Technology Collaboration Programme
by iea

International Energy Agency
Photovoltaic Power Systems Programme

Task 1 Strategic PV Analysis and Outreach

PVPS

National Survey Report of PV Power Applications in Australia

2019

ARENA
Australian Government
Australian Renewable Energy Agency

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 Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's 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.

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 Cop- per Alliance are also members.

Visit us at: www.iea-pvps.org

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 2019. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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COVER PICTURE

Front page photo: A 235 kW array of 812 flexible, light-weight PV modules, installation on the Sydney Maritime Museum. eArche modules are from by Sunman Energy Co Ltd. Image courtesy of Energus Pty Ltd. Fun Fact: The same eArche solar panels were also installed on the world's first solar powered train in Byron Bay.

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ACKNOWLEDGEMENTS

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 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 Linda Koschier
- Task 12 Sustainability, Expert is Jose Bilbao (UNSW)
- Task 13 Performance and Reliability, Expert is David Parveliet (Murdoch)
- 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 AUSTRALIAN 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

EXECUTIVE SUMMARY

Australia remains a strong and growing market for grid-connected photovoltaics.

In 2019, Australia saw renewed growth in the rooftop solar market and strong growth in the utility-scale solar sector.

With the addition of a record 4,1 GW of new solar on both rooftops and ground mount, the total cumulative installed capacity at the end of 2019 reached 16,3 GW.

With 16,3 GW, Australia now leads the world in solar per capita, at 600W/person. Germany is a close second at 580W/person.

Historical trends in total installed capacity are shown in Figure 1, where it can be seen that;

- Australia has seen a greater than ten-fold increase over the total installed capacity of 1,3 GW in 2011.
- Australia's total installed capacity has more than doubled in two years, with 7,1 GW installed at the end of 2017.
- More solar was installed in one year, in 2019, than the total historical installed capacity to the end of 2014.

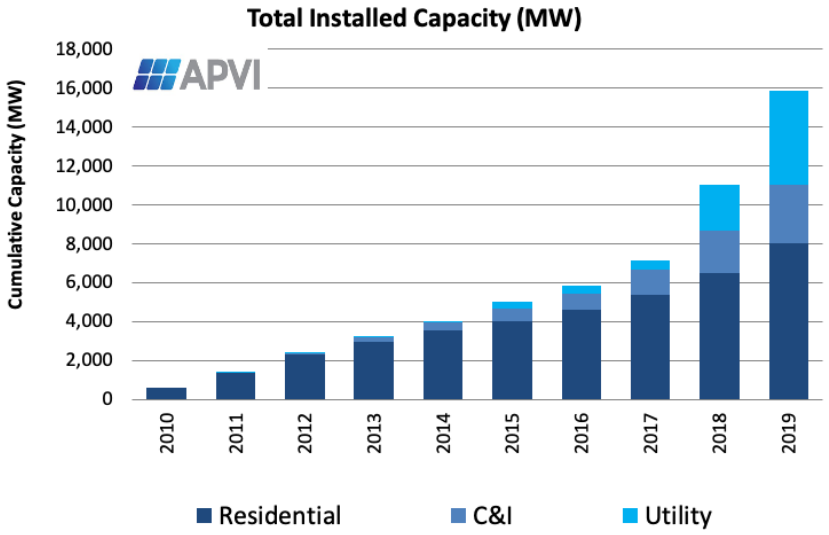

Figure 1. Annual PV installations by sector, where C&I is commercial and industrial.

In annual installs, records were broken in all sectors, shown in Figure 2;

- Residential solar (0-10 kW) grew to over 1,5 GW in new installs
- Commercial solar (10-100 kW) made up a further 680 MW of new rooftop solar.
- Large-scale solar set a significant new benchmark for Australia in 2019, with a total of 2,51 GW solar installation over 5MW in size registered as installed and connected.

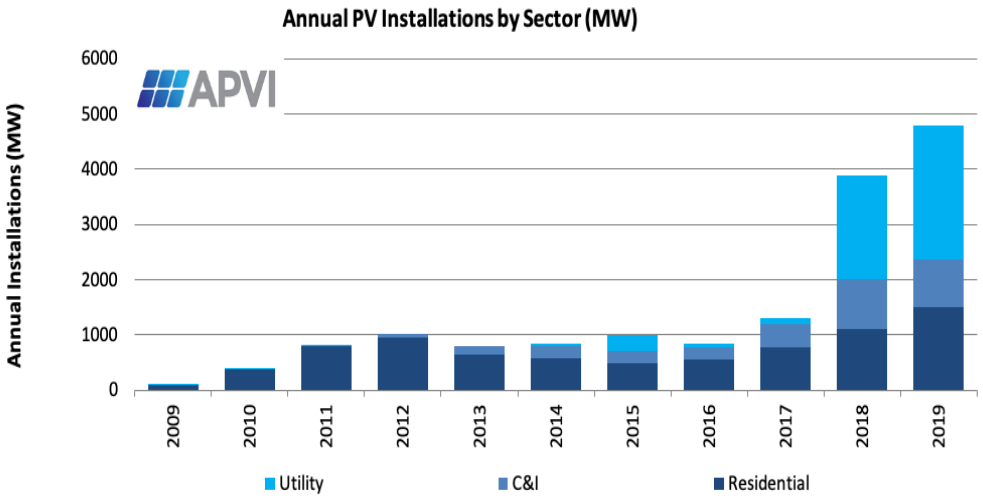

Figure 2. Annual Installs in Australia by Sector.

The Australian market is very different to most world markets as it has been dominated by rooftop PV. At the end of 2019;

- Australia had more than 2,3 million rooftop installations
- 2019 saw a record 280 000 new installs and we are on track for another strong year in 2020
- The 5-year rolling average annual install rate is 1,3 GW/year for residential, commercial and industrial rooftops.
- The nation-wide average of free-standing households with a PV system now exceeds 27%.
- The states of Queensland and South Australia, average over 37% 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.**

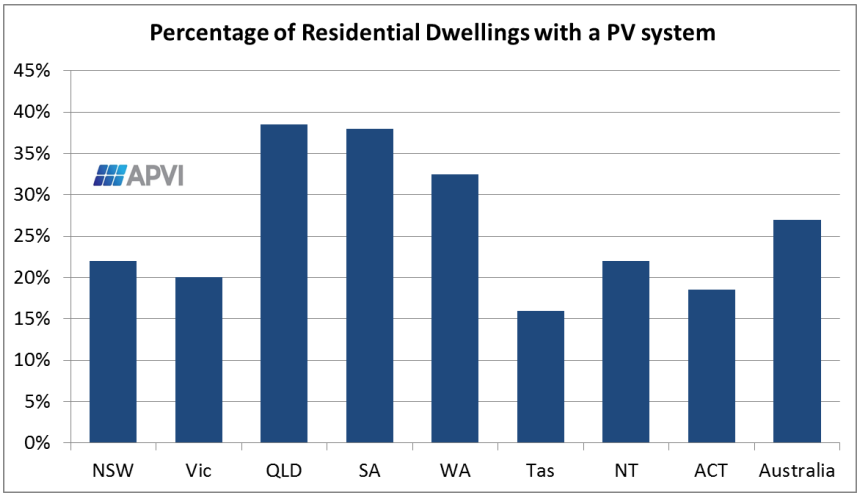

Figure 3. Percentage of residential dwellings with a PV system by state/territory

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 2019, the average rooftop installation (sub 100 kW) was 7,1 kW.

Technology and manufacturing improvements led to a steep drop in prices between 2007 and 2013. Price drops continue, but less dramatically. With price stability and despite declining incentives, the market growth remains strong, with the trends shown in **Figure 4.**

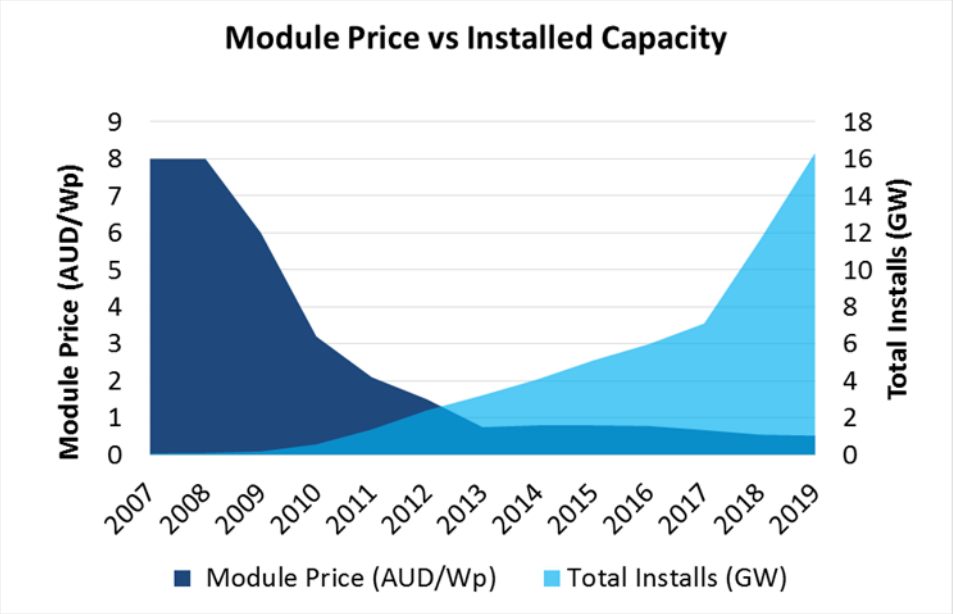

Figure 4. Module Price and Total Installed Capacity (small and large) in the Australian Market

PV connected to the grid in Australia has benefitted from incentives and support from the national government through a Renewable Energy Target. The incentives come with a reporting obligation and are 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.

The Australian market saw 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 rooftop installation in 2017. The return to growth reflects competitive pricing of rooftop solar 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 2019 from the connection of a large number of utility-scale farms.

In 2019, 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 that was due to finish in 2020, was met one year ahead of time in 2019 and is now closed.

These incentive mechanisms have played an important role in early PV markets, as technology, skills, and experience were developed.

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 and industrial and agricultural applications 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.

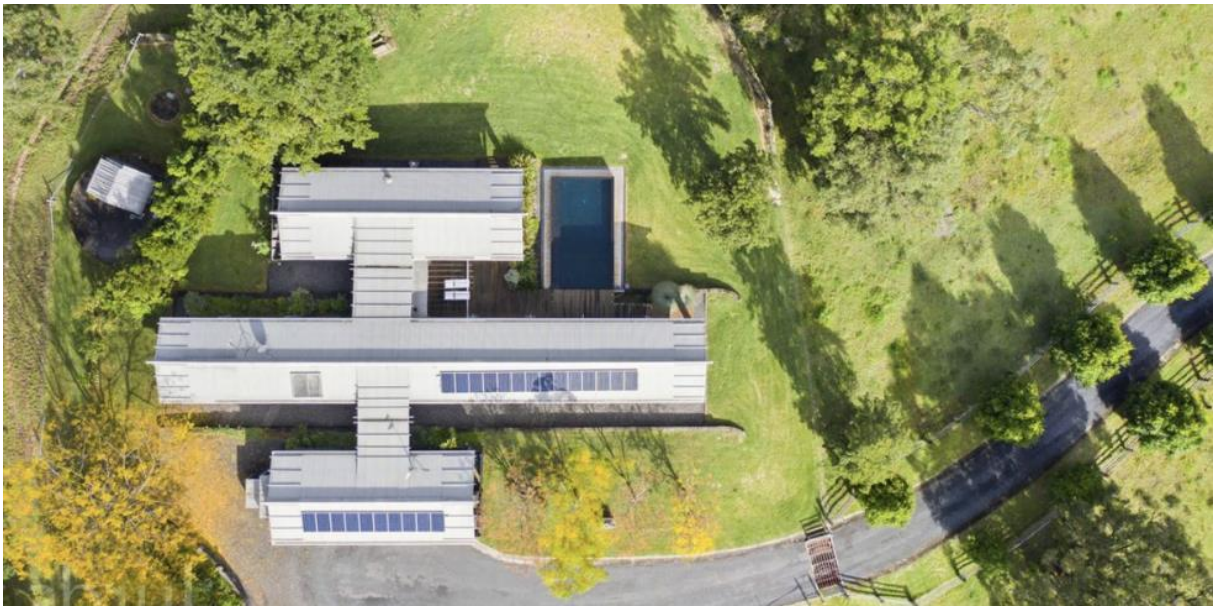

Figure 5. Rooftop solar panels on a rural property. Credit: APVI.

By contrast to other areas of global leadership, very little building-integrated PV (BIPV) was added in 2019, 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 programmed-in transition to no-support by 2030.

Larger system install rates are harder to predict with the large-scale target already being met before 2020, plus some increased market risk around connection agreements and changing market mechanisms balanced by increasing support through state-based initiatives with all Australian states now having zero-carbon targets by 2050.

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 40W 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 2019 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2019, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

The market for photovoltaics in Australia continues to be driven by rooftop installs, 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.

Figure 6. Residential rooftop solar panels on a home in Mount Victoria, NSW. Credit: APVI.

The market for utility-scale solar has seen strong growth since 2017 with ongoing market interest in 2020 and beyond, mitigated by increasing risk associated with grid connection and energy policy that are having an impact on investor confidence.

PV connected to the grid in Australia has benefitted from incentives and support from national government through a Renewable Energy Target (RET). The RET 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 (<100 kW) create Small Scale Technology Certificates (STCs) which are redeemable as an upfront

capital subsidy, where large systems (>100 kW) produce generation certificates (LGCs) which are redeemable annually based on energy generated. These incentives come with a reporting obligation. Within the categories (small-scale/large-scale), 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 2019 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 2019 installations. Installations over 100kW typically take longer to register RECs than systems 100kW 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 Clean Energy Regulator (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 2019

		Installed PV capacity in 2019 [MW]	AC or DC
PV capacity	Off-grid	25	DC
	Decentralized	2 223	DC
	Centralized	2 510	DC
	Total	4 758	DC

Where centralized refers to any PV installation which only injects electricity and is not associated with a consumer (no self-consumption). 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.

Through the course of 2019, Australia installed 372 power stations in total, with 253 producing between 100-500kW, 41 between 500kW-1MW, 49 between 1-5MW, nine between 5 and 10MW, nine in the range from 10-100MW, and 11 with capacity >100MW.

[Source: http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/Large-scale-Renewable-Energy-Target-market-data/large-scale-renewable-energy-target-supply-data]

Table 2: PV power installed during calendar year 2019

			Installed PV capacity [MW]	Installed PV capacity [MW]	AC or DC
Grid-connected	BAPV	Residential	2 223	1 504	DC
		Commercial		628	DC
		Industrial		91	DC
	BIPV	Residential	0		
		Commercial			
		Industrial			
	Utility-scale	Ground-mounted	2 510	2 510	DC
		Floating			
		Agricultural			
Off-grid		Residential	25		
		Other			
		Hybrid systems			
Total			4 758		

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 1,27x 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)	Large Scale: http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/Large-scale-Renewable-Energy-Target-market-data/large-scale-renewable-energy-target-supply-data Small Scale: http://www.cleanenergyregulator.gov.au/DocumentAssets/Pages/Postcode-data-for-small-scale-installations---SGU-Solar.aspx

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	22,6
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	33,5
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	6,9	0,8	60,7
2006	60,5	9	0,8	70,3
2007	66,4	15	1	82,4
2008	73,3	29,9	1,3	105
2009	83,9	101	2,5	187
2010	87,8	479	3,8	571
2011	101	1 268	7,4	1 376
2012	118	2 276	21,5	2 416
2013	132	3 070	24	3 226
2014	148	3 875	68,5	4 092
2015	173	4 580	356	5 109
2016	210	5 329	446	5 985
2017	247	6 145	740	7 132
2018	284	8 030	3 272	11 586
2019	284	10 253	5 783	16 319

Figure 7. Rooftop solar by the sea. Credit: Solar Analytics Pty Ltd

Table 5: Other PV market information

	2019
Number of PV systems in operation in your country	2 320 861
Decommissioned PV systems during the year [MW]	Not known
Repowered PV systems during the year [MW]	Not known
Total capacity connected to the low voltage distribution grid [MW]	10 336
Total capacity connected to the medium voltage distribution grid [MW]	
Total capacity connected to the high voltage transmission grid [MW]	5 711

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

	2018	2019
Total power generation capacities [GW]	57,1	66,7
Total renewable power generation capacities (including hydropower) [GW]	18,0	27,6
Total electricity demand [TWh]	261,4	264,4
Total energy demand*	6 171 petajoules	
New power generation capacities installed [GW]	0,9	5,6
New renewable power generation capacities (including hydropower) [GW]	0,9	5,6
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	15,4	22,8
Total PV electricity production as a % of total electricity consumption	5,9	8,3

*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_statistics_2019_energy_update_report_september.pdf]

1.3 Key enablers of PV development

Table 7: Information on key enablers

	Description	Annual Volume	Total Volume	Source
Decentralized storage systems [#]		22 661	73 371	SunWiz
Electric cars [#]	Data excluding Tesla (which could add a further 3 000)	6 718	15 000 +	Electric Vehicle Council (EVC)

[Sources: Decentralised storage systems information: https://onestepoffthegrid-com-au.cdn.ampproject.org/c/s/onestepoffthegrid.com.au/australians-installed-22661-home-battery-systems-in-2019/amp/ , Electric vehicle information- https://www.theguardian.com/environment/2020/feb/06/electric-vehicle-sales-triple-in-australia-as-sales-of-combustion-engine-cars-fall-8 , https://electricvehiclecouncil.com.au/reports/state-of-evs-in-australia-2019/

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

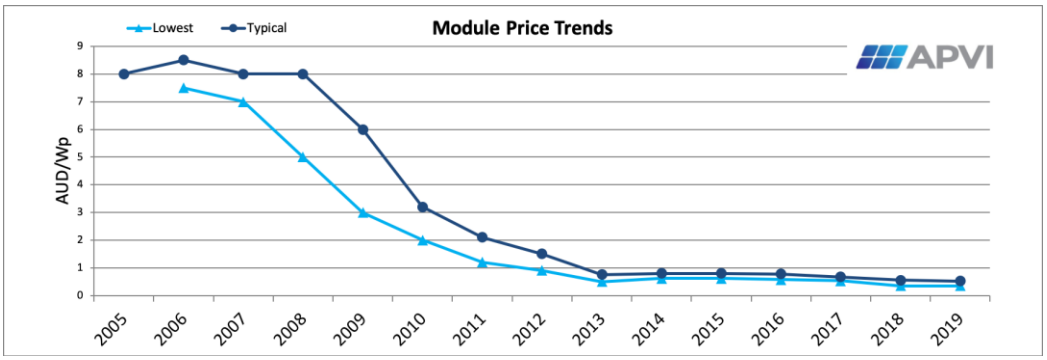

Figure 8. Module Price Trends in the Australian Market

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.

The minimum price that has been achieved in 2019 was 0,35AUD and was imported.

Table 8: Typical module prices for a number of years

Year	Lowest price of a standard module crystalline silicon	Highest price of a standard module crystalline silicon	Typical price of a standard module crystalline silicon
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
2019	0,35	1,15	0,52

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 because it has been dominated by rooftop PV with a 5-year rolling average annual install of 1,3 GW/year on rooftops. As a result, the prices of rooftop installs are highly competitive compared to larger ground mount, utility- scale systems, despite the expected economies of scale.

Residential and commercial system 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 41-57c/Wp in 2019 (depending on insolation), averaged here at 50c/Wp. Prices quoted are also exclusive of sales tax (GST).

Table 9: Turnkey PV system prices of different typical PV systems

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.	1,60
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.	1,68
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.	1,51
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	1,51
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.	N/A
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.	N/A

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 have been eligible for large-scale generation certificates, which can be sold at the end of each year of production. Average pricing for utility scale systems are not published as they are site dependent and commercial in confidence. Utility-scale prices are estimates for those systems connected in 2019. The

prices for systems connected in 2019 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.

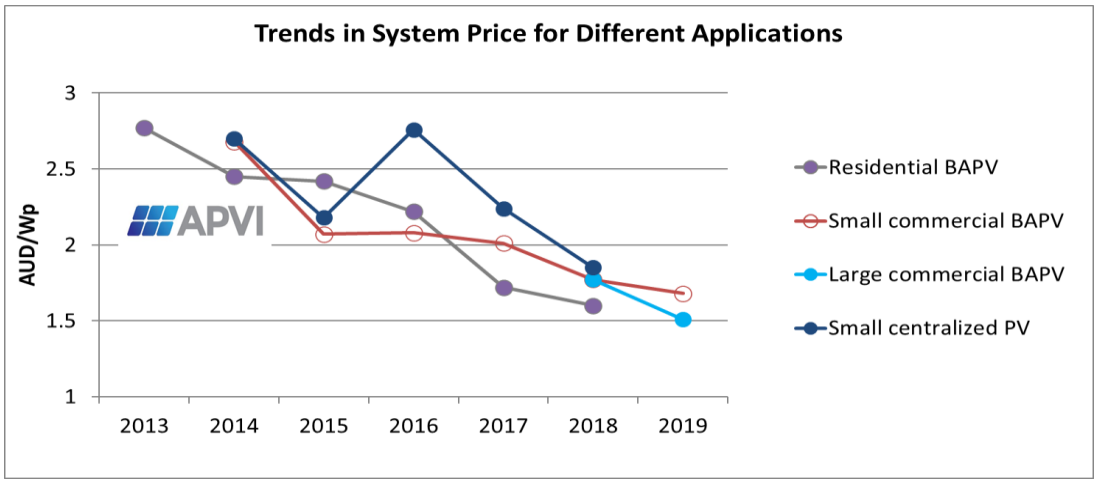

Figure 9. National trends in system prices for different system sizes.

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 [AUDW]
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
2019	1,6	1,68	1,51	N/A

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 and a typical >10 MW Grid-connected, ground-mounted, centralized PV systems at the end of 2019 is presented in Table 11 and Table 12, respectively.

The cost structure presented is from the customer's point of view. I.e. it does not reflect the installer companies' overall costs and revenues. The “average” category in Table 11 and Table 12 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. The “low” and “high” categories are the lowest and highest cost that has been reported within each segment. These costs are individual posts, i.e. summarizing these costs do not give an accurate system price.

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	0,52	0,35	1,15
Inverter	0,26		
Mounting material	0,21		
Other electronics (cables, etc.)			
Subtotal Hardware	**0,99**		
Soft costs			
Planning	0,61		
Installation work			
Shipping and travel expenses to customer			
Permits and commissioning (i.e. cost for electrician, etc.)			
Project margin			
Subtotal Soft costs	**0,61**		
Total (excluding VAT)	**1,6**		
Average VAT			
Total (including VAT)	**1,6**		

Component prices are from averages of wholesaler's prices lists, for a typical 7 kW system.

Data on utility scale solar in Australia is challenging, with costs held as commercial in confidence. New data is not available for 2019.

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]
Total (excluding VAT)	**NA**		
Average VAT			
Total (including VAT)	**NA**		

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 13: PV financing information in 2019

Different market segments	Loan rate [%]
Average rate of loans – residential installations	3,5
Average rate of loans – commercial installations	4
Average cost of capital – industrial and ground-mounted installations	2,8

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 14: 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 16GW of solar and a population of 25,5 million, Australia now leads the world in installed solar per capita, with over 600 Watts per person. Germany is a close second with over 580W of installed solar per capita.

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 15: Country information

Retail electricity prices for a household [AUD/kWh]	0,2 – 0,42			
Retail electricity prices for a commercial company [AUD//kWh]	0,23 – 0,42			
Retail electricity prices for an industrial company [AUD//kWh]	0,20 – 0,30			
Population at the end of 2019	25,5m			
Country size [km^2]	7,69m			
Average PV yield in [kWh/kW]	1 400			
Name and market share of major electric utilities		Electricity production [%]	Share of grid Subscribers [%]	Number of retail customers [%]
	Origin	~25		4m (not sure what %)
	AGL	~17		3,7m
	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 incentivising or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV deployment.

Table 16: Summary of PV support measures

Category	Residential		Commercial + Industrial		Centralized	
Measures in 2019	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	Yes	-	-	Yes	-	-
Feed-in premium (above market price)	Yes	-	-	-	-	-
Capital subsidies	-	-	Yes	-	-	-
Green certificates	Yes	-	Yes	-	Yes	-
Renewable portfolio standards 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	-	-	-	-	-	-
Power Purchase Agreements (PPAs)	-	-	-	-	Yes	-
Reverse Auctions			Yes		Yes	

3.1 National targets for PV

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 target. These are discussed 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) that has no set target. The RET is funded by cross-subsidy, leveraged upon all electricity consumption except for certain classes of industrial electricity consumers.

Figure 10. Residential rooftop solar Credit: APVI

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 each year, in line with the RET completion date of 2030.

The Clean Energy Regulator (CER) manages transfer of STCs through a voluntary 'clearing house' and liable entities are required to surrender STCs to the CER four times a year. The dollar value of these STCs is discounted from the upfront cost of the installation. With support from the SRES, and the declining cost of PV systems, both the volume of new small-scale installs and the average system size has grown year on year.

Figure 11: Large residential rooftop install: Source: Suntech Pty Ltd

Large-scale Renewable Energy Target

The LRET, covering large-scale renewable energy projects like wind farms, commercial-scale solar and bioenergy includes legislated annual targets that reached 33 000 GWh in 2020. This target has been met but is maintained until 2030. Liable entities meet their obligations by acquiring and surrendering Large-scale Generation Certificates (LGCs), with 1 LGC created for each MWh of renewable electricity.

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 2019 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 2018-2019, ARENA supported 3 new projects under Accelerating Solar PV Innovation valued at AUD 2 million including extending a trial of self-powering solar classrooms to more schools, and a further AUD 38 million also committed to extend the Australian Centre for Advanced Photovoltaics to continue world-leading research in solar PV R&D.

Source: https://arena.gov.au/assets/2019/10/arena-annual-report-2018-19.pdf

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.

In the 12 months to 30 June 2019, the CEFC committed almost AUD 1,5 billion in new investments across 30 projects with a total value of AUD 6,3 billion. This included almost AUD 1 billion in renewable energy, and more than AUD 500 million in energy efficiency and low emissions projects. Since inception, CEFC investments have helped drive more than AUD 24 billion in additional private sector investment commitments Australia-wide.

The CEFC investments are expected to reduce Australia's greenhouse gas emissions by an estimated 260 million tonnes of CO2-e over their lifetime, making a considerable contribution to the national emissions reduction effort.

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 AUD 165m were made toward three large scale solar farms including:

- Neoen Australia: Numurkah Solar Farm AUD 56,2m
- Total Eren: Kiamal Solar Farm AUD 51,2m
- Neoen Australia: Gilgandra Solar Farm AUD 57,6m

3.2.2.3 Clean Energy Innovation Fund (CEIF)

The Clean Energy Innovation Fund is an AUD 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.

Figure 12: Residential Solar. Credit: APVI

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

Direct Action is the centrepiece of Australia's current greenhouse gas reduction efforts. To date, A$1.7 billion in subsidies has been committed from the government's Emissions Reduction Fund to projects offering to reduce emissions. The scheme replaced Australia's two-year-old carbon price in 2014 and is a key part of the government's plan to reduce emissions by 5% below 2000 levels by 2020, and 26–28% below 2005 levels by 2030.

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. With the LRET being met, state government programs are becoming a key driver for growth in solar installations. The direct subsidies and feed-in tariffs are described below, with more targeted measures in Sections **Erreur ! Source du renvoi introuvable.**, **Erreur ! Source du renvoi introuvable.**, **Erreur ! Source du renvoi introuvable.** and **Erreur ! Source du renvoi introuvable.**.

3.2.5.1 Direct Subsidies

The NSW government is offering interest-free loans to households in the Hunter region through the Empowering Homes program for solar plus battery installations (AUD 14,000) or battery to an existing solar system (AUD 9,000).

The Victorian government offers the solar rebate scheme up to a maximum of AUD 1,850 as well as an interest free loan up to the value of the rebate which must be paid back over 4 years.

The Queensland government is offering interest-free loans to households of up to AUD 4,500 per solar system, which must be paid back within 7 years.

3.2.5.2 Feed-in Tariff

Each of the State and Territory jurisdictions have run their own feed-in tariff (FiT) schemes, with all now closed to new entrants but with many still operating. These are shown in Table 17. The majority of PV systems now receive feed-in tariffs with a value that is ostensibly based on the wholesale electricity price but is often more because of customer acquisition value; 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.

Table 17: Australian State and Territory Feed-in Tariffs in 2020

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
Comments	Customers lose their FiT if they change their system size or move house.					
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
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.					
ACT						
Gross FiT (closed 31 May 2011)	1 March 2009	30 kW	50,05 (<10kW), 40,04 (10-30kW), after 1 July 2010 45,7 (<30kW)	20 years after connection	Gross	Residential, business

Gross FiT (closed 13 July 2011)	1 April 2011	30-200 kW	34,27	20 years after connection	Gross	Residential, business
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.					
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
Comments	Customers lose their SBS FiT if they change their system size or move house.					
Western Australia						
Residential FiT scheme (closed 1 Aug 2011)	1 July 2010	5 kW (city) 10 kW 1Ø 30 kW 3Ø (country)	40 to 30 June 2011 20 from 1 July 2011	10 years after installation	Net	Residential
RE Buyback Scheme	2005	Up to 5kW	dropped to 7.135 from 9.5 on 1 September 2014	Open ended	Net	Residential, Commercial (Horizon Power)
Comments	The amount of the REBS FiT depends on the local cost of generation, the retail tariff and whether residential or commercial					

3.2.6 Local Government Support

In 2019, local governments continue to play a part in supporting the deployment of solar power systems. Local governments installed PV on their own premises, offered Environmental Upgrade Agreements, supported community bulk-buy initiatives and have financially supported the Australian PV Institute's SunSPoT that allows households and businesses to obtain a better understanding of the financial outcomes of installing solar in their roof.

3.2.7 BIPV development measures

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

Australia maintains a Nationwide House Energy Rating Scheme (NatHERS) that measures the energy efficiency of residential buildings. There is also the National Australian Built Environment Rating System (NABERS), that measures the energy efficiency, water usage, waste management and indoor environmental quality of buildings, tenancies and homes and their impact on the environment. Solar PV can be used to help meet both these schemes.

3.3 Self-consumption measures

Table 18: Summary of self-consumption regulations for small private PV systems in 2019

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/kWh.
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Different types of Feed-in Tariffs
	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	Premium FiTs differ between jurisdictions, and standard FiTs are revised annually
	8	Third party ownership accepted	Yes (e.g. Solar Leasing)
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	No
	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 pricing regulations in Australia stipulate that full network charges must be paid even for locally transmitted electricity, which acts as a barrier to collective self-consumption or virtual net-metering, which are therefore only really practical within 'embedded networks'. Microgrids that include PV operate across the country, particularly in new housing developments and in power supplies for remote communities.

Community solar investment occurs at relatively low levels in Australia. Some examples of state government support are:

- The Victorian government, through the Renewable Energy Jobs Fund, is providing $1 million worth of grants to support community-owned renewable energy projects, directly benefiting the local groups and associations delivering them.
- The New South Wales government held a call for proposal for Regional Community Energy support in 2019. Awarding $15.4 million in grant funding to seven community-owned solar and storage projects in regional parts of the state, in a bid to extend the benefits of cheap solar power beyond household rooftops. Combined, the seven projects will deliver an additional 17.2MW of additional solar generation capacity, as well as 17.9MW/39.3MWh of energy storage.

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 26 trusts to share the benefit of investment in solar
- CORENA (Citizens Own Renewable Energy Network Australia) has funded 34 small projects and attracted almost AUD 600 000 of financial contributions from donors.
- COREM (Community Owned Renewable Energy Mullimbimby) has funded 11 regional community owned solar projects through their Revolving Community Energy Fund.
- 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.

Figure 14. Residential Solar, Credit: APVI

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.

3.5.1.1 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. Proposals were selected based on a mix of lowest price and other evaluation criteria including local community engagement and economic development benefits to the ACT. Projects surrender LGCs as proof of generation, with the LGCs being surrendered to the Clean Energy Regulator and cannot be used to meet the legislated LRET. Payments to projects were based on electricity sent to the grid and used a contract for difference approach, meaning that the ACT's liability was limited to the nominated FiT, with the project proponent earning any additional value where the wholesale price is greater than the FiT, and vice versa. The FiT awarded to these projects is fixed for the next 20 years, reducing the effect of variations in wholesale electricity prices. Four auctions were held between 2012 and 2016, securing 40 megawatts (MW) of capacity from three solar farms, and another auction was announced in 2019, which includes the need for 20MW/40MWh of battery storage.

In 2018, the Victorian Government established the Victorian Renewable Energy Auction Scheme (VREAS) to support achievement of the Victorian Renewable Energy Targets (VRET). Six projects were selected based on a mix of lowest price and other evaluation criteria including financial capability and commercial viability; technical capability and viability; economic development; community engagement and shared benefits; and impact on existing electrical network infrastructure. They totalled 929MW, including three large-scale solar farms totalling 255MW. As for the ACT auction, the LGCs cannot be used to meet the legislated LRET.

Figure 7. Renewable Energy Auction Outcomes in Victoria

In 2019 the Queensland Government conducted a reverse auction under the Renewables 400 program and shortlisted ten projects, including five solar farms. This aims to drive an additional 400MW of renewable generation but has not progressed any further at this stage.

3.6 Other utility-scale measures including floating and agricultural PV

After the construction of one floating solar plant in 2017, there were no new connections in 2019. There are no agriculture-specific large-scale solar plants.

3.7 Social policies

In 2019 a number of measures for solar for low-income households were announced by State Governments;

- The NSW Government is offering the Solar for Low Income Households program to 3000 selected households, with the government installing a 3kW rooftop solar installed for free in exchange for no longer receiving the Low-Income Household Rebate for electricity bills for ten years.

- The Victorian government offers the Solar for Rentals program for landlords up to a maximum of AUD 1850 as well as an interest free loan up to the value of the rebate which must be paid back over 4 years. The AUD 1850 rebate is also available for community housing.

- The ACT Government provides the Solar for Low Income Households Program where eligible participants are able to access a subsidy of up to 50% of the total cost of a solar system.

- The Queensland government offered around 1000 rebates of up to AUD 3500, depending on the size of the system, for landlords to install solar systems. It was available in three local government areas and closed on 30 June 2020.

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

Some examples of rural electrification measures are:

The Commonwealth government is providing up to AUD 50.4 million from 2019/20 to 2023/24 to support feasibility studies looking at microgrid technologies to replace, upgrade or supplement existing electricity supply arrangements in off-grid and fringe-of grid communities located in regional and remote areas

The Western Australian government has developed the DER Resources Roadmap which includes a strong focus on microgrids in rural areas. They have also announced regulatory changes that allow the state government owned network operator, Western Power, to excise customers from fringe-of-grid areas and develop solar powered microgrids to improve power quality.

As part of the AUD 3.6 million Decarbonising Remote Communities program, four Indigenous communities in Queensland's far north – Doomadgee, Mapoon, Pormpuraaw and the Northern Peninsula Area – are receiving over 1MW solar PV installed to reduce the use of diesel power.

3.9.2 Support for electricity storage and demand response measures

There are numerous trials of virtual power plants, demand response and battery integration. Some offer discounts on hardware, others premium payments for demand response. Over 22000 home energy storage systems were deployed in 2019, most of which did not receive any subsidy. The subsidy schemes in place in 2019 included:

- The ACT Government offers an AUD 825/kW subsidy for residential storage systems, as part of an AUD 25 million 'Next Generation Energy Storage Program', which is providing batteries to up to 5000 homes and businesses. This fund is cross subsidised by the ACT government's large-scale renewable auction.
- The NSW government is offering interest-free loans to households in the Hunter region through the Empowering Homes program for solar plus battery installations (AUD 14000) or battery to an existing solar system (AUD 9000)
- The Victorian Government, under the Solar Homes Program is supporting eligible Victorian households to install a solar battery, by providing a point of sale discount up to a maximum of AUD 4174.
- The South Australian Government, under the Home Battery Scheme gives all grid-connected South Australians access to a state government subsidy (to a maximum of AUD 4000) and low-interest loans - to help pay for a home battery system. The subsidy is AUD 300/kWh (or AUD 400/kWh for Energy Concession Holders, ensuring low-income households are supported under the Scheme. Loans may be available to cover the balance should it be required.
- The Northern Territory government is offering homeowners, businesses and not-for-profits AUD 6000 grants for solar battery systems. The minimum battery capacity is 7kWh. The grant is not available for solar-only systems.

Figure 15: Residential Solar. Credit: APVI

3.9.3 Support for electric vehicles (and VIPV)

Government support for electric vehicles (EVs) is slowly taking shape.

The NSW government has developed The NSW Electric and Hybrid Vehicle Plan that includes:

- an AUD 3 million co-investment in fast charging points for electric and hybrid vehicles on major regional corridors, and AUD 2 million for new charging points in commuter car parks
- a 30 per cent procurement target for hybrid and electric vehicles by 2023, with at least 10 per cent of the government's fleet to be all-electric vehicles
- integration of NSW's first fully electric bus trial into a regular route service

The Queensland government is developing the Queensland Electric Super Highway, which will be almost 2000 km long and consists of charging stations that use green energy either through direct green energy credits or offsets, making them a carbon-neutral and pollutant-free transport option.

The Victorian Government is funding:

- a commercial electric vehicle manufacturing facility that is being established in Morwell in the Latrobe Valley and commencing operations in 2021, manufacturing around 2400 vehicles per year and creating up to 500 jobs.
- the roll out of Australia's fastest electric vehicle charging stations by early 2020 at seven sites across Victoria - Euroa, Barnawartha North (near Wodonga), Melbourne, Torquay, Latrobe Valley, Ballarat and Horsham. Powered by 100% renewable energy, the charging stations are capable of fully charging an electric vehicle with a range of up to 400 kilometres in under 15 minutes.

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 1 800 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. 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

The cost of the SRES and LRET schemes and most feed in tariffs are passed through to energy consumers as a levy on their bills.

4 INDUSTRY

4.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

Australia has no solar feedstock, ingot or wafer production.

Table 19: Silicon feedstock, ingot and wafer producer's production information for 2019

Manufacturers (or total national production)	Process & technology	Total Production	Product destination	Price
	Silicon feedstock [Tonnes]	nil	nil	
	sc-Si ingots. [Tonnes]	nil	nil	
	mc-Si ingots [Tonnes]	nil	nil	
	sc-Si wafers [MW]	nil	nil	
	mc-Si wafers [MW]	nil	nil	

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. 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). Total PV cell and module manufacture together with production capacity information is summarised in Table 19 below.

Table 20: PV cell and module production and production capacity information for 2019

Cell/Module manufacturer (or total national production)	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS)	Total Production [MW]		Maximum production capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Tindo Solar			35		60
Totals		**0**	**35**	**0**	**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 flow 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 35 000 sales.
- CatchPower, SwitchdIn, Greensync, Reposit and Evergen 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 prefabricated and rapidly deployable ground mount solar array solution - enabling faster, lower cost and more flexible solar projects.

4.3.5 BIPV

Tractile Solar manufactures composite roof tiles that combine 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 Decathlon, Middle East.

Bristile roofing (part of the Brickworks group of companies) make a PV integrated rooftile see https://bristileroofing.com.au/solar/

5 PV IN THE ECONOMY

This chapter aims to provide information on the benefits of PV for the economy.

The Australian solar supply chain is typically structured as follows:

- Wholesalers (Distributors) import from overseas manufacturers and sell to PV Retailers.
- PV retailers buy products from wholesalers, or 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 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 for installation. The installer is responsible for physical installation and commissioning of the system, as well as signing off on critical paperwork for electrical connection and STCs. Installation teams must include at least one accredited installer (electrician), where this 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.

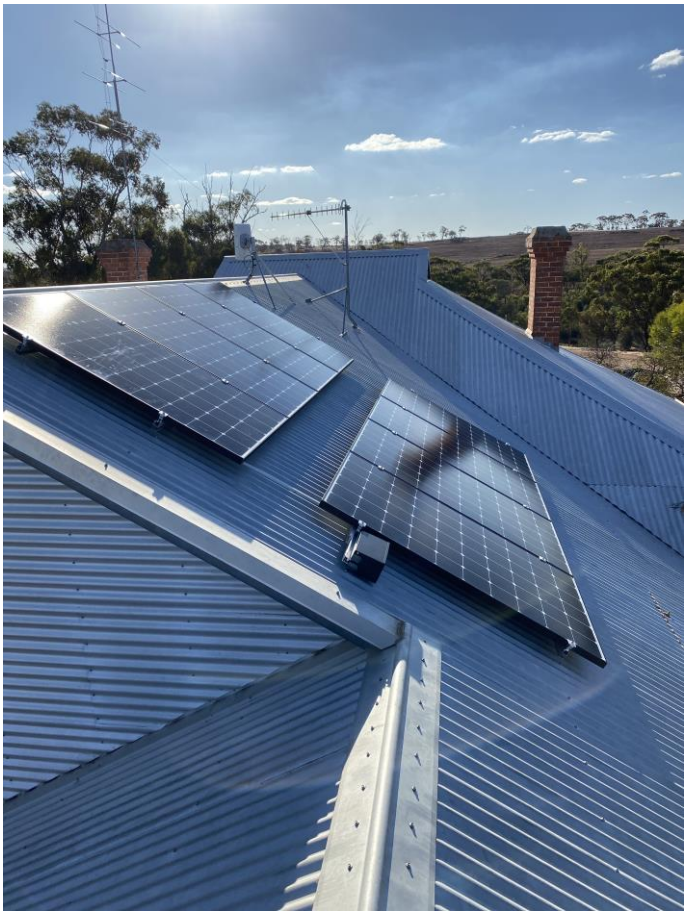

Figure 16. Solar panels installed on a consumer's roof in rural Australia.

Credit: JaeTaylor_Joondalup Electrical Service, Western Australia

5.1 Labour places

According to the Australian Bureau of Statistics, there were 13 070 direct full-time equivalent jobs in Rooftop PV in 2018-19, plus 4 740 in large-scale solar for a total of 17 810 direct jobs.

At 4740, jobs in large scale solar grew threefold from the 1600 positions recorded in 17-18, continuing a rapid increase from less than 1% for each year from 2009-2013. Indirect employment would include jobs related within consultancies, industry associations, government and electricity utilities and would potentially double these numbers.

Research and development are 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 the end of 2022.

Figure 17. Large residential installation Credit: Suntech Pty Ltd

Table 21: Estimated PV-related full-time labour places in 2019

Market category	Number of full-time labour places
Research and development (not including companies)	250
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	30
Distributors of PV products	17 810
System and installation companies	
Total	**18 090**

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

Figure 18. Industrial Rooftop Credit: APVI.

5.2 Business value

Table 22: Rough estimation of the value of the PV business in 2019 (VAT is excluded)

Sub-market	Capacity installed [MW]	Average price [AUD/W]	Value [AUD]	Sub-market [AUD]
Off-grid				
Grid-connected distributed	2 223	1,6	3 560 000 000	3 560 000 000
Grid-connected centralized	2 510	1,6	4 016 000 000	4 016 000 000
Value of PV business in 2019				7 576 000 000

Figure 19. Solar panels installed on a consumer's roof in rural Australia. Credit: JaeTaylor, Joondalup Electrical Service,

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, where 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 and these are all charged to the customer by the retailer.

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, solar 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 use inverters with operation modes under the network operators' influence.

6.2.1 Electricity Network Operators

Though the energy market operator has stopped electricity network operators from discriminating 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 this, 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 party 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 are typically less well-resourced than utility or large government organisations and must operate within the electricity market described above. However, they are backed by a high level of community support for local generation and employment creation.

Many local governments install PV on their own buildings, operate bulk-buy initiatives, and are beginning to set their own renewable energy goals and support community-owned solar installations.

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, which give 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 2019, 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.

Figure 20. Commercial solar on the roof of the Sydney Theatre Company against the backdrop of the Sydney Harbour Bridge. Credit: Suntech Pty Ltd

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

2019 was another strong year for solar installs across the Australian market, with a record total installs of 4 758 MW and new benchmarks set in small-scale installs at 2 223 MW and in large-scale installs at 2 510 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 372 large-scale solar (>100 kW) connections, with 18 between 5 MW and 100 MW and a further 11 over 100 MW.

The addition of 4 785 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 16 060 MW. With 16 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.

Figure 21. Solar panels on the roof of a rural dwelling in NSW. Credit: APVI.

In the small-scale solar market (sub 100 kW), Australia continues to build on its high per-capita rooftop install rate, with over 27% of free-standing households now generating power from their rooftop, with well over 50% in many urban areas. At the end of 2019, there were over 2,2 million household solar installations, with over 280 000 installed in 2019.

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 fail under pressure of peak demand at times of high temperatures during 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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