IEA INTERNATIONAL ENERGY AGENCY

Task 1 Strategic PV Analysis and Outreach

PVPS

National Survey Report of PV Power Applications in Australia 2018

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PHOTOVOLTAIC POWER SYSTEMS
TECHNOLOGY COLLABORATION PROGRAMME

ARENA Australian Government Australian Renewable Energy Agency

AUSTRALIAN PV INSTITUTE

ACKNOWLEDGEMENTS

Front page photo: 266 kWp solar deployment at Eromanga in QLD using revolutionary MAVERICK technology by 5B Pty Ltd. Image courtesy of 5B Pty Ltd. *Fun fact: Eromanga is the furthest town from the sea in Australia.*

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This report is prepared by the Australian PV Institute (APVI) in its role representing Australia on the International Energy Agency (IEA) in the IEA PV Power Systems (PVPS) Technical Collaboration Platform. The APVI is supported in this by ARENA and by its members who are active in the IEA PVPS program of work.

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.

The IEA programme is headed by an Executive Committee composed of representatives from each participating country or organisation. The Australian Executive Committee member is Dr Renate Egan (ACAP) and the alternate member is Olivia Coldrey (Solar for All).

Australian participation in the IEA PVPS tasks is managed by the APVI. The management of individual tasks (research projects/activity areas) is the responsibility of Operating Agents, with participating countries providing Task Leaders and Experts. In Australia, tasks are represented by Australian Experts including;

- Task 1 Communications, Strategy and Outreach. Expert is Warwick Johnson (SunWiz);
- Task 12 Sustainability, Expert is Dr Jose Bilbao (UNSW);
- Task 13 Performance and Reliability, Expert is Lyndon Frearson (Ekistica);
- Task 14 High Penetration PV, Expert is Iain MacGill (UNSW)
- Task 15 Building Integrated PV. Expert is Rebecca Yang (RMIT)
- Task 16 PV and Transport. Experts are Julie Macdonald (ITPower) and N Ekins-Daukes (UNSW)

Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org

THE AUSTRALIA PV INSTITUTE (APVI)

The objective of the 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; and management of Australian participation in the IEA SHC and PVPS Programme.

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

AUSTRALIAN PV INSTITUTE

WHAT IS IEA PVPS TCP

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The IEA carries out a comprehensive programme of energy cooperation among its 30 member countries and with the participation of the European Commission. The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the collaborative research and development agreements (technology collaboration programmes) within the IEA and was established in 1993. The mission of the programme is to "*enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems*."

In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas. This report has been prepared under Task 1, which deals with market and industry analysis, strategic research and facilitates the exchange and dissemination of information arising from the overall IEA PVPS Programme.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Copper Alliance are also members.

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WHAT IS IEA PVPS task 1

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 2018. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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Data for non-IEA PVPS countries are provided by official contacts or experts in the relevant countries.
Data are valid at the date of publication and should be considered as estimates in several countries due to the publication date.

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EXECUTIVE SUMMARY

Australia remains a strong and growing market for grid-connected photovoltaics. In 2018, Australia saw renewed growth in the rooftop solar market and strong growth in the utility-scale solar sector. The **total installed capacity** at end 2019 reached 11,3 GW. Historical trends in total installed capacity are shown in Figure 1, where it can be seen that Australia has seen a ten-fold increase over the total installed capacity of 105 GW in 2008. Total installed capacity has doubled in less than four years, with 5,1 GW installed at the end of 2015, and as much installed in 2018 as the total historical installed capacity at end 2014 (4,1 GW)

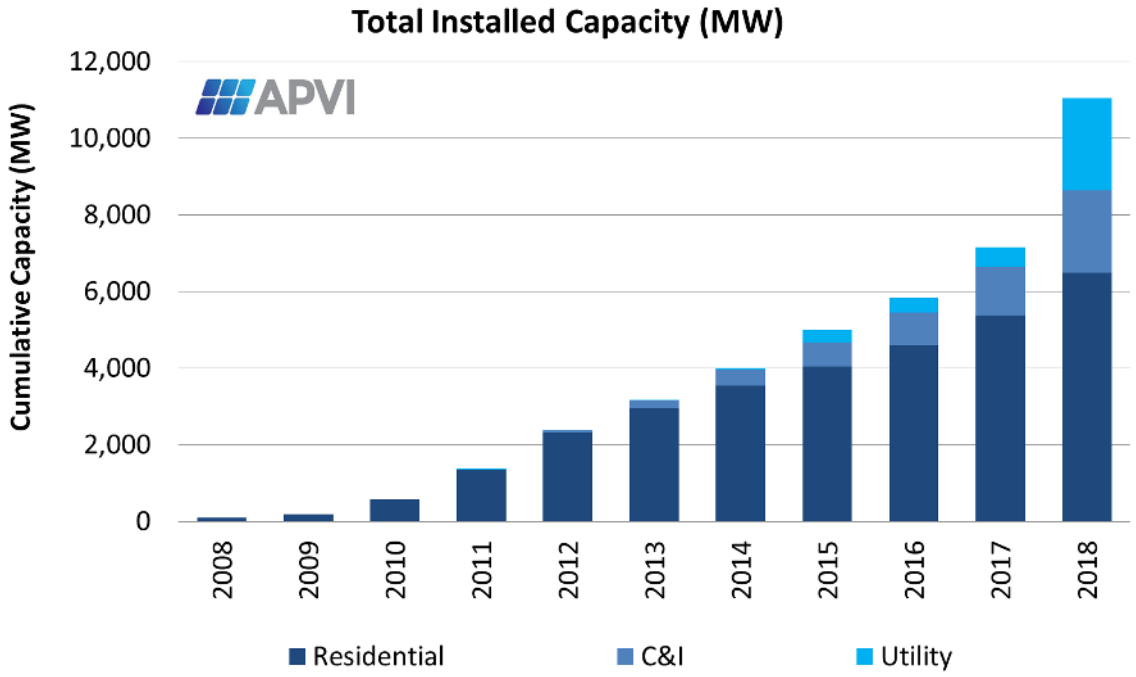

Figure 1 Total Installed Capacity by sector, where C&I is commercial and industrial.

PV connected to the grid in Australia benefits from incentives and support from the national government through a Renewable Energy Target. The incentives come with a reporting obligation and is categorised into small (<100 kW) and large-scale systems (>100 kW). Within these categories residential solar is typically considered 0-10 kW while commercial and industrial installations are rated at 10-100 kW. Above 100 kW there is a mix of commercial and industrial and ground mount out to 5 MW and above 5 MW installations are usually ground mounted.

In **annual installs**, records were broken in all sectors; residential solar (0-10 kW) grew to over 1 GW in new installs while commercial solar (10-100 kW) made up a further 600 MW of new rooftop solar. Large-scale solar also set a significant new benchmark for Australia in 2018, with a total of 2,48 GW recorded as installed and connected, 2,36 GW of which was ground mount systems over 5 MW. The breakdown of annual installs by system size, with historical trends is shown in Figure 2.

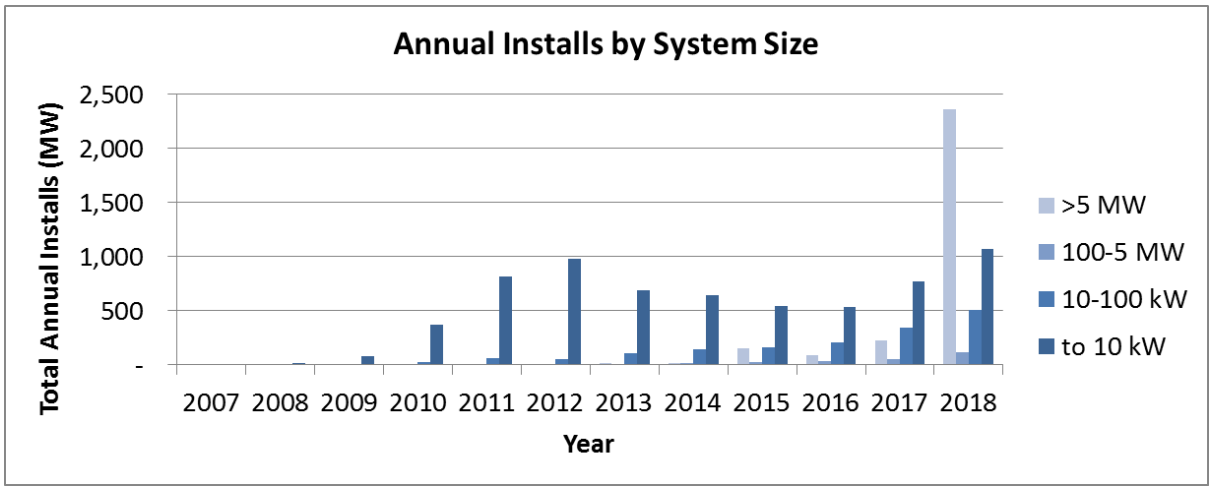

Figure 2 Annual Installs in Australia by System Size.

Growth in these categories is shown in Figure 2. The Australian market saw a strong feed-in-tariff driven growth through to 2012, with the withdrawal of these programs seeing a retraction in the market in the years 2013-2016, followed by a return to growth in 2017 in rooftop installation, reflecting the competitive pricing at both residential and commercial-scale, even with modest feed-in-tariffs. Large-scale solar has also grown strongly since 2017, with a boost in 2018 from the connection of a large number of utility-scale farms.

Australia now has more than 2 million rooftop installations, with over 200 000 new installs in 2018 alone and is on track to install as many again in 2019. Australia continues to lead the world in residential uptake of solar, with a nation-wide average of free-standing households with a PV system over 20% . The states of Queensland and South Australia, average over 34% and a significant number of localities have densities of rooftop solar over 50%. The percentage of residential rooftop dwellings is shown by state in Figure 3.

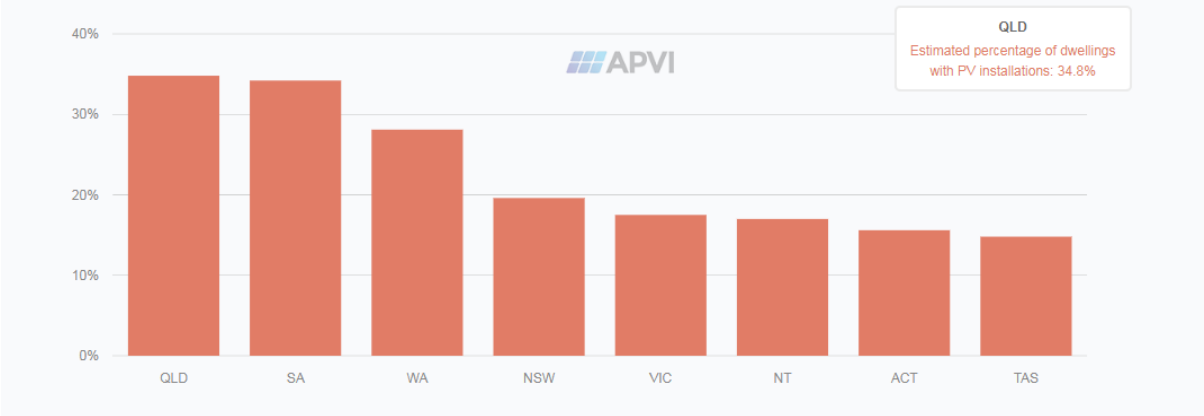

Figure 3. Percentage of residential dwellings with a PV system by state/territory. Source APVI; https://pv-map.apvi.org.au

The average PV system size continues to grow steadily as the size of residential systems increases and as a growing number of businesses purchase PV. In 2018, the average rooftop install (sub 100 kW) was 7,1 kW. Trends in small-scale solar (<100 kW) installations and average system size are shown in Figure 4.

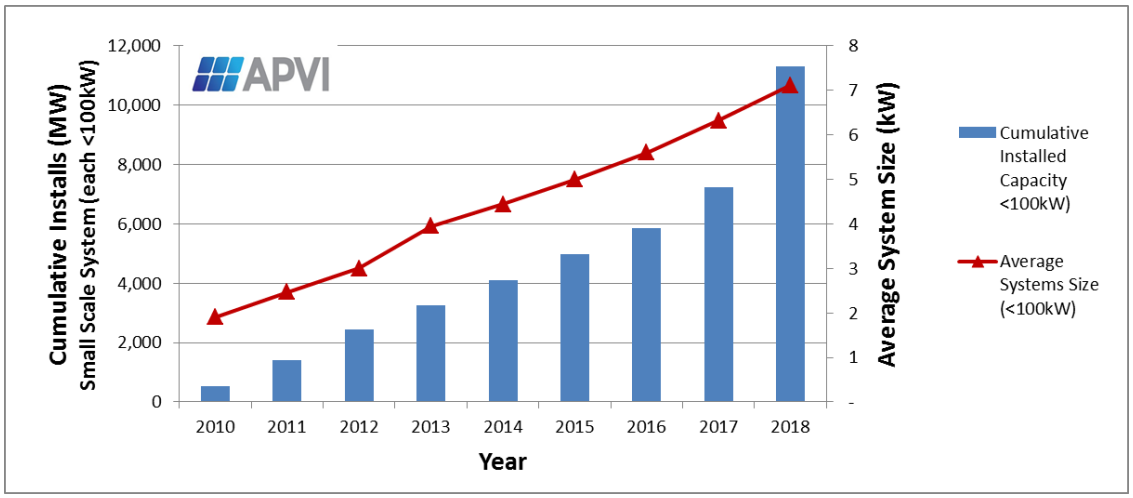

Figure 4. Cumulative Installed Capacity and Average System Size for Systems <100 kW

In 2018, new installations continued to benefit from incentives under the Australian Government's Renewable Energy Target (RET) mechanisms. This is delivered through the Small-scale Renewable Energy Scheme (SRES) for systems up to 100 kW and the Large-Scale Renewable Energy Target (LRET) for systems over 100 kW.

Support from Australia's SRES will decrease each year to 2030, while the LRET is fully subscribed by wind and solar projects either already built commitment, with a further 1 454 MW of wind and solar projects likely to be under construction in 2019 financed by power purchase agreements.

These incentive mechanisms played an important role in early PV markets, as technology and skills were developed. Technology and manufacturing improvements have led to a steep drop in prices, that has now largely stabilised, as shown in Figure 5. Despite declining incentives, the market growth remains strong, also shown in Figure 5.

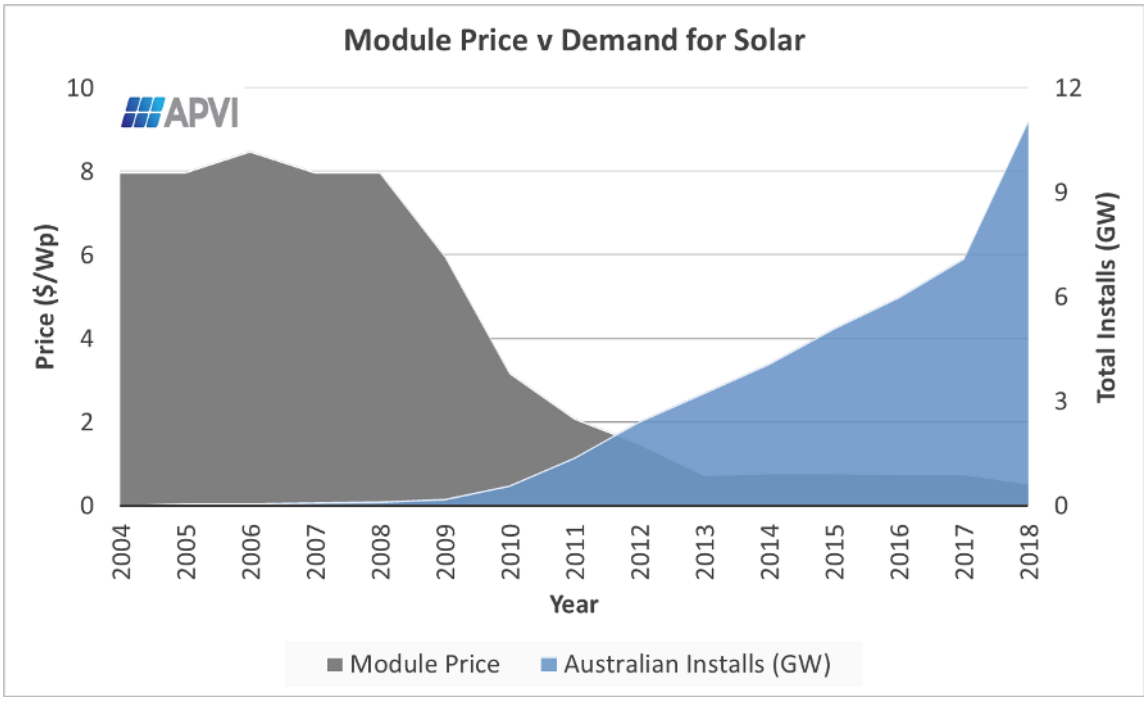

Figure 5 Module Price and Total Installed Capacity (small and large) in the Australian Market

In some cases, projects built in 2018 that had some additional risk or innovation were also eligible for grants and finance assistance provided by the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC).

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 important markets, including power systems for telecommunications, signalling, cathodic protection, water pumping and lighting. Significant markets also exist for fuel saving and peak load reduction on diesel grid systems in communities, mine sites and tourist locations. There is also a reasonably significant market for recreational PV applications for caravans, boats and off-road vehicles.

By contrast to other areas of global leadership, very little building-integrated PV (BIPV) was added in 2018, and no vehicle-integrated PV was known to occur. No additional 'Floatovoltaics' have been recorded, beyond a single 100 kW installation in 2017.

Looking forward, Australia's rooftop market is expected to remain strong through to 2030, supported by the SRES mechanism which has a slow transition to no-support by 2030 programmed in. Larger system install rates are harder to predict with the large-scale system target to be met by or before 2020, plus some increased market risk around connection agreements and changing market mechanisms balanced by increasing support through Power Purchase Agreements.

NATIONAL SURVEY REPORT

The following content is provided in a format required by the IEA PV Power Systems Task 1 to meet standard data requirements for inclusion in international studies.

1 INSTALLATION DATA

The PV power systems 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 2018 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2018, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

Historically, the market for photovoltaics in Australia has been driven by rooftop installs, incentivised by feed in tariffs and capital incentives. These incentives are contracting but the rooftop install market remains strong, reflecting the competitive pricing of behind the meter solar installations. The demand for rooftop solar has kept Australia in the top ten markets for photovoltaics by annual installs and total installed capacity for over ten years, a remarkable outcome for a country of only 25 million people.

The market for utility-scale solar has seen strong growth in the last two years. This is likely to remain strong in 2019 with commitments to be met under a national Renewable Energy Target. There is significant market interest in 2020 and beyond, but risk associated with grid connection and energy policy may lead to some challenges in deployment that will impact investor confidence.

PV connected to the grid in Australia benefits from incentives and support from national government through a Renewable Energy Target (RET). This is delivered through the Small-scale Renewable Energy Scheme (SRES) for systems up to 100 kW and the Large-Scale Renewable Energy Target (LRET) for systems over 100 kW. Small-scale systems create trading certificates (STCs) which are redeemable as an upfront capital subsidy. Large systems generate generation certificates (LGCs) which are redeemable annually based on energy generated.

The incentives come with a reporting obligation and is categorised into small (<100 kW) and large-scale systems (>100 kW). Within these categories residential solar is typically considered 0-10 kW while commercial and industrial installations are rated at 10-100 kW. Above 100 kW there is a mix of commercial and industrial and ground mount out to 5 MW and above 5 MW installations are usually ground mounted.

1.2 Total photovoltaic power installed

The PV power installed in Australia during 2018 is shown in Table 1. In reading this table the following should be noted:

- 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 2018 installations. Installations over 100 kW typically take longer to register RECs than systems 100 kW and under, so the size of this market segment is based upon publicly-announced projects. In addition, not all installed PV is registered with the CER.
- Information on off-grid system installation is based upon historically reported projections and has low accuracy.
- The division between each category is based upon capacity rather than upon application.

Table 1: Annual PV power installed during calendar year 2018.

		Installed PV capacity in 2018 [MW]	AC or DC
PV capacity	Off-grid	37	DC
	Decentralized	1 695	DC
	Centralized	2 359	DC
	Total	4 091	DC

Where centralized refers to any PV installation which only injects electricity and is not associated with a consumer (no self-consumption). Data on centralised stations connected is taken from the Power Station records in the APVI Solar Maps, counting all systems >5 MW). In 2018 there were 31 power stations with >5 MW installed, totalling 2 359 MW.

Decentralized is any PV installation which is embedded into a customer's premises (self-consumption). Total decentralised is all systems eligible for the SRES and those systems eligible for LGCs but less than 5 MW. There are some large systems less than 5 MW that do not record self-consumption. In 2018, there were 55 power stations with <5 MW installed, totalling 18 MW.

Table 2: PV power installed during calendar year 2018.

			Installed PV capacity in 2018 [MW]	Installed PV capacity in 2018 [MW]	AC or DC
Grid Connected	BAPV	Residential	1 695	1 068	DC
		Commercial		510	DC
		Industrial		117	DC
	Utility-Scale	Ground-mounted	2 359		DC
Off-grid			37		DC
Total			4 091		DC

Where Residential grid connect are systems <9,5 kW, commercial are systems between 9.5 and 99,9 kW, industrial are 100 kW to 5 MW. Industrial grid-connect are those systems eligible for LGCs but less than 5 MW. Ground mount are all systems eligible for LGCs over 5 MW. There may be some ground mount less than 5 MW included instead in the Industrial count, in particular there were 55 power stations between 100 kW and 5 MW registered in 2018 for a total of 18 MW**.**

Table 3: Data collection process.

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	Utility-scale capacity is often reported in AC terms, and occasionally in DC terms. Where the DC capacity is unknown, we have assumed a 1,25x DC:AC ratio.
Is the collection process done by an official body or a private company/Association?	PV data for the tables above are derived from the Renewable Energy Certificate (REC) Registry of the Australian Government's Clean Energy Regulator. The data is cleaned and published by the APVI.
Link to official statistics (if this exists)	https://pv-map.apvi.org.au/analyses

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

Year	Off-grid [MW]	Grid-connected distributed [MW]	Grid-connected centralized [MW]	Total [MW]
1992	7,3	0	0	**7,3**
1993	8,9	0	0	**8,9**
1994	10,7	0	0	**10,7**
1995	12,7	0	0	**12,7**
1996	15,6	0,1	0	**15,7**
1997	18,3	0,2	0,2	**18,7**
1998	21,2	0,9	0,5	**22,5**
1999	23,3	1,5	0,5	**25,3**
2000	26,3	2,4	0,5	**29,2**
2001	30,2	2,8	0,5	**33,6**
2002	35,2	3,4	0,5	**39,1**
2003	40,3	4,6	0,7	**45,6**
2004	46,2	5,4	0,7	**52,3**
2005	53,0	6,9	0,8	**60,6**
2006	60,5	9,0	0,8	**70,3**
2007	66,4	15,0	1,0	**82,5**
2008	73,3	29,9	1,3	**105**
2009	83,9	101	2,5	**188**
2010	87,8	479	3,8	**571**
2011	101	1 268	7,4	**1 377**
2012	118	2 276	21,5	**2 415**
2013	132	3 070	24,0	**3 225**
2014	148	3 875	68,5	**4 092**
2015	173	4 580	356	**5 109**
2016	210	5 329	446	**5 985**
2017	247	6 115	740	**7 103**
2018	**284**	**8 030**	**3 272**	**11 586**

The total installed in each category is correct for 2018, using the published data. The difference between 2017 and 2018 may not be the same as the new installs data in Table 1 and Table 2, with a shift to using the unified published data set in 2018.

Table 5: Other PV market information.

	2018 Numbers
Number of PV systems in operation in your country	1,96m residential rooftops and 78 000 commercial and industrial rooftops for a total of 2,04m total PV systems installed
Capacity of decommissioned PV systems during the year [MW]	Not known
Capacity of repowered PV systems during the year [MW]	Not known
Total capacity connected to the low voltage distribution grid [MW]	8 192 less than 100 kW
Total capacity connected to the medium voltage distribution grid [MW]	
Total capacity connected to the high voltage transmission grid [MW]	3 109 total installed capacity (>100 kW) with 2 468 installed in 2018

Information about Australia's broader electricity sector is shown in Table 6, which is derived from reports by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australian Energy Regulator, and the Energy Supply Association of Australia.

Table 6: PV power and the broader national energy market.

	2017 numbers	2018 numbers
Total power generation capacities [GW]	56,2	61,1
Total renewable power generation capacities (including hydropower) [GW]	17,1	22,0
Total electricity demand [TWh]	259,4	261,4
Total energy demand [TWh]	6 146 petajoules	
New power generation capacities installed in 2018 [GW]	1,8 new Plus -1,6 decomm	4,9
New renewable power generation capacities installed in 2018 (including hydropower) [GW]	1,79	4,9
Estimated total PV electricity production (including self-consumed PV electricity) in [TWh]	10,2	15,4
Total PV electricity production as a % of total electricity consumption	3,9%	5,9%

Sources: Data taken from https://www.energy.gov.au/publications/australian-energy-statistics-table-o-electricity-generation-fuel-type-2017-18-and-2018

Total Energy Demand is not updated in time for this report. Previous year data is provided.
Source: https://www.energy.gov.au/sites/default/files/australian_energy_update_2018.pdf

1.3 Key enablers of PV development

Technology enablers of PV in Australia including a strong market for residential batteries. In 2018, installs grew by 9% year on year, with the volume of 259 MWh; an increase on 2017. 10% of PV systems installed in 2018 included a battery (down from 12% in 2017).

A further 109 MWh of grid-scale storage were installed in 2018.

Forecasts for 2019 are for strong growth with a market for 35 000 residential home energy storage systems totalling 358 MWh plus a further 80 MWh of grid-scale storage.

The electric vehicle (EV) market in Australia is weak by international standards and there is no clear correlation with PV market.

Source: Sunwiz.com.au

Table 7: Information on key enablers.

	Description	Annual Volume	Total Volume	Source
Decentralized storage systems In number sold		22 671	50 710	SunWiz
Electric cars (# number sold)	Data excluding Tesla which could add a further 1 400	1 352	7 532 +	Federal Chamber of Automotive Industries (FCAI)

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

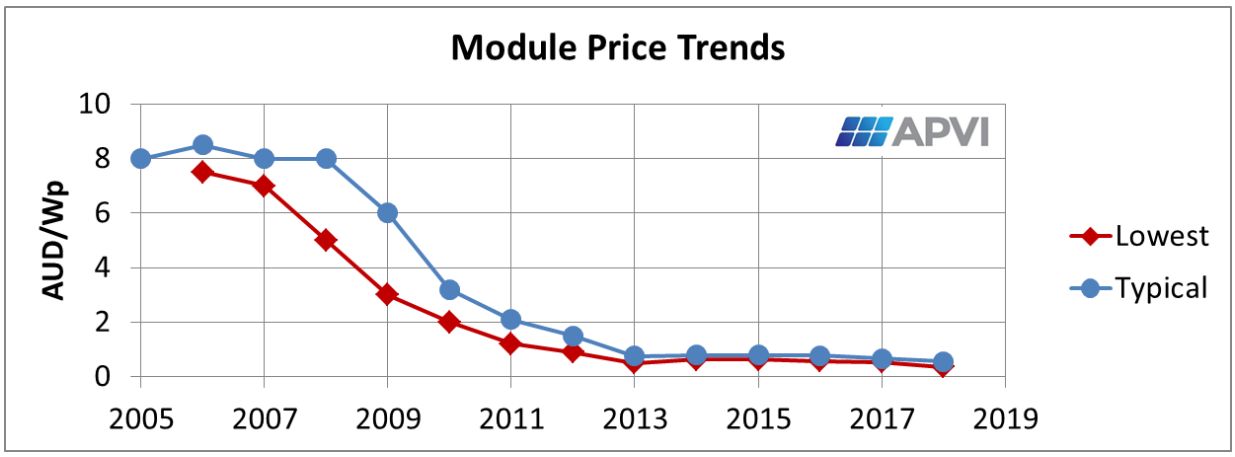

Figure 6. Module Price Trends in the Australian Market

Module price trends (excluding sales tax) by year shown in Table 8. Prices are in AUD/W. Module prices are as provided as standard pricing from wholesalers' price lists.

Table 8: Typical module prices for a number of years.

Year	Lowest price of a standard module crystalline silicon AUD/Wp	Highest price of a standard module crystalline silicon AUD/Wp	Typical price of a standard module crystalline silicon AUD/Wp
2005			8
2006	7,5		8,5
2007	7		8
2008	5		8
2009	3		6
2010	2		3,2
2011	1,2		2,1
2012	0,9		1,5
2013	0,5		0,75
2014	0,62		0,8
2015	0,62		0,8
2016	0,57		0,78
2017	0,53	1,35	0,67
2018	0,35	1,15	0,55

2.2 System prices

A summary of typical fully-installed system prices is provided in the following tables.

The Australian market is very different to most world markets as it has been dominated by rooftop PV with an 5 year rolling average annual install of 990 MW/year installed on rooftops. As a result, the prices of rooftop installs is very highly competitive with larger ground mount, utility- scale systems, despite the economies of scale that would be expected.

Residential and commercial prices are based upon a dataset provided by PV lead generator Solar Choice. Small-scale systems are eligible for an up-front subsidy that is excluded in the table below. The prices are exclusive of incentives which reduce the price to consumers by a further 50-68c/Wp in 2018 depending on insolation, averaged here at 60c/Wp. Prices quoted are also exclusive of sales tax (GST).

The utility-scale solar market has been growing rapidly since 2014 and prices are coming down rapidly. Systems greater than 100 kW of DC capacity are eligible for large-scale generation certificates, which can be sold at the end of each year of production. LGC system sizes average prices are not published as they are site dependent and commercial in confidence. Utility-scale prices are estimates for those systems connected in 2018. The prices for systems connected in 2018 were negotiated some years ago. Future large-scale installs are being negotiated at substantially lower prices, reflecting maturity in the market and an expectation that hardware and soft costs will continue to fall.

Table 9: Turnkey PV system prices of different typical PV systems. All prices are exclusive of sales tax or government incentives.

Category/Size	Typical applications and brief details	Current prices [AUD/W]
Residential BAPV 5-10 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected households. Typically roof-mounted systems on villas and single-family homes.	$1,72
Small commercial BAPV 10-100 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	$1,77
Large commercial BAPV 100-250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected large commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	$1,77
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	$1,77
Small centralized PV 1-20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	$1,85
Large centralized PV >20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	$1,85

Historical trends in system prices for different applications are shown here. Detail on these prices can be found in the description to Table 9 above.

Table 10: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV system 5-10 kW **[AUD/W]**	Small commercial BAPV Grid-connected, roof-mounted, distributed PV systems 10-100 kW **[AUD/W]**	Large commercial BAPV Grid-connected, roof-mounted, distributed PV systems 100-250 kW **[AUD/W]**	Small centralized PV Grid-connected, ground-mounted, centralized PV systems 10-20 MW **[AUD/W]**
2005	12			
2006	12,5			
2007	12			
2008	12			
2009	9			
2010	6			
2011	3,9			
2012	3			
2013	3,1			
2014	2,77	2,68		2,7
2015	2,45	2,07		2,18
2016	2,42	2,08		2,76
2017	2,22	2,01		2,24
2018	1,72	1,77	1,77	1,85

2.3 Cost breakdown of PV installations

The cost breakdown of a typical 5-10 kW roof-mounted, grid-connect, distributed PV system on a residential single-family house at the end of 2018 is presented in Table 11.

The "average" category in Table 11 represents the average cost for each cost category and is the average of the typical cost structure. The average cost is taking the whole system into account and summarizes the average end price to customer.

Component prices are from averages of wholesalers prices lists, for a typical 7 kW system.

Table 11: Cost breakdown for a grid-connected roof-mounted, distributed residential PV system of 5-10 kW.

Cost category	Average [AUD /W]	Low [AUD/W]	High [AUD/W]
Hardware			
Module	0,55	0,35	1,15
Inverter	0,28		
Mounting material	0,21		
Other electronics (cables, etc.)			
Subtotal Hardware	**1,03**		
Soft costs			
Subtotal Soft costs	**0,69**		
Total (excluding VAT)	**1,73**		
Subsidy	**-0,6**		
Average VAT	,11		
Total (including VAT)	**1,23**		

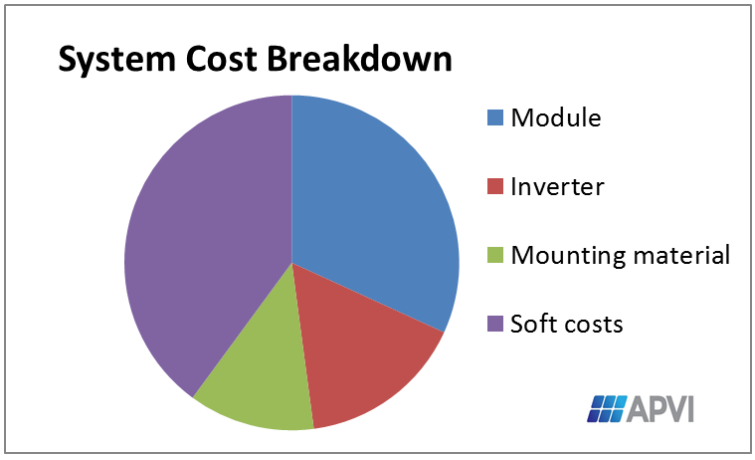

Figure 7. System Cost Breakdown in the Australian Market in 2018 2018 for a grid-connected roof-mounted, distributed residential PV system of 5-10 kW.

Data on utility scale solar in Australia is challenging, with costs held as commercial in confidence. ARENA have been able to provide a limited data set on projects installed and connected to the grid between 1 January and 31 December 2018.

Major EPC costs include: modules, inverters, frames, trackers, grid connection, substation, civil works, electrical works, labour etc.

Major non-EPC costs include: development, owners engineer, management, financing, legal, insurance etc.

Table 12: Cost breakdown for a grid-connected, ground-mounted, centralized PV systems of >10 MW.

Cost category	Average [AUD/W]	Low [AUD/W]	High [AUD/W]
Hardware			
Module			
Inverter			
Mounting material			
Other electronics (cables, etc.)			
Subtotal Hardware			
Soft costs			
Planning			
Installation work			
Shipping and travel expenses to customer			
Permits and commissioning (i.e. cost for electrician, etc.)			
Project margin			
Major EPC Ccosts	1,87	1,66	2,27
Non EPC Ccosts	0,3	0,16	0,48
Subtotal Soft costs			
Total (excluding VAT)	**2,17**		
Average VAT	0,22		
Total (including VAT)	**2,39**		

2.4 Financial Parameters and specific financing programs

A broader range of finance options continue to become available to the market, although 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.

Table 13 shows some information on typical costs of financing a PV system.

Table 133: PV financing information in 2018.

Different market segments	Loan rate [%]
Average rate of loans – residential installations	4,3 to 5,5% (mortgage finance); 16% (unsecured consumer finance)
Average rate of loans – commercial installations	7,75 to 10% (commercial finance)
Average cost of capital – industrial and ground-mounted installations	5% to 7% (average forward interest rate over 5 years)

2.5 Specific investments programs

The majority of installations in Australia are on rooftops, self-financed by the owner, with a small amount of on-bill finance offered by energy retailers. With the growth in commercial and industrial-scale solar, Third Party Ownership agreements are growing, primarily through Power Purchase Agreements, while leasing is well established as a financing mechanism in the Australian market. There is not yet a material market for solar power for rentals in Australia because of the split incentive (owner vs occupier), however, this segment has gained the attention of government, community organisations and innovators.

Table 144: Summary of existing investment schemes.

Investment Schemes	Introduced in Australia
Third party ownership (no investment)	Yes
Renting	No
Leasing	Yes
Financing through utilities	Yes
Investment in PV plants against free electricity	No
Crowd funding (investment in PV plants)	Yes
Community solar	Yes
International organization financing	No
Consumer Finance	Yes

2.6 Additional Country information

With over 11 GW of solar and a population of 25 million, Australia now has over 450 Watts of installed solar per capita, putting it in the top three internationally by this ranking.

With high energy prices and continued support for small-scale installs through the Small-scale Technology Certificates, we expect the small-scale market to continue to grow strongly into the future.

Table 155: Country information.

Retail electricity prices for a household [AUD/W]	AUD 0,20 – 0,42 /kWh (flat tariffs)			
Retail electricity prices for a commercial company [AUD/W]	AUD 0,23 – 0,42 / kWh			
Retail electricity prices for an industrial company [AUD/W]	AUD 0,20 – 0,30 / kWh			
Population at the end of 2018	25,0 million			
Country size [km^2]	7,69 million sq km			
Average PV yield in [kWh/kW]	1 400 kWh/kWp per year			
Name and market share of major electric utilities		Electricity production [%]	Share of grid Subscribers [%]	Number of retail customers [%]
	Origin Energy	~25%		
	AGL	~17%		
	ERM	~12%		
	Energy Australia	~11%		
	Stanwell	7%		
	Synergy	5%		
	Ergon	5%		
	Lumo/Red	4%		
	Others	11%		

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 166: Summary of PV support measures.

	On-going measures in 2018 – Residential	Measures introduced in 2018 – Residential	On-going measures in 2018 – Commercial + Industrial	Measures introduced in 2018 – Commercial + Industrial	On-going measures in 2018 – Centralized	Measures introduced in 2018 – Centralized
Feed-in tariffs	yes	-	-	-	-	-
Feed-in premium (above market price)	-	-	-	-	-	-
Capital subsidies	yes	-	yes	-	-	-
Green certificates	-	-	yes	-	yes	-
Renewable portfolio standards (RPS) with/without PV requirements	-	-	-	-	-	-
Income tax credits	-	-	-	-	-	-
Self-consumption	yes	-	yes	-	-	-
Net-metering	yes	-	yes	-	-	-
Net-billing	-	-	-	-	-	-
Collective self-consumption and virtual net-metering	-	-	-	-	-	-
Commercial bank activities e.g. green mortgages promoting PV	yes	-	yes	-	yes	-
Activities of electricity utility businesses	yes	-	yes	-	yes	-
Sustainable building requirements	-	-	yes	-	-	-
BIPV incentives	-	-	-	-	-	-
Reverse Auctions	-	-	-	-	Yes	-
Government PPAs					Yes	
Corporate PPAs					yes	

3.1 National targets for PV

Australian solar installs currently benefit from Renewable Energy Targets that support investment in either large- or small-scale solar, detailed below.

3.2 Direct support policies for PV installations

3.2.1 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 includes legislated annual targets, which are shown in Table 177. Australia is on track to meet these targets.

Table 177: 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

[source: Clean Energy Regulator, http://www.cleanenergyregulator.gov.au/About/Pages/Accountability%20and%20reporting/Administrative%20Reports/The-2018-Renewable-Energy-Target-Annual-Statement-%E2%80%93-Progress-towards-the-2020-target.aspx]

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).

There is no cap on the number of STCs that can be created, but the scheme has a completion date of 2030. Deeming arrangements mean that PV systems up to 100 kWp could claim 15 years'

worth of STCs up front up to 2015. Since 2015, new installs receive one year less deeming, in line with the RET completion date of 2030.

The Clean Energy Regulator manages transfer of STCs through a voluntary 'clearing house' and liable entities are required to surrender STCs four times a year.

The dollar value of these STCs is discounted from the upfront cost of the installation. At the moment, this can amount to thousands of dollars. With support from the SRES, and the declining cost of systems, both the volume of new small-scale installs and the average system size has grown year on year as shown in **Figure 2**.

3.2.2 National Government Agencies.

The Australian Renewable Energy Agency (ARENA), Clean Energy Finance Corporation (CEFC), and Clean Energy Innovation Fund (CEIF) continued to operate throughout 2018 to support the deployment of renewable and clean energy technologies, with a strong focus on solar PV.

3.2.2.1 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.

In 2018, ARENA supported nine new Solar activities under their Advancing Renewables Program with over 15,7m AUD in funding towards projects valued at over 51,0m AUD described as;

1. Conversion of remote crude oil beam pumps to solar & battery
2. Innovative optimally combined solar forecasts
3. Application of Advanced Short Term Power Generation Forecasting
4. Fulcrum3D CloudCAM Solar Forecasting
5. SolPod Solar PV Demonstration Project
6. NSW Schools Energy Productivity Program (SEPP) Pilot
7. Simply Energy Virtual Power Plant (VPP)
8. SOURCE Hydropanel Demonstration Project
9. Social Access Solar Gardens

[Source: https://arena.gov.au/projects/?project-value-start=0&project-value-end=200000000]

3.2.2.2 Clean Energy Finance Corporation (CEFC)

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.

CEFC finance has helped accelerate the delivery of more than 1 GW in additional solar energy – enough electricity to power about 375 000 average homes. While total CEFC solar investments represent just one per cent of Australia's total electricity generation, they represent a substantial reduction in carbon emissions, of around 1,8 million tonnes annually, making an important contribution to Australia's overall emissions reduction goals.

Despite the welcome increase in private sector investment in large-scale solar projects, CEFC finance remains necessary to fill a gap in investor appetite for projects that are in the process of

finalising power purchase agreements, or which have entered power purchase agreements with corporates or other offtakers outside the large investment grade energy companies.

2019 projects commitments totalling more than $200M include:

- SOLAR-POWERED TRAMS with a CEFC COMMITMENT of $98M. Victoria's largest solar farm, the 88 MW Bannerton Solar Park, is located in the state's Sunraysia district, on an almond orchard no longer suitable for planting. The development is drawing on $98 million in CEFC finance, with equity investment from the Foresight Solar Fund and Korean investors. A significant proportion of its projected output is already contracted to Alinta Energy, as well as the Victoria Government, which plans to use solar power for Melbourne's iconic tram network.
- SOLAR SOLUTIONS FOR THE REEF with a CEFC COMMITMENT of $90M. The 150 MW Daydream and 50 MW Hayman solar farms in Queensland reflect the CEFC's focus on delivering clean energy solutions in the Great Barrier Reef catchment area. The projects, located in a former coal mining hub, take advantage of the area's high insolation rates to accelerate the low emissions transformation of the electricity grid. The CEFC finance of $90 million is part of a syndicated debt facility, alongside the Commonwealth Bank and French investment bank Natixis. BlackRock Real Assets is an equity investor.
- NSW SOLAR GENERATION BELT with a CEFC COMMITMENT of $30M. The 150 MW Coleambally Solar Farm is part of the emerging solar generation belt in regional NSW. While NSW has the largest electricity demand in Australia, it has a relatively low penetration of large-scale solar generation. The project is expected to abate about 300 000 tonnes of carbon emissions annually. Developer Neoen Australia secured $30 million in CEFC finance, and has contracted 70 per cent of the project output to EnergyAustralia

Source: CEFC Annual Report: https://annualreport2018.cefc.com.au/media/1154/cefc-annual-report-2017-18.pdf

3.2.2.3 Clean Energy Innovation Fund (CEIF)

The **Clean Energy Innovation Fund** is a $200 million program supporting the growth of innovative clean energy technologies and businesses. In addition the CEIF funding supports Australia's first Clean Energy Seed Fund.

No solar-specific innovation investments were funded in 2018.

3.2.3 Solar for Communities

There is a national Solar Communities Program that provides funding for community groups in selected regions across Australia to install rooftop solar photovoltaic as well as solar hot water and solar-connected battery systems to reduce emissions, reduce their electricity costs and support renewable energy.

3.2.4 Direct Action

Although the Direct Action Plan supports emissions reduction mechanisms, there has been no direct support for solar-specific projects.

3.2.5 State and Territory Support

Complementing the established RET, state based incentives have helped support PV markets through feed-in-tariffs, cash incentives and reverse auctions. Some examples are described here;

3.2.5.1 Reverse Auctions

The ACT Government was the first jurisdiction in Australia to use the reverse auction mechanism to support the construction of new renewable energy projects. Companies were invited to submit proposals for the construction of new renewable energy projects, with an aim for completing the project at the possible lowest cost. Four auctions were held between 2012 and 2016, ultimately securing 40 megawatts (MW) of solar capacity at record low prices. Importantly, the feed-in tariff awarded to these projects is fixed for the next 20-years, reducing the effect of variations in wholesale electricity prices.

In 2018, the Victorian Government has established the Victorian Renewable Energy Auction Scheme (VREAS) to support achievement of the Victorian Renewable Energy Targets (VRET) and allocated over 900 MW of projects under the scheme in September, 2018.

Queensland

3.2.5.2 Direct Subsidies

The NT Government support solar installations through

- Home Improvement Scheme offering a $2000 subsidy for the installation of residential rooftop solar systems
- Smart Energy Grants in 2018 aimed at helping deliver the Government's target of 50% renewables by 2030, with up to $1000 in matched funding for residential or investment property investments in energy including installing PV or batteries.
- Solar for Schools with $5 million over three years.

No other state offered a direct subsidy in 2018. The Victorian government, elected in 2018, committed to a direct subsidy scheme to be delivered in 2019, supporting up to 40 000 households.

3.2.5.3 Feed-in Tariff

Before 2014, premium feed in tariffs (between 20 and 60 c/kWhr) were offered to incentivise new rooftop installs. The final premium-feed in tariff offer for new installations concluded in 2014.

Most of the incentives had a fixed benefit period that has since passed, with most Australian residential solar customers now receiving feed-in tariffs whose value is little more than the wholesale electricity price; in some states a minimum value is stipulated by the government but in other states the value is left to electricity retailers to decide. In Victoria, the value of avoided greenhouse gas emissions is included in the mandatory minimum feed-in tariff.

There are still large numbers of Australians receiving historic feed-in tariffs, with the next tranche of customers to transition off premium feed-in tariffs will be those in Tasmania (January 2019), then WA and the ACT (from 2020).

3.2.6 Local Government Support

In 2017, local governments played a continued part in supporting the deployment of solar power systems. Local governments installed PV on their own premises, offered Environmental Upgrade Agreements, and supported community bulk-buy initiatives.

3.2.7 BIPV Development Measures

Australia has no specific Building Integrated PV (BIPV) development measures.

Australia maintains a National Building Efficiency rating scheme (NABERS) that measures the environmental performance of commercial buildings. NABERS measure the energy efficiency, water usage, waste management and indoor environmental quality of a building and its impact on the environment.

3.3 Self-Consumption Measures

Table 188: Summary of self-consumption regulations for small private PV systems in 2018.

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 & Renewable Levies	Charged to consumers, incorporated in the retail tariff in c/kWhr
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 (virtual self-consumption or metering)	On site only
Other characteristics	7	Regulatory scheme duration	Unlimited but FiT 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	Some regional limits on system size to connect. Some regional limits requiring self-consumption only.
	12	Electricity system limitations	None (except additional grid codes)
	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'. There are a few trials of PV-driven microgrids operating across the country, particularly in new housing developments and in power supplies for remote communities.

Community solar investment occurs in small numbers in Australia:

- Victorian government is supporting Pilot Community Power Hubs including the Ballarat Renewable Energy and Zero Emissions (BREAZE); Bendigo Sustainability Group (BSG); and Gippsland Climate Change Network.

- The New South Wales government will hold a call for proposal for Regional Community Energy support in 2019.

A number of innovative business models have been developed to test ways of engaging with different communities and sharing the benefit of investments in solar.

- Clear Sky Solar links community investors with quality solar projects and has established over 22 trusts to share the benefit of investment in solar
- CORENA (Citizens Own Renewable Energy Network Australia) has funded 28 small projects and attracted over $400 000 of financial contributions from the donors.
- COREM (Community Owned Renewable Energy Mullimbimby) has a number of regional community owned solar projects
- Embark provides practical capacity-building tools and seed and investment funding. It lists 70 active groups pursuing renewable energy projects.
- Sydney Renewable Power Company created an investment vehicle to allow the local community to benefit from returns on a 520 kW solar installation on the Sydney International Convention Centre.

The Community Power Agency serves as a collective knowledge hub and proponent for community power models.

3.5 Tenders, Auctions & Similar Schemes

Solar tenders 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.

In addition to state government tenders, corporations are running tenders for supply of electricity, known as Corporate PPAs.

3.6 Other Utility-Scale Measures including Floating and Agricultural PV

After the connection of one floating solar plant in 2017, there were no new connections in 2018. And there are no agriculture-specific large-scale solar plants.

3.7 Social Policies

In 2018 there were no specific measures for low-income households. A number of proposals have been discussed and there is an expectation that these will become available in 2019.

3.8 Retrospective Measures Applied to PV

No retrospective measures that impact the profitability of existing PV plants, either positively or negatively have been implemented.

3.9 Indirect Policy Issues

3.9.1 Rural Electrification Measures

None

3.9.2 Support for Electricity Storage and Demand Response Measures

Over 20 000 home energy storage systems were deployed in 2018, most of which did not receive any subsidy. The subsidy schemes in place in 2018 include:

- The ACT Government offers a subsidy for residential storage systems, as part of a $25 million 'Next Generation Energy Storage Program', which will provide batteries to over 5000 homes and businesses by 2020. This fund is cross-subsidised by the ACT government's large-scale renewable auction.
- A subsidy was also made available to SA households that wished to participate in a virtual power plant, which saw installations grow over 2018.
- The Queensland Government initiated a program with interest-free loans and grants for solar power and battery storage in November 2018.

In late 2017, the Australian Renewable Energy Agency funded 10 pilot projects to deliver demand response to manage electricity supply during extreme peaks. The projects target 200 megawatts of capacity by 2020 with at least 140MW in the summer of 2018.

3.9.3 Support for Electric Vehicles (and VIPV)

None

3.9.4 Curtailment Policies

The Australian Energy Market Operator (AEMO) poses strict rules that limit total large-scale solar (and wind) output to protect what it calls system strength. Curtailment happens when combined output reaches a pre-defined level and happens regularly in South Australia, where there is a rapidly growing large-scale solar capacity now standing at 110 MW and more than 1800 MW of wind capacity.

Output of solar farms is also discounted using a Marginal Loss Factor (MLF). The MLF is a calculation used to estimate how much a plant's output actually reaches a destination and reflects distance to load. An MLF of 0,9, for instance, suggests losses of 10 per cent, so a solar plant will be credited for just 90 MWh out of every 100 MWh registered at the meter at the plant.

MLFs are revised and set annually and lead to increased risk in establishing business models around return on investment in large-scale solar.

3.9.5 Indirect Policy Measures

Australia lacks an energy strategy beyond the 2020 vision that established the Renewable Energy Target.

A lack of political will around climate change and carbon pricing has impacted energy sector investment more broadly where uncertainty in energy and climate policy has increased investment risk and meant that long term investments bear a higher cost than they may otherwise.

Recognising the low cost of wind and solar and the need for storage, the Commonwealth Government has made a commitment to increased investment in large-scale pumped hydro to provide central storage.

3.10 Financing and Cost of Support Measures

Table 199 shows the source of finance for solar-related government programs.

Table 199: 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, Queensland Government support for ARENA projects	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

4 INDUSTRY

4.1 Production of Feedstocks, Ingots and Wafers (crystalline silicon industry)

No feedstock, ingot or wafer manufacture occurs in Australia.

4.2 Production of Photovoltaic Cells and Modules (including TF and CPV)

Module manufacturing is defined as the industry where the process of the production of PV modules (the encapsulation) is done. A company may also be involved in the production of ingots, wafers or the processing of cells, in addition to fabricating the modules with frames, junction boxes etc. The manufacturing of modules may only be counted to a country if the encapsulation takes place in that country.

For many years, Tindo Solar has been the sole manufacturer of solar panels in Australia. In early 2017, Tindo solar was bought by SA PV retailer 'Cool or Cosy', though the panels continue to be branded Tindo Solar. Tindo imports cells to produce poly and PERC-mono panels, doing module assembly and testing in Australia. Tindo's business model is to both sell panels wholesale and retail PV systems (now via Cool or Cosy).

Tindo Solar manufactured 20 MW of panels in 2016, but no information on 2017 and 2018 production was available.

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

Table 20: PV cell and module production and production capacity information for 2018.

Cell/Module manufacturer (or total national production)	Technology (sc-Si, mc-Si)	Total Production [MW]		Maximum production capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Tindo			NA		60
Totals			**NA**		**60**

4.3 Manufacturers and Suppliers of Other Components

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

4.3.1 PV Inverters (for grid-connection and stand-alone systems)

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 Technologies is an Australian intelligent hybrid PV-storage inverter manufacturer.

MIL Systems is an Australian power systems engineering company that produces a residential grid-connect inverter.

4.3.2 Storage Batteries

Australian company RedFlow manufactures Zinc Bromine batteries. Its ZBM product delivers up to 3 kW of continuous power (5 kW 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 Ecoult.

There are large numbers of foreign manufactured battery companies supplying to the Australian market, some of whom are setting up local manufacturing.

4.3.3 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 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.
- Wattwatchers have developed low-cost, ultra-compact, multi-circuit meters with built in wireless communications.
- Solar Analytics – provide a home energy monitoring solution with a focus on solar, with over 22 000 sales to by mid 2018.
- CatchPower, SwitchdIn, Greensync, Reposit are developing internet-of-energy solutions including to optimise solar and battery interactions with the grid.

4.3.4 Supporting Structures

Practically all racking is imported from China, with the exception of local manufacturers IXL who manufacture a range of mounting and tracking systems to suit local conditions.

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. Images throughout this report are supplied by 5B.

Figure 8. Innovative prefabricated mounting array lowers the cost of deployment in remote regions. Images courtesy of 5B Pty Ltd.

4.3.5 BIPV

Tractile Solar combines PV cells with Thermal Hot Water. Tractile listed on the Australian Stock Exchange in 2015 and was showcased in the Desert Rose House, that took second place in 2018 Solar Decathalon, Middle East.

5 PV IN THE ECONOMY

The Australian solar supply chain is currently typically structured as follows:

- Wholesalers import from overseas manufacturers, and sell to PV Retailers.
- PV retailers buy products from wholesalers, or a direct from the manufacturer, and arrange for installation. . PV retailers often outsource installation to contract installers, though it's not uncommon for them to employ in-house accredited installers. The PV retailer is responsible for collecting the paperwork from the installer that is needed for STC creation
- Installers collect equipment from retailers (or from wholesaler's bonded warehouses) and transport it to site to then install. The installer is responsible for physical installation and commissioning of the system, and signing off on critical paperwork for electrical connection and STCs. Installation teams need to include at least one accredited installer (electrician). Accreditation is run by the Clean Energy Council (CEC). The CEC-accredited installer signing off on the job is liable to ensure both the system design and installation meet Australian Standards and CEC guidelines. Some PV installers are also micro-retailers

Figure 9. PV is increasingly used for power supply at isolated communities where there can be skills shortages. Novel deployment technologies lower the cost of deployment. Images courtesy of 5B Pty Ltd.

5.1 Labour Places

According to the Australian Bureau of Statistics, there were 8 240 direct full-time equivalent jobs in Rooftop PV in 2017-18, plus 2 880 in large-scale solar for a total of 11 120 direct jobs. The increase in FTE employment in renewable energy activities to 2018 was driven by an increase in construction activity for large-scale solar photovoltaic (PV) systems (1 950 additional FTE jobs) and roof-top solar PV (1 720 additional FTE jobs).

Indirect employment would include jobs related within consultancies, industry associations, government and electricity utilities and would potentially double these numbers[1].

Research and development is well supported in Australia, with close to 250 employed in solar energy research and over 300 students in higher education research in solar energy. The significant R&D budget is supported principally by the national funded Australian Renewable Energy Agency which has a budget to end 2022.

[Source: https://www.abs.gov.au/ausstats/abs@.nsf/mf/4631.0]

Table 20: Estimated PV-related full-time labour places in 2018

Market category	Number of full-time labour places
Research and development (not including companies)	250 (estimate based on budget)
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	30 (estimate)
System and installation companies	11 120 (ABS)

Figure 10. Solar research & development in advanced photovoltaics, technology transfer and training of next generation photovoltaics engineers. Image courtesy School of PV and Renewable Energy Engineering, UNSW, Sydney.

[1] 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.

5.2 Business Value

Estimate of value of PV business in Australia

Table 21: Rough estimation of the value of the PV business in 2018 (VAT is excluded).

Sub-market	Capacity installed in 2018 [MW]	Average price [AUD/W]	Value [AUD]	Sub-market [AUD]
Off-grid	37	$2,00	74 000 000	*1%*
Grid-connected distributed	1 695	$1,75	2 970 000 000	40%
Grid-connected centralized	2 359	$1,85	4 360 000 000	59%
Value of PV business in 2018				7 400 000 000

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 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 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.

There are over 100 registered participants in the NEM, both State government owned and private, including market generators, transmission network service providers, distribution network service providers, and market customers.

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

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 states. 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.

6.2 Interest from Electricity Utility Businesses

The businesses that make up the electricity industry have collectively recognised the inevitability of solar power rolling out across Australia, and most have opted to play a constructive role.

Solar is impacting the energy market operation both technically and financially. Financially, PV is reducing the amount of energy transported and sold, and reducing the wholesale electricity price during the daytime. Technical issues most commonly relate to inverter response to system disturbance and impacts upon local voltages. 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.

6.2.1 Electricity Network Operators

Though the energy market operator has largely prevented the solar industry from attempts by electricity network operators to discriminate against solar customers with solar-specific tariffs that would financially penalise solar households, most network operators still impose delays and conditions to network connection approval that increase the soft costs of solar deployment. Despite that, some network operators have spun-off solar retailing companies of their own, managed at arm's length through ring-fencing provisions.

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-entrant distributed energy market participants.

The Energy Networks Association is actively considering a future with high-penetration PV, working with CSIRO to produce an Electricity Network Transformation Roadmap.

6.2.2 Electricity Generators and Retailers

Electricity generators and retailers are commonly the same company in many parts of Australia, and are therefore collectively referred to as 'gentailers'.

Three large companies dominate the energy retail space in Australia, all offer feed-in-tariffs, have made some investment in large-scale solar and/or are currently participating in the rollout of solar farms by contracting PPAs from solar farms, in order to meet their Renewable Energy Target obligations. The three largest electricity retailers also have their own solar retailing divisions.

A number of small retailers with a solar-energy focus have been established to address a market opportunity in the community demand for access to solar, the significant portion of Australian households with an investment in solar and increased electricity prices.

6.3 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.

Specific examples of local government solar PV support initiatives include:

- City Power Partnerships, an initiative of the Climate Council that brings together local government organisations with a commitment to clean energy.
- The Melbourne Renewable Energy Project is a consortium of local government, educational institutions, and private companies that successfully purchased 110 GWh worth of energy from new large-scale renewable energy facilities.
- The Sunshine Coast Council completed construction of a 15 MW solar farm in 2017, Australia's first Local Government-owned solar farm.

Other examples of programs used by local governments include:

- Solar Bulk Buy Programs – Gives households and businesses in these municipalities access to bulk purchase discount deals. Many local government bulk-buy programmes exist.
- 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.

State and Territories: In 2018, state governments continued to progress measures that would support the deployment of renewable energy, by identifying areas of opportunity, 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.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

2018 was another strong year for solar installs across the Australian market, with a record total installs of 4 091 MW and new benchmarks set in small-scale installs at 1 795 MW and in large-scale installs at 2 468 MW. Panel prices continued to decline, and system prices reached record lows.

The strongest growth was in the large-scale solar market, with a total 329 large-scale solar (>100 kW) connections, with 20 between 5 MW and 100 MW and a further 11 over 100 MW.

The addition of 4 091 MW of new solar put Australia in the top five markets for solar in the world and takes the total installed capacity in Australia at end 2018 at 11 302 MW. With 11 GW of solar capacity and good insolation, around 5,9% of total electricity demand is now met by solar generation.

The growth in the large-scale connections reflects national support for utility-scale solar in programs run by ARENA in earlier years. These programs have increased awareness, developed expertise and accelerated learning in utility-scale solar. However, the rapid escalation in utility-scale investments has resulted in pressure on expertise, market, regulatory and connections. Until these issues are resolved, uncertainties arising from these pressures are likely to increase risk and so cost in future investments.

In the small-scale solar market (sub 100 kW), Australia continues to build on its high per-capita rooftop install rate, with over 22% of free-standing households now generating power from their rooftop, with well over 50% in many urban areas. At the end of 2018, there were over 2 million household solar installations, with over 200 000 installed in 2018. For rooftop solar installs, the average system size continues to grow, with 2018 setting a new benchmark at 7 kW. This reflects a shift from residential to commercial-scale installations.

7.2 Prospects

Prospects remain strong for a strong and stable market in both small and large scale solar installs in Australia. High electricity prices, PV market maturity and inexpensive PV systems means payback can commonly be achieved in 3-5 years and is expected to continue to improve. Momentum continues to build in the commercial PV deployment, and corporate interest in solar PPAs is growing.

Enthusiasm for private investment in large and small-scale solar is framed against a background of uncertainty; after years of reviews and proposal Australia still lacks a national energy policy beyond 2020 and is host to ageing coal plants scheduled for closure that are starting to failing under pressure of peak demand at times of high summer.

Despite this, and perhaps because of it, solar continues to be installed in record numbers. There is acceptance amongst incumbent electricity businesses and regulators that renewable energy is the least-cost source of new-build electricity, and will soon outcompete Australia's existing generation fleet, state and local governments are competing for energy investment in the form of new solar and wind firmed with storage. Network operators are looking at setting up

autonomous micro and mini-grids and generator/retailers are investing in virtual power plants (VPPs). With a view to the expected growth in renewables, the market operator (AEMO) is looking at managing market operations when, on occasions, total demand in some regions could be met by rooftop solar alone as soon as 2025.

Commitments to new investments in large-scale solar remain strong even after 2020, when national government incentives related to the RET end, reflecting the competitive pricing, the maturity of and confidence in the commercial models for large-scale solar. Barriers to growth in this area include grid and connection constraints and changing economics as Marginal Loss Factors (MLF) are adjusted to reflect co-incidence of supply and connection and distance to load.

To maintain the rapid pace of renewable energy deployment, Australia urgently needs additional electricity transmission, energy storage and demand response mechanisms, electricity market reform and policy certainty to support electricity infrastructure investments.

END

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