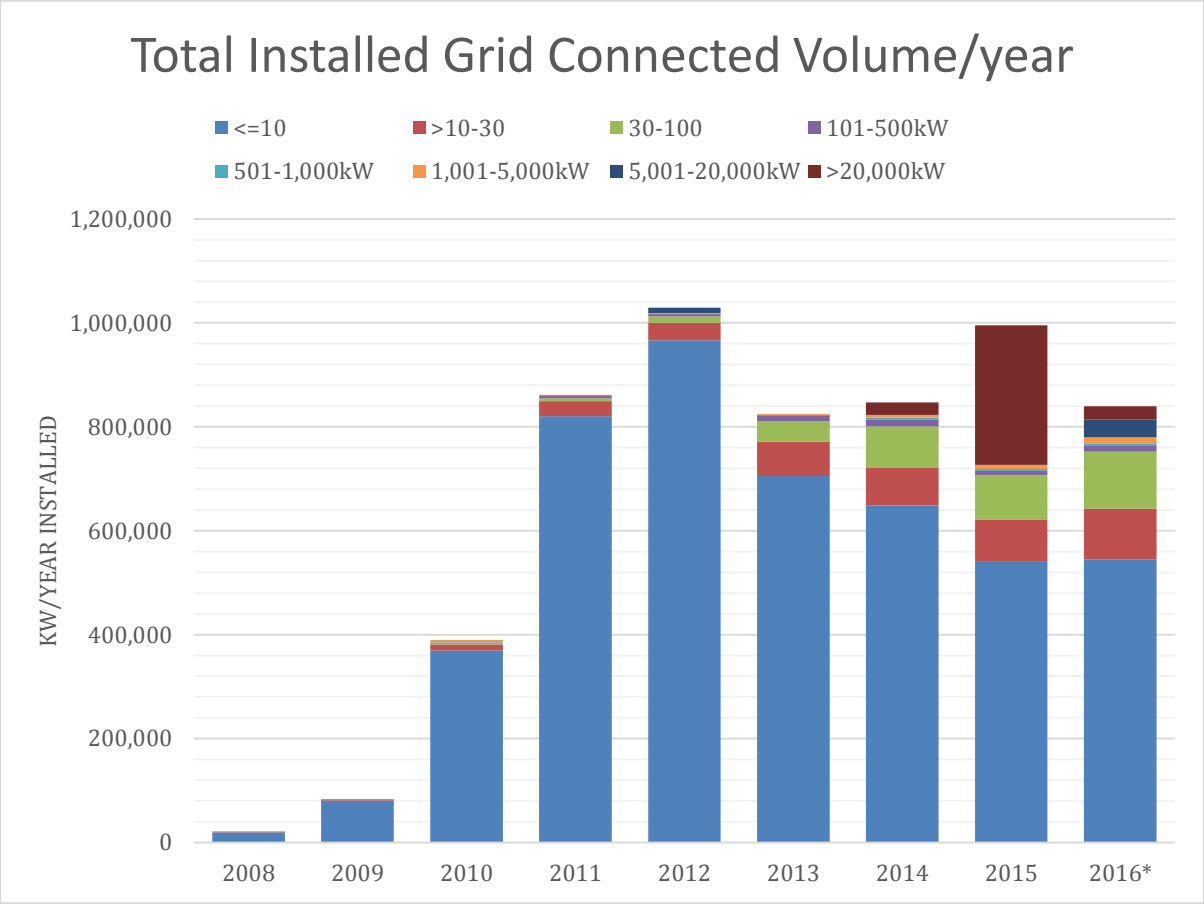


Figure 1: 2016 Australian PV market contracts after spike in utility-scale volume in 2015

Australia has the worlds-leading uptake of household PV systems, with over 20% of houses hosting one of Australia's 1.6 million PV systems. In many parts of cities and townships across Australia, the penetration of household PV exceeds 40% of suitable dwellings already owning a PV system, as illustrated in Figure 2. This high market penetration is one reason for the progressive decline in

residential volumes in recent years; a contraction that was halted in 2016 by increased household awareness of forthcoming significant electricity price rises.

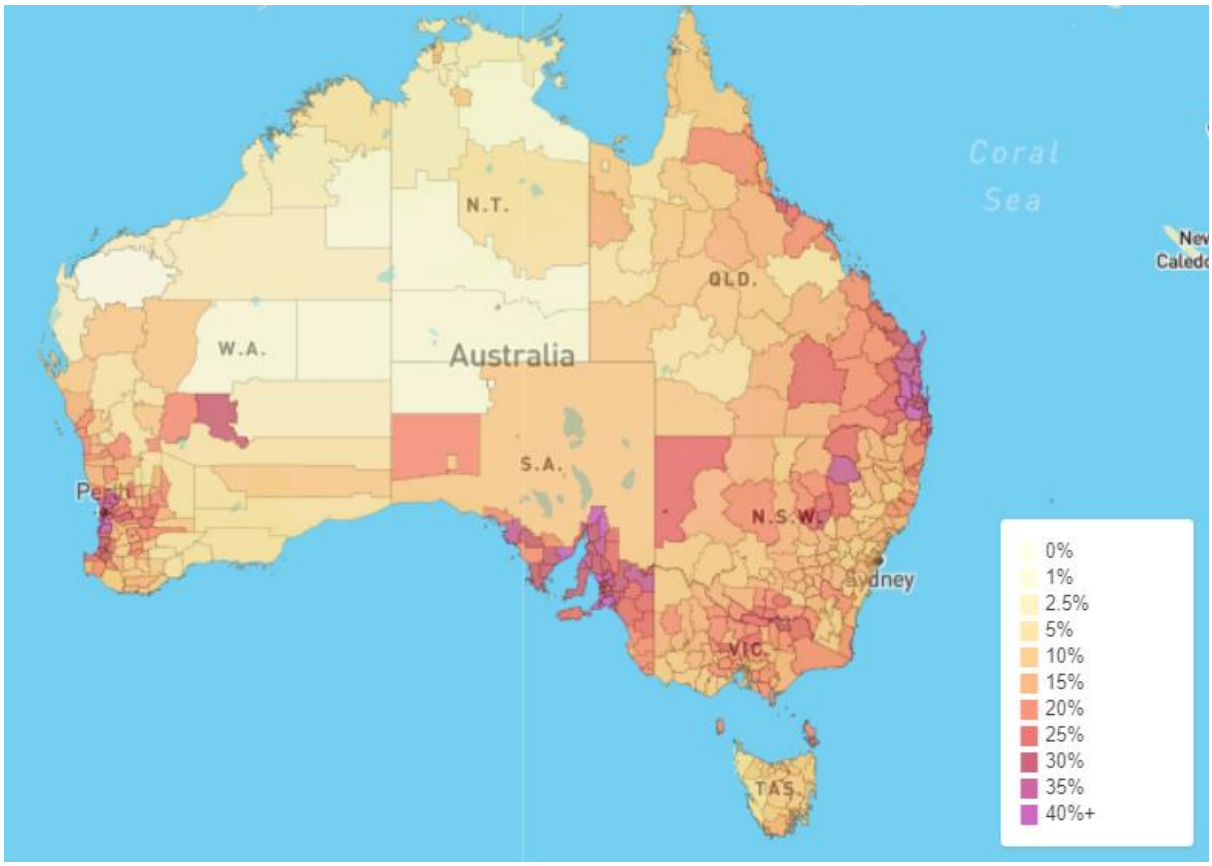


Figure 2: Residential PV penetration levels exceeding 40% (Source: APVI)

In 2016, 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). Voluntary surrender of Renewable Energy Certificates (RECs) by programs such as GreenPower and policies from the ACT Government drives deployment of renewable energy that is additional to the amount mandated by the RET.

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 and growing markets also exist for fuel saving and peak load reduction on diesel grid systems in communities, and tourist locations, with mine sites substantially increasing their adoption of solar as illustrated by Figure 3. There is also a reasonably significant market for recreational PV applications for caravans, boats and off-road vehicles.

Figure 3: 10.6MW Solar Farm at Sandfire Resources Degrussa Copper-Gold Mine

Interest is also surging in grid-connected systems with batteries, with installation volumes numbering approximately 6750 residential systems in 2016 totalling 42 MWh, plus a handful of projects worth a combined 10 MWh.

1.2 Total photovoltaic power installed

The PV power installed in four sub-markets during 2016 is shown in Table 1. PV data for the tables above are derived from the Renewable Energy Certificate (REC) Registry of the Australian Government's Clean Energy Regulator (CER) and information supplied by PV companies, supplemented by a manually-recorded tally of projects over 100 kW. 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 2016 installations, though a projection has been made of historical trends in 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 publicly-announced projects. The amount of off-grid power is an estimate only and is based on historical figures, with an addition for known major projects (Degrussa Sandfire). Table 2 and Table 3 provide some context broader about the broader Australian electricity industry and solar power's place within it.

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

Table 1: PV power installed during calendar year 2016

AC			MW installed in 2016 (mandatory)	MW installed in 2016	AC or DC
Grid-connected	BAPV	Residential	780	544	DC
		Commercial		208	DC
		Industrial		28	DC
	BIPV		<1		DC
	Ground-mounted	cSi and TF	60	60	DC
		CPV		0	DC
Off-grid		Residential	26	26	DC
		Other	11	36	DC
		Hybrid systems			
		Total	876		

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

MW-GW for capacities and GWh-TWh for energy	2016 numbers	2015 numbers
Total power generation capacities (all technologies)	56.0 GW	55.8GW
Total power generation capacities (renewables including hydropower)	15.3 GW	14.1GW
Total electricity demand (= consumption)	252.3 TWh[2]	248.3 TWh
New power generation capacities installed during the year (all technologies)	410MW (1196 MW Renewables, less 786 MW decommissioned fossil fuel power stations)	390MW (1690MW Renewables, less 1300MW of decommissioned fossil fuel power stations)
New power generation capacities installed during the year (renewables including hydropower)	1196 MW	1690MW
Total PV electricity production in TWh	8.4TWh	7.0TWh
Total PV electricity production as a % of total electricity consumption	3.3%	2.8%

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

Table 3: Other information

	2016 Numbers
Number of PV systems in operation in your country	1,631,000
Capacity of decommissioned PV systems during the year in MW	0
Total capacity connected to the low voltage distribution grid in MW	5432
Total capacity connected to the medium voltage distribution grid in MW	107
Total capacity connected to the high voltage transmission grid in MW	362

A summary of the cumulative installed PV Power, from 1992-2016, broken down into four sub-markets is shown in Table 3, and illustrated in Figure 4 for the years 2007-2016.

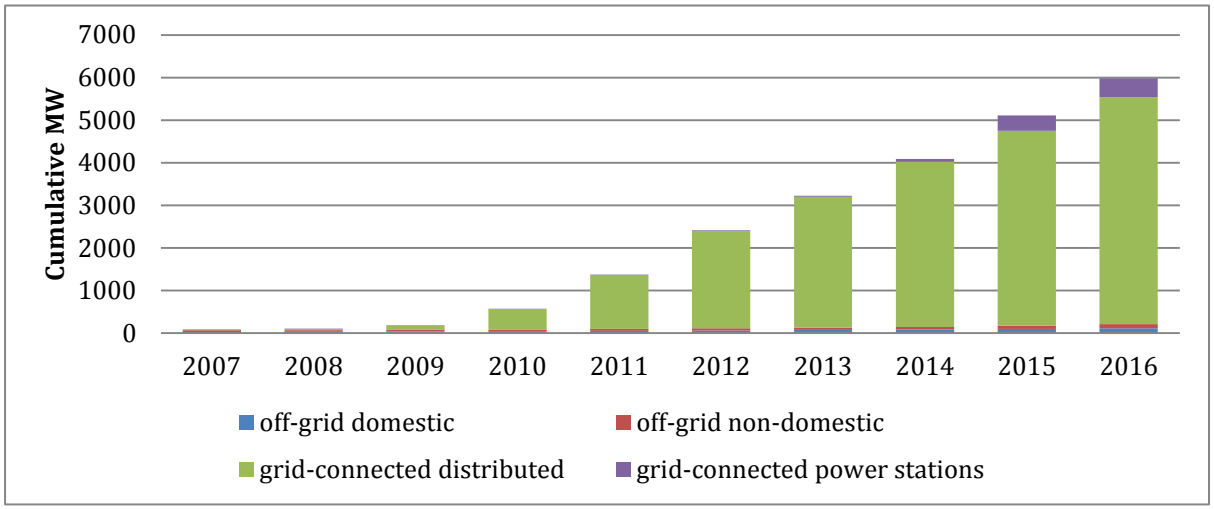


Figure 4: Cumulative Australian PV Installations by Category 2007-2016.

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	2016
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	86.9	102.9	118.3
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	61.2	70.4	91.9
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	3871	4578	5329
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	68.5	358.3	445.8
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	5986

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Table 5: Typical module prices for a number of years

Prices are listed in AUD and are based upon a combination of survey responses and analysis of wholesale PV price lists.

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Standard module price(s): Typical	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	.78
Best price														7.5	7	5	3	2	1.2	0.9	0.5	0.62	0.62	0.54

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 60-70c/Wp, depending on insolation. Residential prices are based upon a dataset provided by PV lead generator Solar Choice; Commercial prices are based upon SunWiz analysis of a commercial pricing database; Ground-mounted prices are based upon the publicised price of the Barcaldine Solar Farm. It is worth noting the increase in ground-mounted system price in 2016, which relates to the depreciation of the value of the Australian dollar, and the fact that the single major installation in 2016 was a 25MW tracking system, whereas larger fixed-mount systems are represented in the 2015 price per watt.

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

Price/Wp	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
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	2.45	2.42
Commercial and industrial																		2.68	2.07	1.80
Ground-mounted																		2.70	2.18	2.76

Table 7: Turnkey Prices of Typical Applications – Australian Dollars

Category/Size	Typical applications and brief details	Current prices per W
OFF-GRID Up to 1 kW	Water pumps, lighting, remote homes	$5.5-$11
OFF-GRID >1 kW	Pastoral systems	$5.50 - $11
Grid-connected Rooftop up to 10 kW (residential)	Residential	$2.42
Grid-connected Rooftop from 10 to 250 kW (commercial)	Commercial rooftop	$1.79
Grid-connected Rooftop above 250kW (industrial)	Industrial	$1.82
Grid-connected Ground-mounted above 1 MW	Solar Farms	$2.76
Other category (hybrid diesel-PV, hybrid with battery…)	Battery Hybrid	$3.15/W

Table 5 and Table 6 are graphically illustrated in Figure 5.

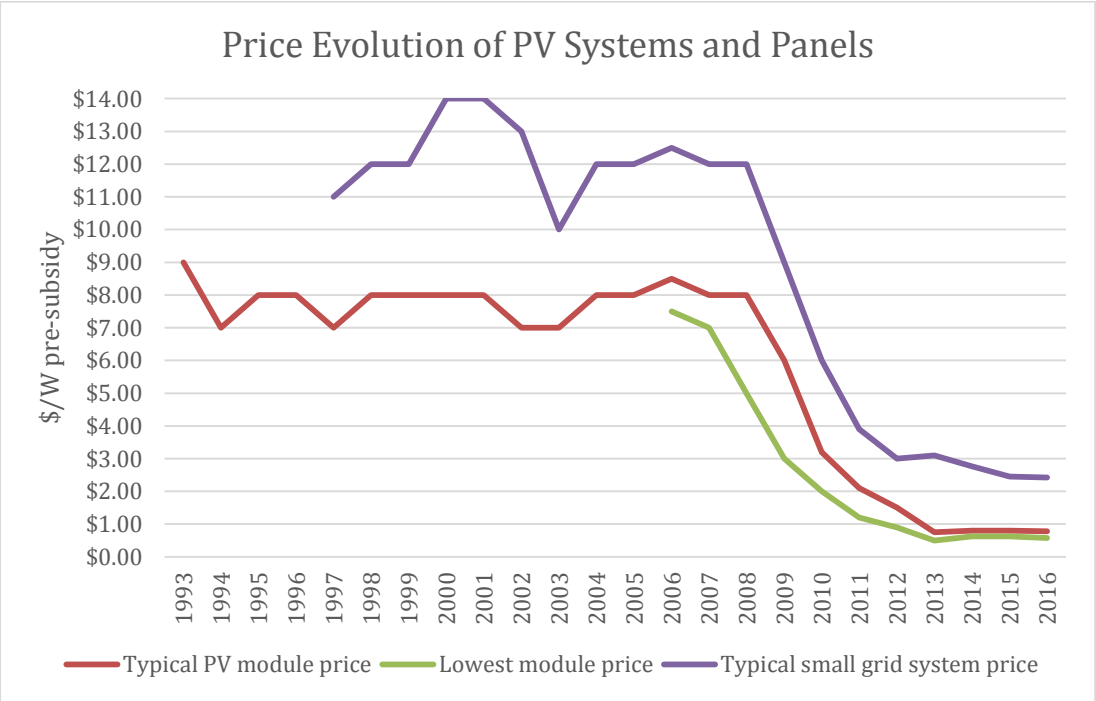


Figure 5: Price evolution of PV Panels and Systems

2.3 Cost breakdown of PV installations

Table 8 provides a cost breakdown for a sample 5kW PV system that was typical of low-priced systems in 2016. Higher priced systems commonly used more expensive panels and inverters, leading to higher profit margin and sales tax.

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

Cost category	Average ($/W)
Module	$0.54
Inverter	$0.29
Other (racking, wiring…)	$0.15
Installation	$0.32
Customer Acquisition	$0.06
Profit	$0.36
Other (permitting, contracting, financing…)	$0.04
Subtotal Hardware	$0.98
Subtotal Soft costs	$0.79
Sales Tax (GST)	$0.18
Total	$1.95
Subsidy (STCs)	-$0.8
Total Customer Price	$1.15

Table 9: Cost breakdown for an utility-scale PV system – local currency

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 Hardware			
Subtotal - Soft cost			
Total Installed Cost			

Not available yet, will be updated when provided

2.4 Financial Parameters and specific financing programs

More finance providers and a broader range of finance options continued to come to the market in 2016, 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.

Power Purchase Agreements (PPAs) increased in prevalence in 2016, though mostly they were the domain of a handful of large solar retailers.

Table 10: PV financing scheme

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	NA

2.5 Specific investments programs

Third Party Ownership (no investment)	Third Party Ownership exists in Australia primarily through Power Purchase Agreements, which have had limited success to date but are growing in the commercial and industrial market sectors.
Renting	There is no material market for solar power rentals in Australia, owing to the costs of grid connection and relocation. However this segment was the focus of an ARENA grant and may start to emerge as a market in 2017.
Leasing	Leasing is well established as a financing mechanism in the Australian market.
Financing through utilities	Electricity retailers now offer on-bill financing and PPAs
Investment in PV plants against free electricity	Most residential solar purchases are paid directly by homeowners.
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. Some large, energy intensive companies are now installing PV arrays for their own use.

2.6 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 11 and more detail on electricity market operation is provided in Section **Error! Reference source not found.**

Table 11: Country information

Retail Electricity Prices for a household (range)	AUD 0.21 – 0.33 /kWh (flat tariffs)[3]
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 2016 (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 (~25%) AGL (~17%) Energy Australia (~13%) Synergy (~6%) ERM Power Retail (~6%) Ergon Energy (~5%) Lumo / Red Energy (~4%) Others (~24%)

[3] http://www.aemc.gov.au/getattachment/be91ba47-45df-48ee-9dde-e67d68d2e4d4/2016-Electricity-Price-Trends-Report.aspx

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 or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

Table 12 summarises the support measures for PV in Australia, which are described in detail in the following sections.

Table 12: PV support measures (summary table)

	On-going measures residential	Measures that commenced during 2016 - residential	On-going measures Commercial + industrial	Measures that commenced during 2016 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2016 – ground mounted
Feed-in tariffs	Yes	Some premium feed-in tariffs wound up in 2016	No		No	
Feed-in premium (above market price)	Not accessible to new entrants		No		No	
Capital subsidies	STCs[4]		STCs		No[5]	
Green certificates	STCs		STCs or LGCs		LGCs	
Renewable portfolio standards (RPS) with/without PV requirements	STCs		STCs or LGCs		LGCs	
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	
Collective self-consumption	No		No		N/A	

[4] Small-scale Technology Certificates

[5] Except grant funding for specific projects from ARENA

and virtual net-metering						
Commercial bank activities e.g. green mortgages promoting PV	Yes (through CEFC)		Yes (through CEFC)		Yes (through CEFC)	
Activities of electricity utility businesses	Yes		Yes		Yes	
Sustainable building requirements	Yes, PV can contribute to a building's energy rating in some jurisdictions		Yes, PV can contribute to a building's energy rating		N/A	
BIPV incentives	No		No		No	
Other	No		No		Yes, Large Scale Solar Grant Funding with CEFC support	

3.1 Direct support policies for PV installations

3.1.1 The Renewable Energy Target

The Renewable Energy Target (RET) consists of two parts – the Large-scale Renewable Energy Target (LRET), of 33 000 GWh by 2020, 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 cross-subsidy leveraged upon all electricity consumption except for certain classes of industrial electricity consumers.

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 are shown in Table 13.

Table 13: 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	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, but 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 2016 are shown in Figure 6.

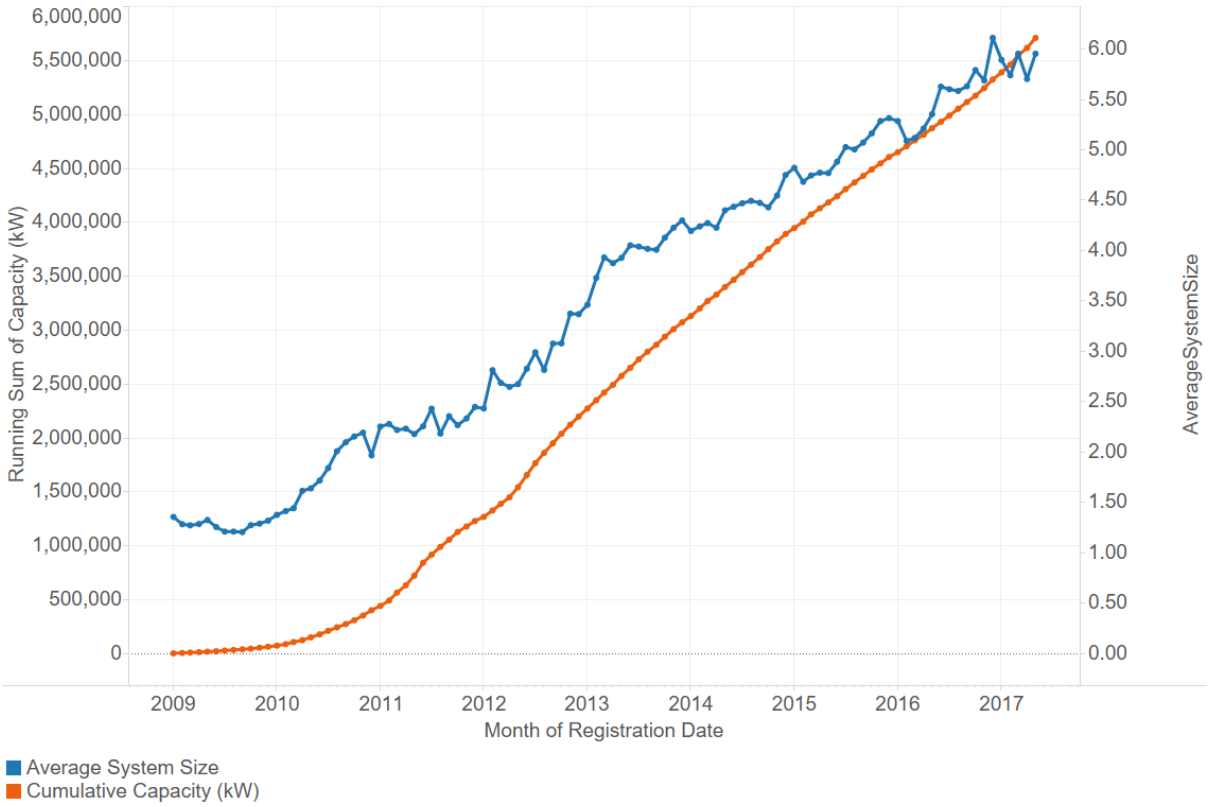


Figure 6: Cumulative capacity and average system size for SRES systems 2009-2016.

The Clean Energy Regulator has established a voluntary 'clearing house' as a central point for the transfer of STCs at AUD 40.00, 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.

3.1.2 The Australian Renewable Energy Agency (ARENA), Clean Energy Finance Corporation (CEFC), and Clean Energy Investment Fund (CEIF)

In March 2016, the government announced its intention to retain ARENA and the CEFC, reversing its previously held policy position that the Parliament's upper house had blocked it from executing. However, the government sought to discontinue ARENA's grant function, "*to be replaced by a new joint ARENA-CEFC Clean Energy Innovation Fund (CEIF). The CEIF would be provided with $100 million per annum for 10 years, (funded from the CEFC's investment pool), to make early-stage investments in clean energy technology. These investments would carry a lower average return and higher risk than the general CEFC pool. ARENA would serve as the technical advisor, but final investment decisions would be made by the CEFC. As a result of the discontinuance of grants, the Government proposed to withdraw $1,260.8 million in future funding from ARENA, leaving it with only enough money to cover pre-existing commitment…. After negotiation, the Government and Opposition agreed to reduce the funding cut to ARENA by $800 million, allowing ARENA to continue its grants program at a reduced rate.*"[6]

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.

[6] http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/FlagPost/2016/September/ARENA-changes

In 2016, the following ARENA solar projects were completed:

1. The 102 MWac Nyngan and 53 MWac Broken Hill Solar Flagships began feeding power into the grid, with $166.7m support from ARENA
2. The 56 MWac Moree Solar Farm started feeding into the grid, with $101.7m support from ARENA plus $46m of debt finance from the CEFC
3. The 1.8MW Ayers Rock Resort solar farm was completed, supported by $450k or ARENA funding and a $4.7m CEFC loan
4. The Degrussa copper-gold mine was completed, with 34000 panels and 6MW/1.8MWh of battery storage, supported by a $20.9m ARENA grant and $15m CEFC loan.

In addition, ARENA announced funding for these projects:

5. From 77 expressions of interest, ARENA announced 22 shortlisted projects within its $100m large-scale solar PV competitive round. 12 of those 22 projects were eventually supported, totalling 482 MWac for $91.7m of ARENA funding. [see Figure 7]
6. ARENA provided $8.4m funding support to construct the 5 MWdc Normanton Solar farm, which will help demonstrate how integrating solar into the grid can improve energy reliability in regional Australia
7. ARENA's provided a $2.9m commercialization grant towards a concentrating PV tower technology from Raygen
8. $9.9m support for the 10MW Gullen Range PV plant to be build adjacent to an existing wind farm.
9. $17.4m funding for the 10.8 MWac with 1.4MW/5.3MWh battery storage project near Lakeland
10. $2.1m for monitoring of solar power systems for better energy outcomes
11. $875k for a robotic vision system for automatic inspection and evaluation of solar plants
12. $900k to increase the uptake of solar photovoltaics in strata residential developments
13. $995k to maximise solar photovoltaic with phase change thermal energy storage
14. $100k for a Pilot Landfill Solar Project
15. $1.0m for Real-time operational PV simulations for distribution network service providers

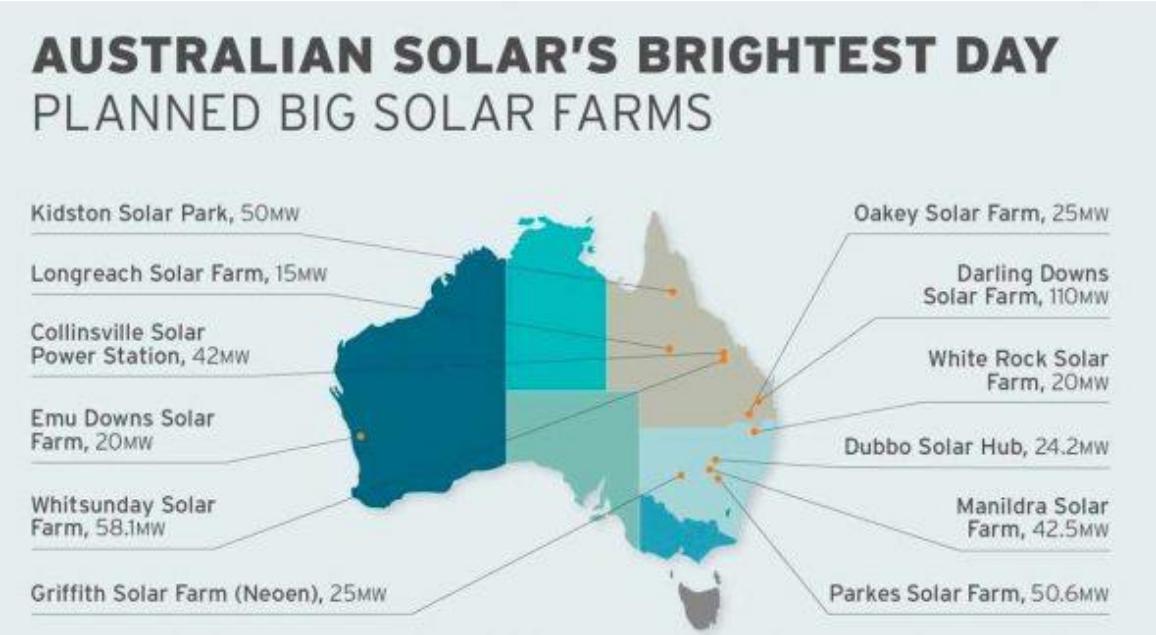


Figure 7: ARENA funded projects under large-scale solar PV competitive round

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. 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 continued its $250 million Large-Scale Solar financing program that provides 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 $15 million or more. Figure 8 illustrates the funding commitments made to May 2017.

PROJECT	CEFC DEBT FINANCE COMMITMENT ($ MILLION)	MW (AC)	ARENA FUNDING
Parkes Solar Farm, NSW	150	55	$18 million
Griffith Solar Farm, NSW		30	
Dubbo Solar Hub, NSW		25	
Whitsunday Solar Farm, Qld	77	57.5	$9.5 million
Hamilton Solar Farm, Qld		57.5	N/A
Gannawarra Solar Farm, Victoria		50	N/A
Kidston Solar Project Phase One, Qld	54	50	$8.9 million
Longreach Solar Farm, Qld	12	15	$3.5 million
Oakey Solar Farm, Qld	19.5	25	
Collinsville Solar Farm, Qld	60	42.5	$9.5 million
Totals	**$372.5**	**407.5**	

Figure 8: CEFC Large-Scale Solar Program

Other CEFC investments in 2016 include:

- $20m in the 25 MWdc Barcaldine[7] Solar Farm, Australia's first fully merchant edge-of-grid solar farm
- Facilitated the creation of green finance instruments with three major banks, Palisade Investment Partners, Flexi Group.

[7] http://www.cefc.com.au/media/files/barcaldine-milestone-highlights-potential-of-large-scale-solar-in-australia.aspx

The **Clean Energy Investment Fund's** first action was a $20m Clean Energy Seed Fund, which has a short-term goal to invest at seed, angel and later stages in startups across sectors of Internet of things, battery storage, biofuels, and metering and control.

Direct Action

The federal 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 doesn't directly support the growth of PV.

3.1.3 State and Territory Support

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

Though the final premium-feed in tariff concluded in 2014, historical feed-in tariffs applied in many Australian states in 2016 for systems less than 30kW, as shown in Table 14. In 2016, premium feed-in tariffs wound up for some 250,000 Australian households. Every customer in New South Wales that was receiving a 60c/kWh FiT on all generation now receives an amount set by their electricity retailer in the range of 6-12c/kWh. Segments of customers on transitional feed-in tariffs in Victoria and South Australia also lost their feed-in tariff at the end of 2016.

In 2016,

- The New South Wales government tendered for renewable energy from its Sydney Metro Northwest rail project.
- The Queensland government will support up to 60MW worth of ARENA-funded projects through 20 year Power Purchase Agreement.
- 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.
- Victoria is developing a state Renewable Energy Target using a reverse auction mechanism, and also announced in early 2017 a tender for renewable electricity supply for its tram network. In 2016, Victoria also regulated an increase in the feed-in tariff paid for solar energy export to the grid, to additionally account for environmental benefit (in addition to wholesale value and avoided network losses).
- The Northern Territory government's Home Improvement Scheme offers a $2000 subsidy for the installation of rooftop solar systems.

Table 14: Australian State and Territory Feed-in Tariffs in 2016

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 (<10kW), 40 (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) SBS 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 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 Support for electricity storage and demand response measures

The City of Adelaide provides 50% of the cost of batteries up to a value of $5000, plus up to a further $5000 for 20% of the price of a PV system[8].

The ACT government's Next Generation Storage Program paid a subsidy of $900 per sustained kW of peak output, as part of a rollout of 36MW of distributed storage across 5000 homes and businesses between 2016 and 2020.

The Northern Territory government's Home Improvement Scheme offers a $2000 subsidy for the installation of rooftop solar and storage systems.

In 2016, many electricity network operators conducted trials of batteries within their substations, and within homes. For example, Energex and Ergon trialled 80 sites across Queensland; SAPN offered highly subsidised PV- storage systems as part of a trial of 100 houses.

The demand response market within Australia is small in overall volume, and limited to a small number of industrial facilities, plus a large number of homes with air-conditioners that can be operated at reduced power during times of peak demand. However, this market is expected to increase significantly in coming years, with several major programs now underway.

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

3.3 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 FiT in some states 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…)	Export restrictions for PV + Battery systems
	11	PV system size limitations	In some network areas where PV penetration levels are high or distribution feeders have restricted capacity
	12	Electricity system limitations	None (except additional grid codes). However curtailment of supply may be enforced by the regulator
	13	Additional features	None

3.4 Collective self-consumption, community solar and similar measures

Current network operation regulations act as a barrier to collective self-consumption or virtual net-metering in Australia, and are only really practical within 'embedded networks'.

Community solar investment occurs in Australia – for example

- the recently re-developed Sydney International Convention Centre hosts a 520kW PV system that is investor-owned.
- Embark is a non-profit organisation focused on accelerating the uptake of community renewable energy projects by providing practical capacity-building tools and seed and investment funding. It lists 70 active groups pursuing renewable energy projects.
- The Citizens Own Renewable Energy Network Australia has funded 16 projects

Some of the groups working to develop community solar projects received support from the NSW government's Growing Community Energy grants[9].

[9] http://www.environment.nsw.gov.au/communities/community-energy-grants.htm

3.5 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.

- The Australian Capital Territory (ACT) ran two reverse auctions for solar power in recent years.
- 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 Agreement.
- The New South Wales government will tender for renewable energy from its Sydney Metro Northwest rail project in 2016.
- The Victorian government is developing a reverse auction process as part of its state renewable energy target.

3.6 Financing and cost of support measures

Table 15 shows the source of finance for solar-related government programs.

Table 15: Common financing methods

Financing type	Programs	Finance Source
Cross subsidy	RET (LGCs and STCs), most Feed-in Tariffs	Levy on electricity bills
Subsidised Loan	CEFC-backed projects, and CECF-backed financial instruments from banks and some PV retailers.	Government borrowing at lower interest rates than commercially available
Direct Subsidy	ARENA-funded projects, NT Government Home Improvement Scheme	Typically from government budget
Contract for Difference	ACT Solar Auction	Typically from government budget, offset by reduced electricity expenditure
Purchase Agreement for LGCs and/or Power	Sydney Metro Northwest Rail Project, Victorian Trams, Queensland Government	Typically from government budget, offset by reduced electricity expenditure

3.7 Indirect policy issues

Continued political differences around climate change and carbon pricing have impacted the renewable energy sector and made long term investments higher cost than they may otherwise have been. This has also led to antagonism towards renewables, which are routinely blamed for price rises and supply disruptions, even when these have been shown to have other causes.

4 HIGHLIGHTS OF R&D

4.1 Highlights of R&D

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.

4.1.1 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 2016 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

4.1.2 CSIRO PV Performance Laboratory

CSIRO continued to operate its IEC 17025 accredited PV cell measurement facilities through 2016 as part of its growing PV Performance Laboratory brand that includes both indoor and outdoor testing of PV cells and 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 the research of CSIRO and partners in new perovskite solar cells.

Figure 9: (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

4.1.3 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 2016 from the Australian Research Council and ARENA. 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.

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.

4.1.4 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.

In 2016 work continued in the following areas:

- 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
- Numeric modelling and simulation work on Photovoltaic solar cells, Photodetectors and photosensors
- 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.
- Evaluation of options to mitigate voltage rise in distribution networks with increasing PV penetration.

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. The first of these reports has been recently released and the second is due out soon. Planning is ongoing for the extension to Task 13.

4.1.5 University of Melbourne

The University of Melbourne undertakes a range of research in photovoltaic technologies with particular emphasis on the development and characterisation of new photovoltaic materials. Together with other research partners in Victoria, a comprehensive printing capability has been developed for bulk heterojunction organic solar cells. The objective is to bring organic solar photovoltaic technology to a level where it can be commercialised, with product development

leading to cost competitive products and finally to printed modules rivalling traditional silicon solar cells. This printing capability also includes new hybrid organic-inorganic photovoltaic materials.

As a node of the Australian Centre for Advanced Photovoltaics, The University of Melbourne is actively examining new materials classes and device architectures through a fundamental understanding of structure-function relationships and the synthesis of materials. This includes the development of new high performance organic molecular materials with photovoltaic performance efficiencies exceeding 10%. In other research the University is developing luminescent solar concentrators (LSCs) using a new class of concentration quenching resistant emitting dyes. 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.

4.1.6 University of New South Wales (UNSW Australia)

UNSW, Sydney has a long history of solar research, first established in the 1970s and 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 and with an estimated 20% of the current manufacturing capacity using the UNSW Passivated-Emitter, Rear-Contact (PERC) concepts.

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.

In 2013, UNSW was established as the home for the Australian Centre for Advanced Photovoltaics (ACAP) an ARENA Special Research Initiative. The Centre delivers near-term research outcomes with industry-partners leveraged by government funding through to long term research outcomes ACAP aims to significantly accelerate photovoltaic development beyond that achievable by Australia or its partners individually, developing the next generations of photovoltaic technology and providing a pipeline of opportunities for performance increase and cost reduction.

UNSW researchers are pioneering work in second generation photovoltaics with activities in perovskite solar cell research, as well as CZTS (copper-zinc-tin-sulphide) solar cell technology and other new materials discover, with a particular focus on materials compatible with silicon tandems.

Significant research is also undertaken in the areas of PV and renewable energy systems and policy. During 2016, 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.

4.1.7 University of Queensland

Research at the Centre for Organic Photonics & 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 Australian Centre for Advanced Photovoltaics (ACAP). Within ACAP, COPE focuses on the creation of new molecules for advanced photon harvesting concepts as well as applying electro-optics and charge transport physics in organic semiconductors and organohalide perovskites for the development of efficient solar cells.

The Power & Energy Systems Group (School of ITEE) focuses on the integration of renewable energy sources, in particular wind and solar energy, into electricity transmission and distribution networks. The group is also working to implement and test an innovative state estimation algorithm for monitoring low and medium voltage electricity distribution networks with funding from ARC and ARENA.

UQ has more than five MW solar PV in its campuses, which brings a unique research opportunity in renewable energy integration. Based on the UQ Gatton campus 3.275MWp, St. Lucia campus 2 MWp PV system and a large 760 kWh lithium ion battery, UQ solar researchers are actively working with electricity industry to address emerging issues with cost-effective integration of the large-scale PV plant into weak rural power networks.

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

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

	R & D	Demo/Field test
National/federal	NA	NA
State/regional	NA	NA
Total		

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. Tindo supplies DC 275W four-busbar poly panels using minghwei cells and flash tests its panels in Australia. Tindo's business model is to both sell panels wholesale and retail PV systems.

Tindo Solar manufactured 20MW of panels in 2016. Total PV cell and module manufacture together with production capacity information is summarised in Table 9 below.

In early 2017, TIndo solar was bought by SA PV retailer 'Cool or Cosy'.

Table 16: Production and production capacity information for 2016

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			20		60
TOTALS			20		60

5.2 Manufacturers and suppliers of other components

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

5.2.1 PV inverters 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. Redback is an Australian intelligent hybrid PV-storage inverter manufacturer.

5.2.2 Storage batteries

Australian company RedFlow manufactures Zinc Bromine batteries. Its Zinc Bromine 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's 400kWh lithium polymer battery storage system is in operation at a NSW utility.

Batteries manufactured by foreign companies are also readily available in Australia:

- LG have lithium iron phosphate battery technologies which can be scaled up to 18kWh (2kWh each).
- Tesla have made Australia one of their first international markets to release the PowerWall; first installations occurred in January 2016.
- Enphase launched its energy storage product in Australia in mid-2016
- AuOptronics and Sunverge batteries are sold by electricity retailer AGL
- German companies such as Sonnen and SolarWatt took a particular interest in the Australian market in 2016,

A range of research programs 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. Here are a few examples of charge controllers & switchgear implementations in Australia:

- 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.
- Solar Analytics – provide a home energy monitoring solution with a focus on solar, with over 12,000 sales to the end of 2016.
- Wattwatchers have developed low-cost, ultra-compact, multi-circuit meters with built in wireless communications with thousands of sale to end of 2016
- CatchPower, SwitchdIn, Greensync, Reposit are developing internet-of-energy solutions including to optimise solar and battery interactions with the grid.

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.

5B is a Sydney based renewable energy technology business that has created a completely pre-fabricated and rapidly deployable solar array solution - enabling faster, lower cost and more flexible solar projects. 5B's technology is completely home grown having been born in a Sydney backyard, prototyped in a dusty sand quarry nearby, polished in a R&D workshop in Marrickville and now under commercial production in 5B's 30MW p.a. production facility in Alexandria, Sydney

5.2.5 BIPV

Bluescope steel has proto-typed the manufacture of 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.

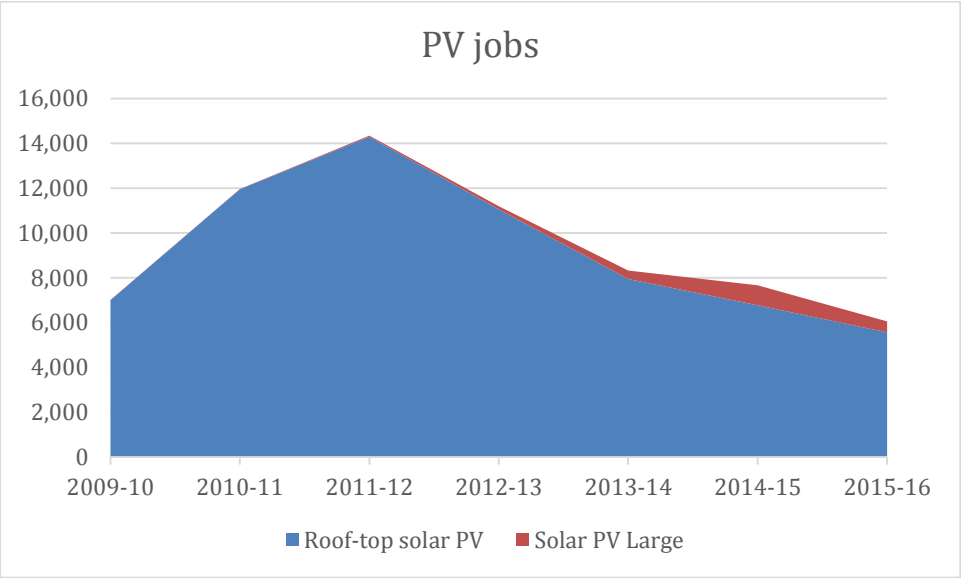
Tractile Solar has been established to combine PV cells with Thermal Hot Water. Tractile listed on the Australian Stock Exchange in 2015.

6 PV IN THE ECONOMY

6.1 Labour places

The Australian Bureau of Statistics (ABS) lists 5570 full-time equivalent (FTE) jobs in rooftop solar (PV & Hot Water) in 2015-16, plus 490 in large-scale PV, and 1160 renewables-related jobs in Government and Non-profit institutions. The total has been trending down since a peak in 2011-12, presumably owing to reduced PV volume over that period and improved productivity.

Table 16: Estimated PV-related labour places in 2016 in Australia according to the ABS



In addition to these figures are those people involved in Research & Development, and those involved in electricity distributors and retailers that provide services to the solar industry. This brings the tally to 7210 jobs, as illustrated by Table 17.

Table 17: Jobs in the Australian Solar Industry 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	200
Distribution, sales and installation companies	6060
Electricity utility businesses and government	550
Total	7210

6.2 Business value

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

Table 18: Value of PV business

Sub-market	Capacity installed *in 2016*(MW)	Price per W (from table 7)	Value	Totals
Off-grid domestic	15.0	$6.5	100	
Off-grid non-domestic	4.0	$6.5	26	
Grid-connected distributed	752	$2.32	1745	
Grid-connected centralized	87	$2.76	241	
				2112
Import of PV products				995
Value of PV business				1117

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

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, electricity 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 in 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. 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. Though solar farms are about to become increasingly common, until 2016 most PV installed in Australia to date was small-scale, residential, connected to the distribution network, and supplied loads directly. Before 2016, a few major electricity retailers were selling residential solar power systems in relatively small quantities.

A turning point was reached in 2016 when incumbent electricity retailers attempted to carve out a significant market share of solar sales to both commercial and residential customers. The electricity distribution network operators also took an interest in solar sales; though ring-fencing regulations that prohibit network operators selling electricity forced them to spin-off separate business entities. The incumbent electricity retailers also began to take interest in power purchase agreements from solar farms, in order to meet their growing obligations under the RET.

Though it only comprises 3.3% of overall electricity generation, solar uptake is impacting the energy market operation technically and financially. Technical issues most commonly relate to impacts upon local voltages, and network operators have been given the ability to constrain the amount of PV that is connected to their networks, and impose these constraints upon individual applicants unless applicants used inverters with operation modes under the network operators' influence. Financially, PV is reducing the amount of energy transported and sold. The energy market operator has largely

prevented attempts by electricity network operators to discriminate against solar customers with solar-specific tariffs that would financially penalise solar households.

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 part access to this market is not available. Regardless, momentum is swinging towards a more neutral playing field that balances the needs of both incumbents and the new distributed energy market participants.

7.3 Interest from municipalities and local governments

There is 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 described above, but 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 $5000, plus up to a further $5000 for 20% of the price of a PV system[10].
- City of Melbourne has a rebate for commercial PV that range from $2,000 and $4,000 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 Programs – Gives 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 implemented by lower than market, fixed interest rate loans over a longer than usual loan term.
- Community solar programs have gained much popularity in recent years with the formation of many community bulk-buy solar programs and various initiatives to encourage solar PV investments.

7.4 Interest from state and territory governments

In 2016, state governments continued to progress measures that would support the deployment of renewable energy, by accelerating the development approval of some solar farms, tendering for renewable energy for their facilities, creating state-based targets for renewable energy uptake, and launching tenders for grid-scale batteries.

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

8 HIGHLIGHTS AND PROSPECTS

The Australian PV market contracted by 16% in 2016, to 866 MW. The contraction occurred despite the annual stability of volume in the residential segment (544 MW), and healthy 26% growth in the commercial and industrial segments (235 MW). The primary factor in 2016's contraction was the near-complete absence of utility-scale solar farm commissioning, which tallied 268 MW in 2015 but only 29 MW in 2016. This can be understood in light of extraordinary circumstances that saw Australia's first three solar farms over 50 MW deployed concurrently in 2015, themselves a culmination of five years of project development and government funding.

Despite a lack of deployments of utility-scale PV in 2016, there was plenty of project development activity in this sector that was catalyzed by ARENA's competitive funding round and supported by CEFC loans. From 77 expressions of interest, ARENA announced 22 shortlisted projects; 12 of which were eventually supported, totalling 482 MWac for a $91.7m of ARENA funding. A large number of solar farms are expected to commence deployment in 2017, and as much as 2.3GW of utility-scale PV is expected to be deployed over the period of 2017-2020 as the solar industry ramps up to meet Australia's Renewable Energy Target.

At the end of 2016, installed PV capacity approached 6GW threshold, accounting for 11% of national electricity generation capacity and 3.3% of electrical energy generation. Panel prices continued to decline, and system prices reached record lows. Australia boasts the highest per-capita number of PV systems internationally, with 20% of households hosting one of 1.6m PV systems. The residential market is destined to grow in 2017 as electricity prices surge across the nation.

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. Having weathered years of attacks by incumbent generators and network operators, PV has returned to favour and many electricity retailers and network operators have themselves expanded their sales of PV systems and are also looking to incorporate battery storage.

Energy security was a hot issue in 2016 following multiple blackouts in South Australia and load curtailments in NSW, and remains under intense scrutiny in 2017. PV is recognized as contributing to network stability with valuable supply during peak demand periods, though increasing amounts of variable renewable energy generation and the continuing exit of major fossil fuel power stations are presenting concerns for the network operator. In 2016, the energy ministers of the Australian commonwealth and state governments commissioned Australia's chief scientist Alan Finkel to prepare a blueprint for the future energy system, which addressed the trilemma of energy security, affordability, and environmental objectives. The Finkel review is due to be delivered in mid 2017.

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 the intermittency challenges which plague the compatibility between PV and the main electricity grid. For the time being, some network operators are conducting trials of energy storage.

According to a major survey of the industry[11], there were 6750 installations of grid-connected batteries on new PV systems in 2016, plus a few major projects, with a total of 52MWh installed; up 13-fold on 2015. The Victorian and South Australian governments have announced tenders for 90MW and 100MW of utility-scale battery storage, which will guarantee market growth in 2017.

[11] SunWiz, "Australian Battery Market Report", January 2016.

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