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

2020

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 2020. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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COVER PICTURE

2.12MW solar deployment at Port Bonython, South Australia to support a hydrocarbon processing facility using revolutionary MAVERICK technology by 5B Pty Ltd. Image courtesy of 5B Pty Ltd.

Fun fact: Ground preparations took 14 days then 5880 panels were deployed by a team of 3 in 21 day deployment.

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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 (Sustainable Energy 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 and Co-Operating Agent is Jose Bilbao (UNSW)
- Task 13 Performance and Reliability. Expert is David Parveliet (Murdoch)
- Task 14 High Penetration PV. Expert is Iain MacGill (UNSW)
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- Task 16 Solar Resource for High Penetration and Large Scale Applications. Expert is John Boland (UniSA)
- Task 17 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

The Australian market for grid-connected photovoltaics (PV) continues to show growth, seeing a record 40% increase in new systems with 370,000 rooftop systems installed in 2020 with no sign of slowing in 2021.

Additional annual rooftop installs hit a new high of 3GW, with 1.8GW on residential roofs and 1.2GW on commercial and industrial roofs, setting records in each of the rooftop sectors.

This year also saw a contraction in utility scale solar off a high in 2019, with the end of the large-scale systems support under the Commonwealth Governments Renewable Energy Target.

With the addition of 4.5GW of new solar on rooftops and ground mount combined, the total installed capacity at the end of 2020 reached 20.8GW, meaning Australia now leads the world in solar per capita with 810W/person, ahead of Germany with 650W/person. 2021 looks set to extend this lead.

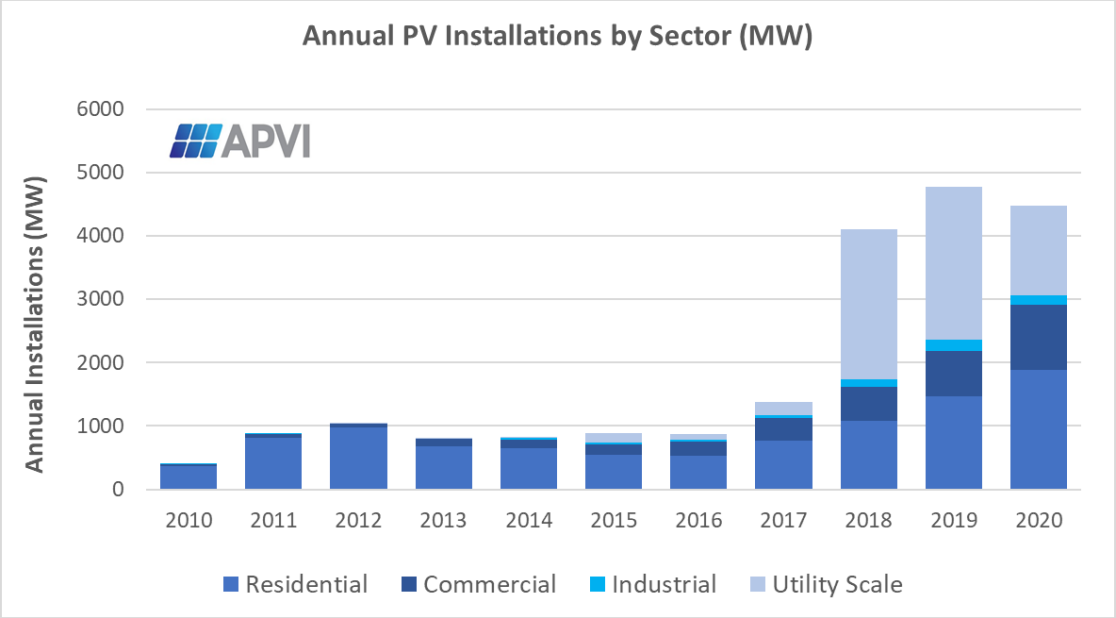

Figure 1. Annual PV installations by sector.

In annual installs, records were broken in all rooftop sectors, shown in Figure 1:

- Residential solar (0-10kW) grew to over 1.8GW in new installs.
- Commercial solar (10-100kW) made up a further 1GW of new rooftop solar.

Large-scale solar contracted compared to a record in 2019, with a total of 1.44GW solar installations each over 5MW registered as installed and connected to the grid in 2020.

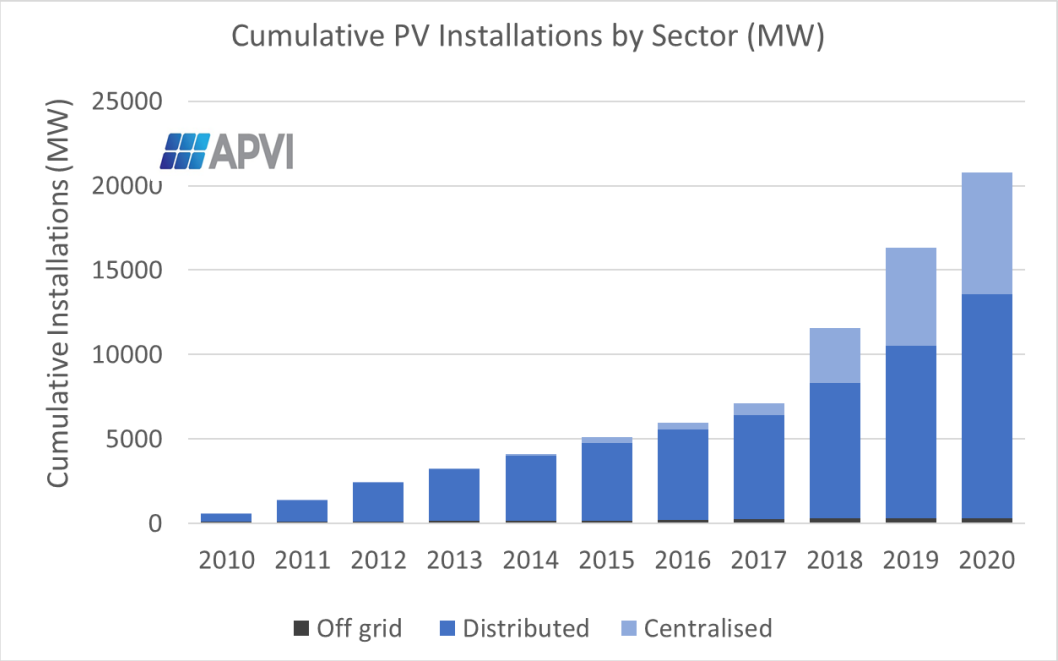

Figure 2. Cumulative Installs in Australia by connection.

Historical trends in total installed capacity are shown in Figure 2, where a few highlights can be seen:

- With 13GW on rooftops, Australia has seen a greater than ten-fold increase over the total installed capacity of 1.3GW in 2011.
- The amount of centralised or utility scale solar connected has also increased ten-fold in just three years - from 740MW in 2017 to 7.4GW in 2020.
- The total installed capacity across all sectors has nearly tripled to 20.8GW in three years
- More solar was installed in 2020 than the total historical installed capacity of 4.1GW to the end of 2014.

The Australian market is very different to most world markets as it has been dominated by rooftop PV. 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 25.7 million people.

At the end of 2020, Australia saw:

- A record 370,000 new rooftop installs (<100kW) – a 40% increase on the previous record of 280,000 set in 2019.
- More than 2.69 million rooftop installations.
- Over 31% of free-standing households across the nation are now powered with a PV system.
- The states of Queensland and South Australia, average close to 40% of free-standing homes, powered by solar - 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.**

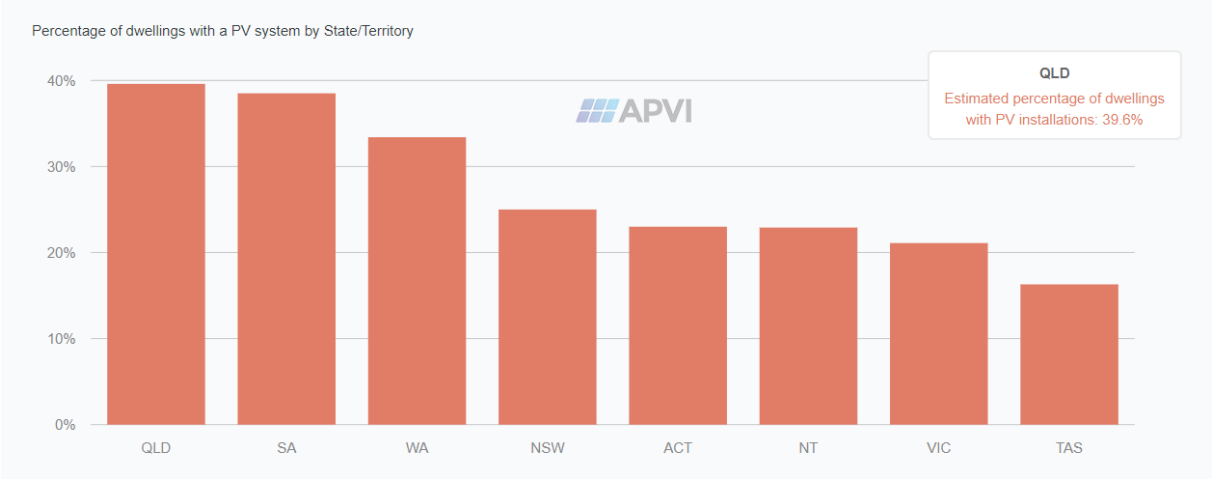

Figure 3. Percentage of residential dwellings with a PV system by state/territory

In 2020, the average rooftop install (<100kW) was 8.0kW, up from 7.1kW in 2019. 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.

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, market growth remains strong, with the correlation shown in **Figure 4.**

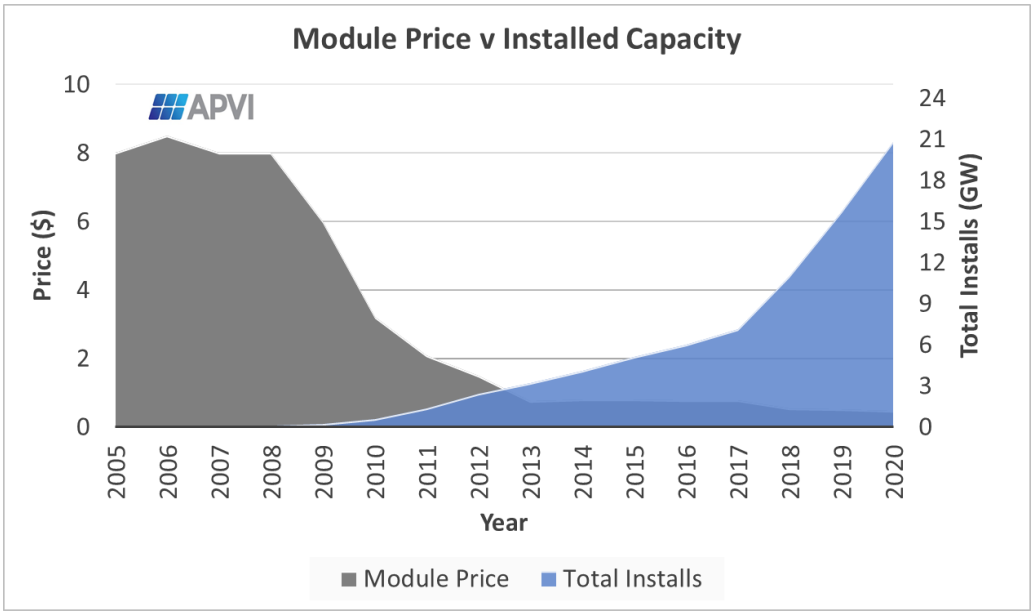

Figure 4. Module Price and Total Installed Capacity in the Australian Market

In contrast to other areas of global leadership, very little building-integrated PV (BIPV) was added in 2020, and no vehicle-integrated PV was known to occur. No additional 'Floatovoltaics' have been recorded beyond the single 100kW installation in 2017.

Australian governments are making a collective move in favour of clean energy, together investing over AUD 7 billion in stimulus measures in the field. The Tasmanian government is leading progress, having achieved 100% renewables and setting the goal of becoming the Battery of the Nation. Amongst these support measures, 2020 saw some advances to policy supportive of battery uptake. In particular, the Victorian (VIC) government's expansion of its Solar Homes program has opened new doors for residential consumers to access battery storage. Most of Australia's states and territories also have some form of subsidy program in place to assist residential and business consumers in accessing energy storage.

One of the most exciting moves in the renewable energy industry in 2020 was the New South Wales (NSW) state government's development of renewable energy zones (REZs), and the accompanying bipartisan support for a significant clean energy package. This move was followed closely by the Queensland (QLD) and VIC governments committing to the development of similar REZs.

Figure 5. 30.21kW capacity ground-mounted PV in rural Australia. Credit: Tindo Solar.

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. In Western Australia (WA), microgrids and stand-alone power systems (SPS) are being tested for wider implementation to better serve remote communities by taking advantage of new renewable energy technologies. These systems make use of PV technology along with energy storage to provide reliable renewable power generation to isolated and fringe-of-grid communities, particularly those in areas prone to extreme weather events.

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.

Looking to the future, Australia's rooftop market is expected to remain strong through to 2030, while larger system install rates are difficult to predict after the premature achievement of the large-scale target in 2019. There remains 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.

Figure 6. Rooftop PV system with 4.13kW capacity. Credit: Tindo Solar.

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 2020 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2020, although commissioning may have taken place later.

1.1 Applications for Photovoltaics

The market for photovoltaics in Australia remains strong, with continued demand from the rooftop sector 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 25.7 million people.

Figure 7. Rooftop solar PV system with 9.9kW capacity. Credit: Tindo Solar.

The market for utility-scale solar saw strong growth to 2020, driven by renewable energy targets. Large scale incentives ended in 2020 and there is increasing risk associated with grid connection and energy policy that is 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 100kW and will continue to 2030. The Large-Scale Renewable Energy Target (LRET) for systems over 100kW concluded in 2020.

Small-scale systems create trading certificates (STCs) which are redeemable as an upfront capital subsidy. Large systems produce generation certificates (LGCs) which are redeemable annually based on energy generated. These incentives come with a reporting obligation and are categorised into small (<100kW) and large-scale systems (>100kW). Within these categories residential solar is typically considered 0-10kW while commercial and industrial installations are rated at 10-100kW. Above 100kW there is a mix of commercial, industrial, and ground mount up to 5MW; installations above 5MW are usually ground mounted.

1.2 Total photovoltaic power installed

The PV power installed in Australia during 2020 is shown in Table 1. This data is collected by the Clean Energy Regulator and cleaned and analysed by the Australian PV Institute. In reading this table the following should be noted:

- Renewable Energy Certificates (RECs) can be created up to one year after system installation, so the data available by the time of publication of this report may not include all 2020 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 2020

		Installed PV capacity in 2020 [MW]	AC or DC
	Decentralized	3,056	DC
	Centralized	1,422	DC
	Off-grid	25	DC
	Total	4,503	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 5MW. There are some large systems less than 5MW that do not record self-consumption.

Through the course of 2020, Australia accredited 372 power stations in total, with 197 producing between 100-500kW, 37 between 500kW-1MW, 29 between 1-5MW, twelve between 5-10MW, seven in the range from 10-100MW, and six 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 2020

			Installed PV capacity [MW]	Installed PV capacity [MW]	AC or DC
Grid-connected	BAPV	Residential	3,056	1,882	DC
		Commercial		1,029	DC
		Industrial		145	DC
	BIPV	Residential			
		Commercial			
		Industrial			
	Utility-scale	Ground-mounted	1,422	1,422	DC
		Floating			
		Agricultural			
Off-grid		Residential	25	25	DC
		Other			
		Hybrid systems			
Total			4,503		DC

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 based on an average from those plant that report the ratio. The average is available for more than 50% of new plant.
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. www.apvi.org.au
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	53.0	6.9	0.8	60.7
2006	60.5	9.0	0.8	70.3
2007	66.4	15.0	1.0	82.4
2008	73.3	29.9	1.3	104.5
2009	83.9	101	2.5	187.4
2010	87.8	479	3.8	570.6
2011	101	1,268	7.4	1,376
2012	118	2,276	21.5	2,416
2013	132	3,070	24.0	3,226
2014	148	3,875	69.0	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	16,320
2020	309	13,309	7,205	20,823

Table 5: Other PV market information

	2020		
Number of PV systems in operation in your country	Residential	2,693,035	2,515,958
	Commercial		175,779
	Industrial		1,275
	Utility-scale		23
	Off-grid		
Decommissioned PV systems during the year [MW]		insignificant	
Repowered PV systems during the year [MW]		Unknown	

Table 6: PV power and the broader national energy market

	2019	2020
Total power generation capacities [GW]	66.7	72.2
Total renewable power generation capacities (including hydropower) [GW]	27.6	34.6
Total electricity demand [TWh]	264.4	265.2
New power generation capacities installed [GW]	5.6	5.6
New renewable power generation capacities (including hydropower) [GW]	5.6	5.6
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	22.8	29.1
Total PV electricity production as a % of total electricity consumption	8.3%	11%
Average yield of PV installations (in kWh/kWp)	1,400	1,400

1.3 Key enablers of PV development

Table 7: Information on key enablers.

	Comment	Annual Value	Total Value	Source
Decentralized storage systems	Registered grid connected batteries.	9,323 sites	238MWh	CEC report
Electric cars [#]	This data includes an estimate for Tesla sales, as Tesla does not disclose local sales numbers.	6,900	20,000 +	Electric Vehicle Council (EVC)

Sources:
CEC Report: https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2021.pdf

EVC Report: https://electricvehiclecouncil.com.au/wp-content/uploads/2021/08/EVC-State-of-EVs-2021-3.pdf

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Module price trends (excluding sales tax) by year shown in Table 8. All prices listed are in AUD/W. Module prices are average prices inferred from system prices.

The minimum price quoted achieved in 2020 was <0.30 AUD and was imported.

Table 8: Typical module prices

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
2020	0.3	1.15	0.47

2.2 System prices

Residential and commercial prices are based upon a dataset provided by PV lead generator Solar Choice. The figures reported in the table below are an average price for a rooftops installation of 7kW and are all inclusive for household installation.

Rooftop (small-scale) systems are eligible for an up-front subsidy that is not included in the values tabled below. This subsidy is an incentive, which reduces the price to consumers by a further 45-61c/Wp in 2020 depending on insolation, averaged here at 50c/Wp.

Prices quoted are exclusive of sales tax (GST).

The utility-scale solar market has been growing rapidly since 2014 and prices are coming down rapidly. 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 2020.

The prices for systems connected in 2020 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

Category/Size	Typical applications and brief details	Current prices [AUD/W]
Residential BAPV 5-10kW	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.	1.52
Small commercial BAPV 10-100kW	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.	1.58
Large commercial BAPV 100-250kW	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.	1.44
Industrial BAPV >250kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	1.44
Small centralized PV 1-20MW	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 >20MW	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

Table 10: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV system 5-10kW **[AUD/kW]**	Small commercial BAPV Grid-connected, roof-mounted, distributed PV systems 10-100kW **[AUD/kW]**	Large commercial BAPV Grid-connected, roof-mounted, distributed PV systems 100-250kW **[AUD/kW]**	Centralized PV Grid-connected, ground-mounted, centralized PV systems 10-50MW **[AUD/kW]**
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
2019	1.6	1.58	1.44	N/A
2020	1.52	1.58	1.44	N/A

2.3 Cost breakdown of PV installations

The cost breakdowns of a typical 5-10kW roof-mounted, grid-connected, distributed PV system on a residential single-family house and of a typical >10MW grid-connected, ground-mounted, centralized PV system at the end of 2020 are presented in Table 11.

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 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 costs that have been reported within each segment. Summing the minimum costs do not give an accurate minimum system price.

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

Cost category	Average [AUD/W]	Low [AUD/W]	High [AUD/W]
Hardware			
Module	0.47	0.3	1.15
Inverter	0.25		
Mounting material	0.21		
Other electronics (cables, etc.)			
Subtotal Hardware	**0.93**		
Soft costs			
Planning	0.59		
Installation work			
Shipping and travel expenses to customer			
Permits and commissioning (i.e., cost for electrician, etc.)			
Project margin			
Subtotal Soft costs	**0.59**		
Total (excluding VAT)	**1.52**		
Average VAT			
Total (including VAT)	**1.52**		
Total (excluding VAT)			
Average VAT			
Total (including VAT)			

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

Table 12: PV financing information in 2020

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

Most 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 13: 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 20GW of solar and a population of 25.7 million, Australia now leads the world in installed solar per capita, with 810W per person. Germany is a close second with 650W of installed solar per capita.

The current 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.

The Australian electricity market is described in more detail in Section 6.

Table 14: Country information

Retail electricity prices for a household [AUD/kWh]	0.20 – 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	25,694,393
Country size [km^2]	7.69 million
Average PV yield in [kWh/kW]	1,400
PV yield value information	This value is a generalised average as conditions vary significantly across Australia.

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 15: Summary of PV support measures

Category	Residential		Commercial + Industrial		Centralized	
Measures in 2020	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	Yes	-	-	-	-	-
Feed-in premium (above market price)	-	-	-	-	-	-
Capital subsidies	Yes	-	Yes	-	-	-
Green certificates	-	-	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 delocalized net-metering	-	-	-	-	-	-
Commercial bank activities e.g., green mortgages promoting PV	Yes	-	Yes	-	-	-
Activities of electricity utility businesses	Yes	-	Yes	-	-	-
Sustainable building requirements	-	-	Yes	-	-	-
BIPV incentives	-	-	-	-	-	-
Other (specify)	-	-	-	-	-	-

3.1 National targets for PV

The Renewable Energy Target (RET) is designed to reduce emissions of greenhouse gases in the electricity sector and encourage the additional generation of electricity from sustainable and renewable sources.

The RET is made up of two parts – the Large-scale Renewable Energy Target (LRET), of 33,000GWh met before 2020, and the Small-scale Renewable Energy Scheme (SRES), with no set target. Detail is provided below.

3.2 Direct support policies for PV installations

3.2.1 The Renewable Energy Target

The Renewable Energy Target works by allowing both large-scale power stations and the owners of small-scale systems to create large-scale generation certificates and small-scale technology certificates for every megawatt hour of power they generate. Certificates are then purchased by electricity retailers (who supply electricity to householders and businesses) and submitted to the Clean Energy Regulator to meet the retailers' legal obligations under the Renewable Energy Target. This creates a market which provides financial incentives to both large-scale renewable energy power stations and the owners of small-scale renewable energy systems.

The RET is funded by cross-subsidy, leveraged upon all electricity consumption except for certain classes of industrial electricity consumers.

Figure 8. Rooftop mounted PV system, 5.4kW capacity installed on a new house in suburban Australia. Credit: Tindo Solar.

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 100kWp 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.

Small-scale technology certificates can be created following the installation of an eligible system and are calculated based on the amount of electricity a system produces or replaces (that is, electricity from non-renewable sources). Generally, householders who purchase these systems assign the right to create their certificates to an agent in return for a lower purchase price. The level of this benefit differs across the country depending on the level of solar energy.

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 9. 13.14kW capacity rooftop PV system installed on a roof overlooking bushland and the city. Credit: Tindo Solar.

Large-scale Renewable Energy Target (LRET)

The LRET, covering large-scale renewable energy projects like wind farms, commercial-scale solar and bioenergy includes legislated annual targets had an initial target of 41,000GWh, reduced in 2015 to 33,000GWhr, which was achieved in late 2019 ahead of the 2020 target. Liable entities met 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 2020 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's purpose is to improve the competitiveness of renewable energy technologies and increase the supply of renewable energy through innovation that benefits 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.

ARENA has been directly responsible for many renewable energy success stories including:

- World-leading solar photovoltaic (PV) research, principally through ongoing funding of the Australian Centre for Advanced Photovoltaics (ACAP), including, in 2020, the first payments under the AUD 19 million Infrastructure Project Funding Round for research infrastructure to maintain Australia's world-class solar PV research program.
- Support for innovation, trials and pilots in demand response, virtual power plants and energy engagement to help pave the way for a better understanding of consumer behaviour and identify opportunities to reduce consumer costs, and
- Co-investment in large-scale solar and batteries to de-risk large projects, to enhance the reliability of supply and to provide support for power system security as Australia transitions to a low emissions energy future.

[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 more than AUD 1 billion supporting investments with a combined value of AUD 4.2 billion in the year to 30 June 2020

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.

2020 project commitments related to solar photovoltaics include:

- Hayman and Daydream solar farms 21.2m in debt finance,
- Jemalong and Kidston large scale solar farms 20m debt facility,
- Hornsdale 50m, debt finance for a large-scale battery storage facility, and
- Kiamal Solar Farm 11m investment in synchronous condenser for grid support.

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.

3.2.2.4 Australian Energy Market Operator (AEMO)

AEMO develops and maintains an Integrated System Plan; a whole-of-system plan that provides an integrated roadmap for the efficient development of the National Electricity Market (NEM) over the next 20 years and beyond. The 2020 release reports an expectation that distributed energy will provide as much as 22 per cent of total underlying annual energy consumption by 2040, with more than 26 GW of additional renewable energy required to replace coal-fired generation and a further 6-19GW of new dispatchable resources required in the form of utility scale pumped hydro, fast response gas-fired generation, battery storage, demand response and virtual power plants.

3.2.2.5 Technology Investment Roadmap developed by the Commonwealth Department of Industry, Science, Energy and Resources (DISER).

The Technology Investment Roadmap is a strategy to accelerate development and commercialisation of low emissions technologies. These include energy storage to assist cost effective, reliable low emission electricity, hydrogen, carbon capture and storage, soil carbon sequestration, biofuels, resources, and energy exports to reduce emissions while strengthening our economy.

Figure 10. A rooftop installed PV system in suburban Australia. Credit: Power Saving Solutions.

3.2.3 Solar for Communities

In 2020, the Energy Efficient Communities Program – Community Energy Efficiency and Solar Grants 2020 provided community groups with grants up to AUD 12,500 for energy efficient equipment, energy generation and storage systems, and energy audits.

3.2.4 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.

[Source: https://www.energy.gov.au/rebates]

3.2.4.1 Direct Subsidies

Most state governments are now offering some type of incentive for solar plus battery installations or to add a battery to an existing solar system:

- The NSW Government is offering up to 3,000 free 3kW solar installations for low-income households.
- The ACT Government offers an AUD 2,500 incentive for low-income households to invest in rooftop solar PV panels.
- The Victorian Government Solar Homes assists landlords and renters with a rebate of up to AUD 1,850 to install solar PV panels.
- The Victorian Government Solar PV rebate offers 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 Victorian Government Small Business Rebate offers up to AUD 3,500 to reduce the upfront cost of installing a small-scale solar PV system up to 30kW.

3.2.4.2 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 15. Most 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.

Figure 11. Rooftop PV system in a residential area. Credit: Power Saving System

Table 16: 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	5kW	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	30kW	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	30-200kW	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	5kW (city) 10kW 1Ø 30kW 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 Sept. 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					

3.2.5 Local Government Support

In 2020, 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.

3.2.6 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 17: Summary of self-consumption regulations for small private PV systems in 2020

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 with a change to 5 mins pending.
	6	Geographical perimeter (use of the public or private grid)	Feed-in-tariff payments only, no use of grid possible for trading
Other characteristics	7	Regulatory scheme duration	Premium FiTs differ between jurisdictions, and standard FiTs are revised annually.
	8	Third party ownership accepted	Yes (for ex-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.

The state of South Australia (SA) with 1.77 million residents has sufficient rooftop solar to meet the entire states demand at times. To manage the significant volumes of rooftop solar, to allow for further uptake and to help stabilise the grid by allowing the market regulator to better match supply with demand, new regulations have been introduced for all new rooftop solar installations.

From late September 2020, any new rooftop solar systems must also be capable of remote disconnection and reconnection and inverters must have internet capability and an onboard communications port and offer low voltage ride-through.

More information can be found here: https://www.gses.com.au/south-australian-regulations-for-new-solar-power-systems/

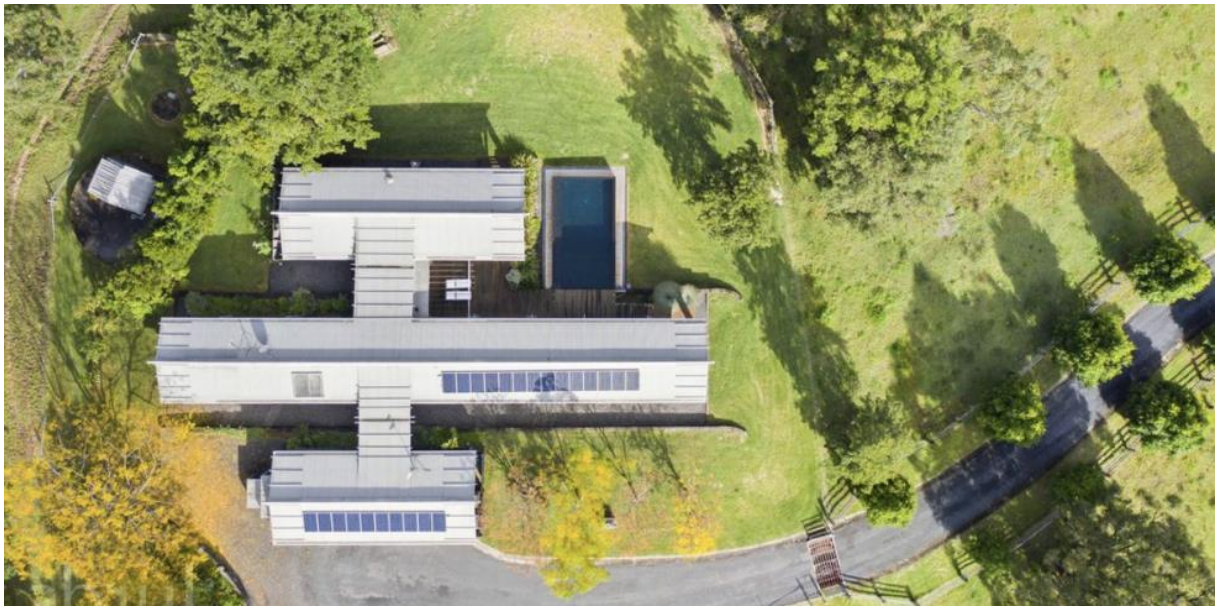

Figure 12: **Rooftop solar panels on a rural property. Credit: APVI.**

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 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:

- Haystacks 1MW solar garden, planned for NSW. Members have options to purchase a solar garden plot, through which each 3kW receives an on-bill credit each quarter from the sale of electricity from the Solar Garden.
- The Victorian government, through the Renewable Energy Jobs Fund, is providing AUD 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 funded seven projects under a Regional Community Energy fund awarding AUD 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 520kW solar installation on the Sydney International Convention Centre.
- Community battery projects are of increasing interest to complement existing household batteries and to allow more solar energy to be stored locally, with different tariff arrangements and business models under investigation.

The Community Power Agency serves as a collective knowledge hub and proponent for community power models. For more information: https://cpagency.org.au/

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 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, where the LGCs being surrendered to the Clean Energy Regulator 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 40MW of capacity from three solar farms, and another auction was announced in 2019, which includes the need for 20MW/40MWh of battery storage. As of June 2021, the ACT Government has run 5 reverse auctions, resulting in contracts for 840MW of contracts.

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. Victoria has not had a follow-on auction since the 929MW allocation in 2018.

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. Queensland has not had a follow-on auction since the 400MW contracted in 2019.

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 2020. There are no agriculture-specific large-scale solar plants. Two GW-scale solar projects are under development:

- The Australian-ASEAN Power Link in the Northern Territory, which is projected to be the world's largest solar farm and battery storage facility with 10GW of solar and an under-sea cable delivering power into Southeast Asia.
- The Asian Renewable Energy Hub in Western Australia, which will see 26GW of wind and solar proposed to provide energy to large energy users in the Pilbara region, including new and expanded mines and downstream mineral processing. The bulk of

the energy will be used for large scale production of green hydrogen products for domestic and export markets.

3.7 Social Policies

In 2020 several measures for solar for low-income households were maintained by State Governments:

- The NSW Government is offering the Solar for Low Income Households program to 3,000 selected households, with the government installing a 3kW rooftop solar 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 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 AUD 1,850 rebate is also available for community housing.
- The ACT Government provides the Solar for Low Income Households Program where eligible participants can access a subsidy of up to 50% of the total cost of a solar system.
- The Queensland government offered around 1,000 rebates of up to AUD 3,500, 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.

Figure 13. Installing a rooftop PV system in suburban Australia. Credit: Power Saving System

3.8 Retroactive 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 Distributed Energy Resources (DER) 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 22,000 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 5,000 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 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, 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 4,174 for 17,500 household battery rebates over the next three years.
- 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 4,000) 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.

Figure 14. A rooftop PV system with capacity of 6.05kW. Credit: Tindo Solar.

3.9.3 Support for electric vehicles and vehicle-integrated photovoltaics (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% procurement target for hybrid and electric vehicles by 2023, with at least 10% 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 2,000km 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 2,400 vehicles per year and creating up to 500 jobs.
- The roll out of Australia's fastest electric vehicle charging stations 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 110MW and more than 1,800MW 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 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 90MWh out of every 100MWh 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 Other Support Measures

3.9.5.1 State-Based Emission Reduction Targets

State and territory governments are driving the Australian energy market's progress in emissions reductions. All states and territories except Western Australia now have strong renewable energy targets or net zero emissions targets in place. Both the ACT and Tasmania are now powered by 100% renewables, and in addition now Tasmania plans to decarbonise their whole electricity and energy system with a 200% renewables target.

This contrasts both with the position that the Australian Commonwealth Government has taken of developing a Roadmap for low emissions technologies, and with the Prime Minister's stated goal to "reach net-zero emissions as soon as possible, and preferably by 2050". The state-based targets that are in place are broadly consistent with the level of renewable energy needed across Australia by 2030 to contribute to keeping global temperature rise below two degrees Celsius (2°C).

3.9.5.2 Renewable Energy Zones (REZs)

State based Renewable Energy Zones (REZs) aim to motivate regional investment in generation from wind and solar, in storage (e.g., batteries), and in high-voltage poles and wires.

- Queensland has announced plans for three REZs with 60GW of projects proposed from the market.
- NSW has announced plans for a targeted AUD 32 billion investment in five REZs, calling for 12GW of renewable energy to be built and an additional 2GW for storage, with bipartisan support.
- Victoria has announced an AUD 1.6 billion plan for clean energy including the biggest battery in the southern hemisphere.

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.

Financing for large scale projects from government funds in 2020 was by way of recuperable grants or equity.

Figure 15. An array of ground mounted solar panels alongside property in rural Australia. Credit: Tindo Solar.

4 INDUSTRY

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

Australia has no solar feedstock, ingot or wafer production.

Table 18: Silicon feedstock, ingot and wafer producer's production information for 2020

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 through parent company Cool or Cosy.

2020 saw a 40% increase in Tindo's wholesale business and in early 2021, secured funds to expand manufacturing capacity to 150MW/yr.

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

Table 19: PV cell and module production and production capacity information for 2020

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**

Figure 16. Tindo Solar facility at Mawson Lakes, Adelaide. Credit: Tindo Solar.

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 system 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 3kW of continuous power (5kW peak) and up to 8kWh 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.

Figure 17. 2.2MW Large Scale PV array Port Bonython roll out of 5B Maverick Technology. Image courtesy of 5B

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. They 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, except for 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 18. A team installing rooftop PV amongst trees. Credit: Tindo Solar.

5.1 Labour places

Through 2020 there were an estimated 25,340 full-time equivalent (FTE) labour places in the PV industry, increasing by 7,250 places from 2019. 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 with funding to the end of 2030.

Table 20: Estimated PV-related full-time labour places in 2020

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	90
Distributors of PV products and installations	25,000
System and installation companies	
Operation and maintenance companies	
Electricity utility businesses and government	
Total	**25,340**

5.2 Business value

Table 21: Rough estimation of the value of the PV business in 2020 (VAT is excluded)

Sub-market	Capacity installed [MW]	Average price [AUD/W]	Value	Sub-market
Off-grid				
Grid-connected distributed	3,056	1.6	4,930,000,000	4,930,000,000
Grid-connected centralized	1,422	1.5	2,275,000,000	2,275,000,000
Value of PV business in 2020				7,205,000,000

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, 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 400 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.

Figure 19. A PV system mounted on a residential rooftop. Credit: Tindo Solar.

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 several 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 considering these developments, are currently themselves restricted by their own governance arrangements and reporting structures. Nevertheless, 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.

Several 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.

Figure 20. Residential solar. Credit: APVI.

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 over 150 local government organisations, over 500 cities and towns representing 60% of the population. The CPP has a commitment to clean energy, representing almost 60% of the Australian population.
- The Melbourne Renewable Energy Project (MREP) 1 and 2: a consortium of local government, educational institutions, and private companies that successfully purchased 88h and 110h per year (respectively) of energy from new large-scale renewable energy facilities. Together, MREP 1 and 2 contributed to reducing the equivalent of 5% of Melbourne's emissions.
- Solar My School, a Council-run program initially founded by three Sydney Councils, now involves over 160 schools across Sydney and regional NSW. This program aims to help schools install solar with support through the whole process.

Other examples of broader programs used by, and in some cases established 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.
- Community Groups and Energy Foundations including the Australian Energy Foundation (formerly Moreland Energy Foundation) and the Yarra Energy Foundation.

6.4 States and Territories

In 2020, state governments continued to progress measures that would support the deployment of renewable energy, by identifying areas of opportunity, 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.

Collectively Australian governments are investing over AUD 7 billion in clean energy stimulus measures, with the Tasmanian government leading progress having already achieved 100% renewables and South Australia following with its 500% renewables goal.

Figure 21. 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

Despite the challenges faced through 2020 posed by the COVID-19 pandemic, this year was another strong one for solar installs across the Australian market. The year saw a total install capacity of 4.5 taking the country to a total capacity of 20.8, nearly doubling the total capacity from 2018. In total, small-scale and large-scale solar combined contributed to 35.8% of national renewable energy generation and met around 9.9% of total electricity demand in Australia.

The small-scale solar sector (<100kW) had an incredible year, finishing its fourth straight record-breaking year with more than 3 of installed capacity, and surpassing the 2012 record for systems installed with over 370,000 new systems added. Local government and community initiatives and the decline in module and small-scale system prices have continued to drive this market through what was otherwise a challenging year. Australia continues to build on its high per-capita rooftop install rate with over 30% of free-standing households now generating power from their rooftop, with well over 50% in many urban areas. At the end of 2020 there were 2.7 million household solar installations across the country, with rooftop solar alone providing 520 W per person in Australia and a world-leading 810 W per person when utility scale solar is included.

With the end of the Large-scale Renewable Energy Target in 2020, Australia saw a decrease in support for the utility-scale solar market alongside facing the challenges posed by the global pandemic. These factors contributed to a decrease in large-scale installations (>100kW) from 2019, however, the 1.4 installed capacity across 2020 was still double the total capacity installed between 1992 – 2017. This continued rapid escalation in the large-scale sector is maintaining pressure on expertise, market, regulation and infrastructure. Australia is now faced by challenges in managing storage, low minimum demand maintaining stability of the electricity market when production and consumption become unaligned.

Figure 22. Large residential PV installation.

Credit: Suntech Pty Ltd.

To counter some of the trials arising from a rapidly growing market, Australian state governments are continuing to invest in a future of clean energy and prioritising the development of storage and connection infrastructure. The Tasmanian government has reached 100% renewable energy already, SA following with their goal of 500% renewables, and exciting progress made in NSW, VIC and QLD committing to the development of several REZs.

7.2 Prospects

Building off a strong base, Australia is likely to see ongoing growth in the solar PV market and the electricity system is set to adapt and develop to meet increasing decentralisation.

- Continuing support from Small-scale Technology Certificates through to 2030 will provide ongoing momentum for rooftop solar, with strong growth expected in commercial and industrial markets. Australia-wide supermarket chains Woolworths and Aldi both had big solar years, installing large numbers of rooftop systems across their locations through 2020 to reach respective totals of 150 and 250 stores with rooftop solar.
- State-based government competition for investment in Renewable Energy Zones, including related infrastructure investments will drive large-scale investment in both solar and wind by providing a roadmap, reducing risk and increasing investor confidence.
- The Commonwealth Government has developed a Low Emissions Technology Roadmap and conducts annual reviews to provide Low Emissions Technology Statements that currently identify a path to a hydrogen economy and low emissions minerals processing that will be reliant on a low cost of energy only possible through a massive roll-out of solar PV.
- The Commonwealth Government has extended the funding of the Australian Renewable Energy Agency (ARENA) for a further ten years with 1.6 BAUD s to support the global transition to net zero emissions by accelerating the pace of precommercial innovation, to the benefit of Australian consumers, businesses and workers.
- The energy market operator (AEMO) is designing for 100% renewable penetration across the market by 2025, with instances already with the entire state of South Australia (SA) entirely powered by renewables.
- New infrastructure connecting SA-NSW and VIC-NSW grids to help stability of electricity market are under development. Project EnergyConnect passed significant milestones on the way to approval through 2020 (and has now been approved for construction as of mid-2021). The further development of REZs and AEMO's updated ISP has started to paint a clearer picture of the ways that the country can adapt to the challenges posed by phasing out existing coal-based infrastructure and moving towards renewable energy.
- Network operators are looking at setting up autonomous micro and mini-grids and generator/retailers are investing in virtual power plants (VPPs).
- Storage capacity set to increase with large-scale storage project approvals and the increasing competitiveness of small-scale, behind the meter storage options.
- Big vison projects are under development to support renewable energy exports including Sun Cable's plans for 13GW of solar in the Northern Territories delivering power by under-sea cable into Southeast Asia and the Asian Renewable Energy Hub with up to 26GW of wind and solar to support hydrogen exports.

The ongoing investment in renewables will present market and engineering challenges that will need to be met by policy and regulatory change, by a redesign of tariffs to incentivise use of low-cost, low-emissions power, investments in storage, in transmission and distribution.

New benchmarks continue to be set, with South Australia achieving 100% renewable energy over a 24 hour period in late September 2021.

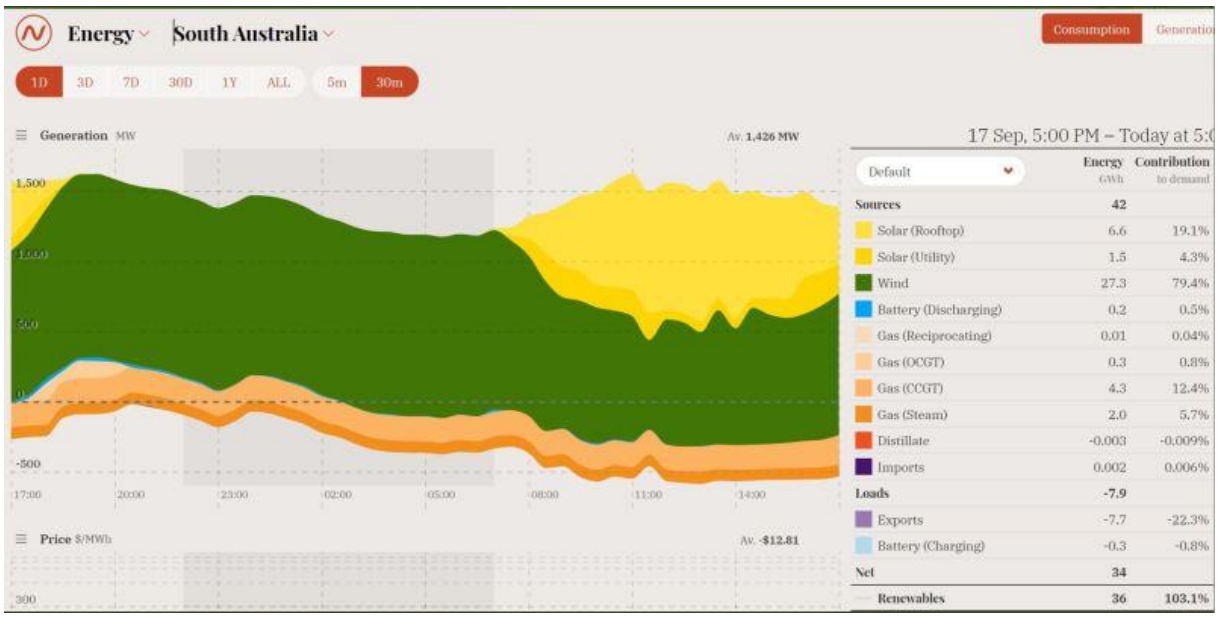

Fig X: The state of South Australia is 100% renewables for a 24hour period for the first time on Sept 20 2021. Source: https://opennem.org.au/

Challenges include grid and connection constraints for utility scale solar and changing economics as Marginal Loss Factors (MLF) are adjusted to reflect co-incidence of supply and connection and distance to load.

Technology is moving faster than policy and regulation and to maintain the rapid pace of renewable energy deployment, Australia needs to support national electricity market reforms and provide policy certainty to support the needed electricity infrastructure investments and additional electricity transmission, energy storage and demand response mechanisms.

END

This report was prepared by the APVI
with support from ARENA and APVI members
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