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

2022

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 2022. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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COVER PICTURE

Happy Valley, South Australia - 12.8 MWp powering a water treatment plant. Image provided by 5B Pty Ltd, Australia

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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 Olivia Coldrey (APVI) and the ExCo Alternate is Renate Egan (ACAP, UNSW).

Australian participation in the IEA PVPS tasks is managed by the APVI. The management of 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 and Renate Egan (UNSW)
- Task 12 Sustainability. Expert is Rong Deng (UNSW)
- Task 13 Performance and Reliability. Expert is David Parveliet (Murdoch)
- Task 14 High Penetration PV. Expert is Iain Macgill (UNSW) and Niraj Lal
- Task 15 Building Integrated PV. Expert is Rebecca Yang (RMIT)
- 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)
- Task 18 Off Grid and Fringe of Grid. Expert is Chris Martell (GSES)

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) slowed through 2022, in both centralised (utility scale) and decentralised (rooftop) installs, with 4.2 GW of new solar registered, a 15% decline on 2021 installations of 5 GW, with a significant drop in both residential rooftop (-23%) and utility scale installs (-20%).

Additional annual rooftop installs on residential, commercial and industrial roofs was 2.8GW in 2022, after 3 GW in 2021. In 2022, commercial and industrial roofs exceeded residential rooftops for the first time, due largely to the drop in residential installs, with 1.36 GW on residential roofs and 1.47 GW on commercial and industrial roofs.

New centralised, utility scale solar connections dropped to the lowest annual install rate for five years with less than 1.4 GW annual installs, off a high of 2.4 GW in 2018 and 2019, due to the end of the large-scale systems support in 2020 under the Commonwealth Government's support for Large Scale Solar under the Renewable Energy Target, challenges with connection to the grid and limited incentives or support mechanisms to encourage long-term investment.

The total installed capacity at the end of 2022 reached 30 GW, meaning Australia has a remarkable, and world leading installation rate of over 1.2 kW of solar per person, ahead of the Netherlands and Germany with around 1 kW/person [https://iea-pvps.org/wp-content/uploads/2023/04/IEA_PVPS_Snapshot_2023.pdf]. However, should the drop in installs to continue, Australia can be expected to lose this leadership position.

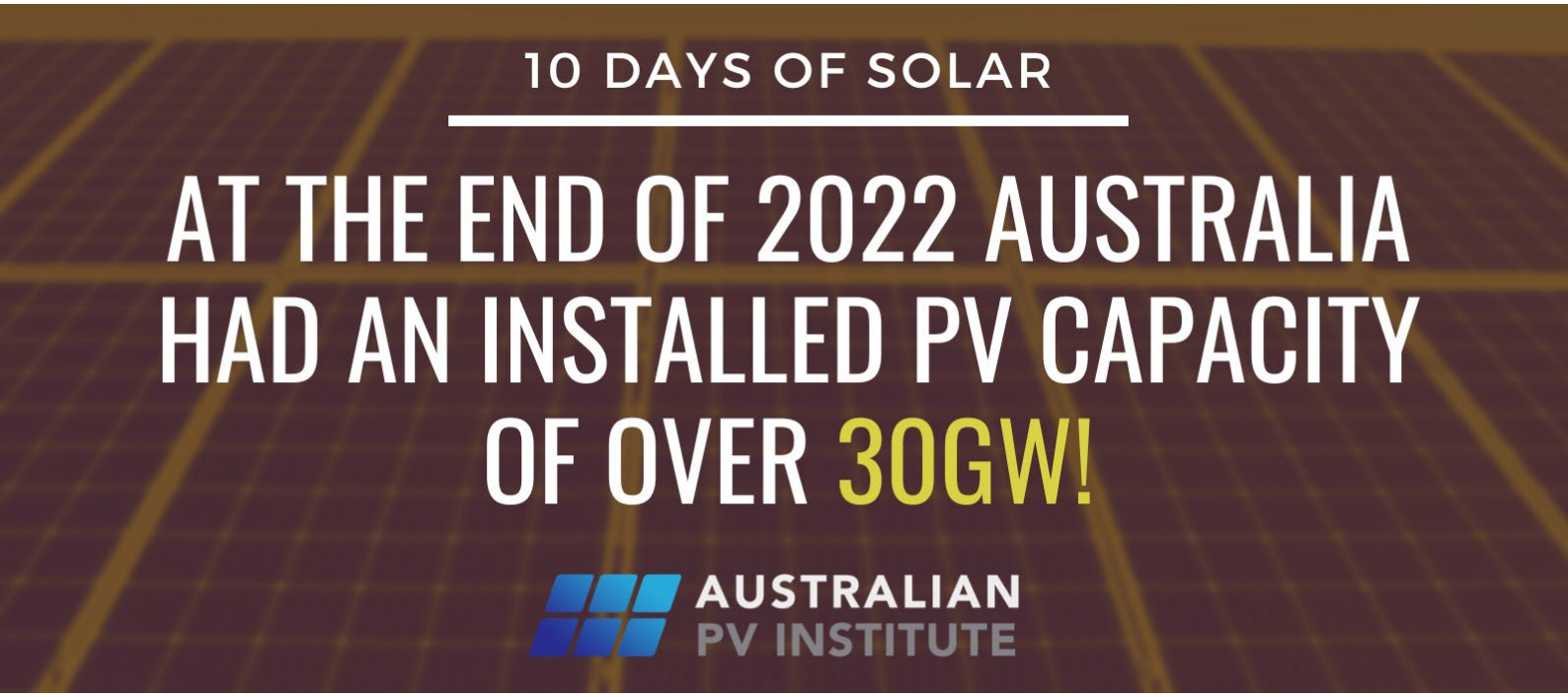

Image: APVI Social Media campaing at end 2022, Ten Days of Solar.

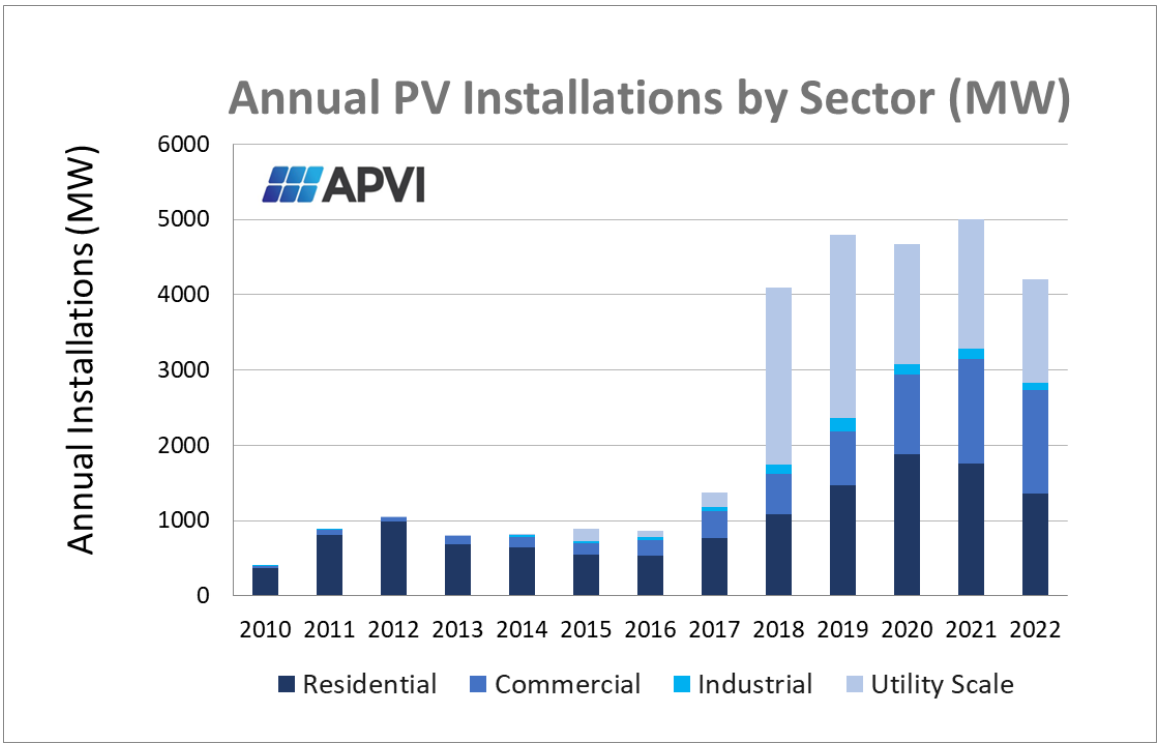

Figure 1. Annual PV installations by sector.

By end 2022, the average penetration of solar on free-standing homes reached 37%, and the average size of new installations remained high at over 8.7 kW.

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

- In ten years, since 2012, the install rate has grown more than four-fold, from 1 GW/year in 2012 to 4.2 GW a year in 2022.
- More solar was installed in the single year 2022 (4.2 GW) than the sum of all installations to the end of 2014 (4.1 GW)
- With close to 20 GW on rooftops (residential, commercial, and industrial), Australia has continued the trend of doubling every three years with 10.4GW at end 2019 and 5.3GW at end 2016.

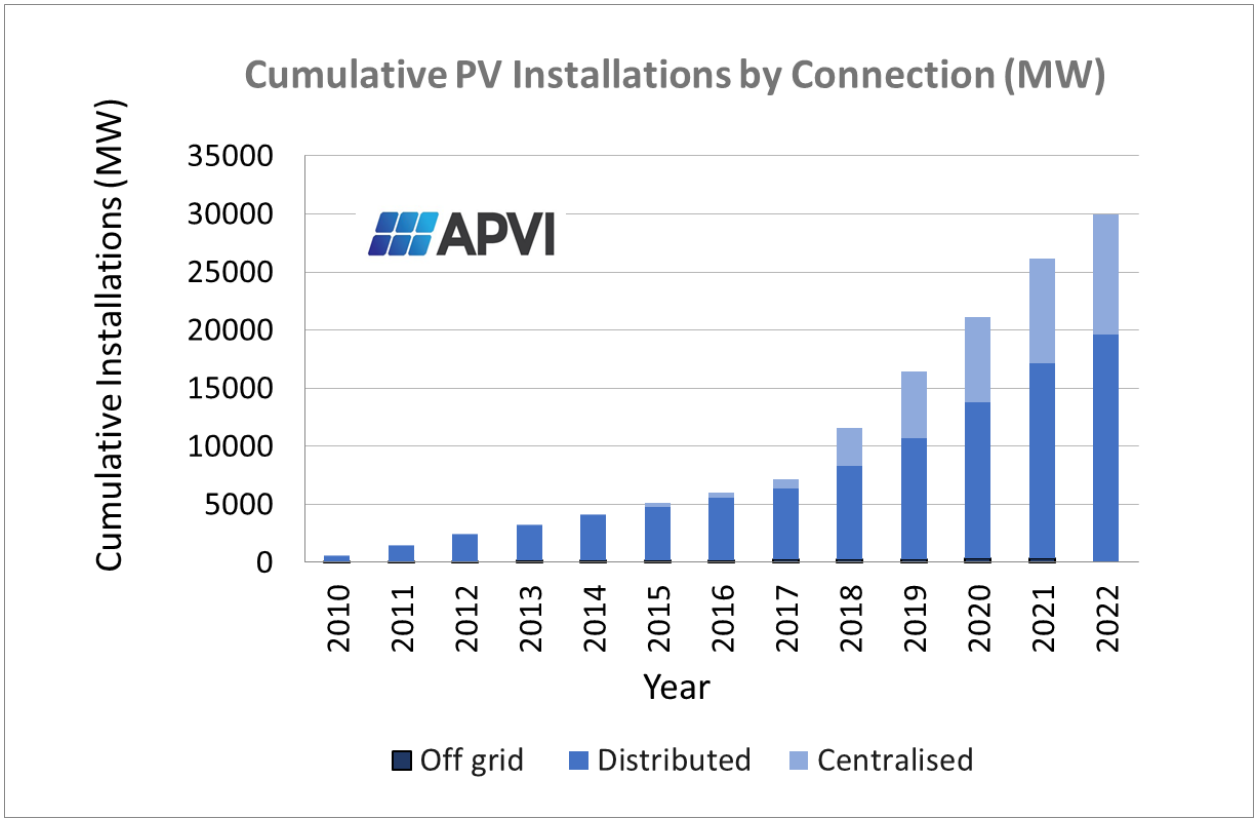

Figure 2. Cumulative Installs in Australia by connection.

The Australian market is very different to most world markets as it has been dominated by rooftop PV rather than utility-scale systems. 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 26 million people.

At the end of 2022, Australia saw:

- The total number of rooftop-installs exceed 3.3 million rooftop installations.
- Over 37% 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.** Highlighting an average penetration in the states of Queensland and South Australia close to 45%, with populations of 5.2 million and 1.8m respectively. Tasmania, with a relatively low average insolation of 3.67kWhrs per year has 20% of free-standing homes powered by solar PV.

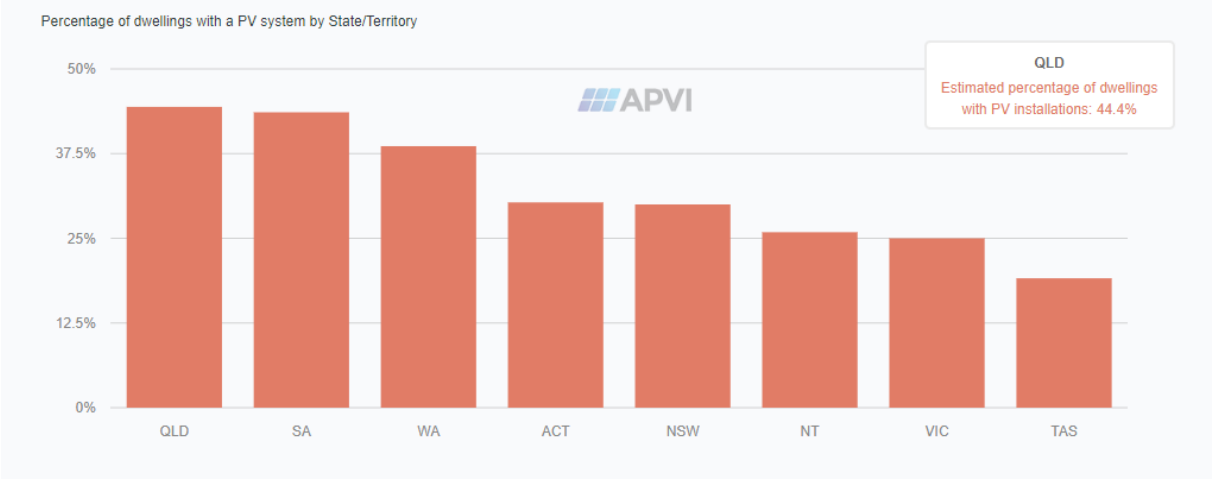

Figure 3. Percentage of residential dwellings with a PV system by state/territory

In 2022, the average rooftop install (<100kW) was 8.7 kW, similar to 2021 at 8.8kW. The average PV system size has grown steadily in the ten years since 2012, when systems averaged less than 3kW. Over that time, the price of solar dropped, the number of commercial and industrial rooftops grew and electricity prices increased.

Technology and manufacturing improvements led to a steep drop in prices between 2007 and 2013. Price then continued to drop, but less dramatically until 2022, when compounding factors of supply chain challenges and growing demand has led to the first significant price increase in years. Evidence is that the situation is improving over 2023, with a drop in the price of silicon itself flowing through to lower module prices.

AgriPV has grown in interest over recent years, with a number of case-study plants built over the last few years, typically around sheep grazing. In addition, there is significant interest in massive PV plants of 10-30GW for industrial use and electricity export, with a number of projects in the planning stage. In contrast, very little building-integrated PV (BIPV) was added in 2021, and no new 'Floatovoltaics' have been recorded beyond the single 100kW installation in 2017.

Policy settings remain a challenge, with issues around connection approvals, congestion management and fragmentation with access arrangements, adding cost and risk to grid scale projects.

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, 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 system technologies. These systems make use of PV technology along with energy storage and advanced management systems to provide reliable renewable power generation to isolated and fringe-of-grid communities, particularly those in areas prone to extreme weather events.

Looking to the future, Australia's rooftop market is expected to remain strong through to 2030, with increasing interest due to price pressures related to supply of coal and gas resulting from the Russian invasion of the Ukraine and increasing reliability issues with old cold-fired plant facing decommissioning in the next decade.

For large scale solar, there is a firm pipeline of projects, supported by state-based initiatives, with all Australian states now having zero-carbon targets by 2050 and plans for Renewable Energy Zones. A change of Federal government in Australia in mid-2022 led to an acceleration in commitments to net-zero emissions that is expected to result in increased investor confidence and growth in the solar PV sector. Some large prospective projects, in support of energy exports, green-hydrogen and green-minerals processing could result in a market significant boost, with each of the prospective projects positioned to add 4 GW per year in demand if actioned.

Image: 30 MW King of the Hills Solar Farm Image provided by 5B Pty Ltd.

1 INSTALLATION DATA

The PV power systems market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components. 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 2022 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2022, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

Unlike most other markets, Australian solar installations are dominated by rooftop demand, supported by a successful government incentive that delivers an upfront capital cost reduction and will run until 2030. Over 30% of Australian free-standing homes are now powered by solar, and an estimated 15% of total electricity demand, nationally, is met by solar energy.

The commercial and industrial rooftop market remains strong across the nation, and the demand for rooftop solar has kept Australia in the top ten markets world-wide for photovoltaics by both annual installs and total installed capacity since records started (https://iea-pvps.org/annual-reports/), a remarkable outcome for a country of only 25.7 million people. The utility scale solar market grew with the benefit of incentives through until 2020. With the removal of incentives, the utility scale market initially contracted and has averaged 1.5GW/annum over the last three years.

There are only small activities that target BIPV, floating PV and VIPV, typically only at research or demonstration scale. AgriPV is however of growing interest with several trials underway, largely involving the grazing of sheep under the array.

At times over 2022, in the state of South Australia, with a population of 1.77 million, rooftop solar alone has been sufficient to power the state and excess power from rooftop and large scale solar was exported to neighbouring states for over the four hours around mid-day (https://reneweconomy.com.au/rooftop-solar-meets-all-local-network-demand-in-south-australia-for-more-than-five-hours/).

1.2 Total photovoltaic power installed

PV connected to the grid in Australia has benefitted from incentives and support from the 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. Data is collected by the Federal Governments Clean Energy Regulator.

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 typically 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. The STC system will run to 2030, with an annual reduction in the support. The LGC system is closed, with certificates to continue to be redeemed and traded for some time.

Table 1: Annual PV power installed during calendar year 2022.

		Installed PV capacity in 2022 [MW]	AC or DC
	Decentralized	2,828	DC
	Centralized	1,377	DC
	Off-grid	34	DC
	Total	4,239	DC

Image: 1,905 Suntech solar panels at a total capacity of 380kW on the roof of the Sydney Theatre Company. Image provided by Suntech.

Table 2: PV power installed during calendar year 2022.

			Installed PV capacity [MW]	Installed PV capacity [MW]	AC or DC
Grid-connected	BAPV	Residential	2,828	1,360	DC
		Commercial		1,375	DC
		Industrial		93.9	DC
	BIPV	Residential			
		Commercial			
		Industrial			
	Utility-scale	Ground-mounted	1,377	1,377	DC
		Floating			
		Agricultural			
Off-grid		Residential	34	34	DC
		Other			
		Hybrid systems			
Total			4,239		DC

Table 3: Data collection process

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	
Is the collection process done by an official body or a private company/Association?	Official
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] (including large hybrids)	Grid-connected distributed [MW] (BAPV, BIPV)	Grid-connected centralized [MW] (Ground, floating, agricultural…)	Total [MW]
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	303	10 396	5 701	16 400
2020	330	13 476	7 285	21 101
2021	361	16 760	9 008	26 129
2022	395	19 588	10 385	30 368

Small changes have been made to historical values reflecting changes in the source data. Installs can be reported as much as a year later.

Table 5: Other PV market information

		2022
Number of PV systems in operation in your country	Residential	3 019 411
	Commercial	358 250
	Industrial	1 498
	Utility-scale	150
	Off-grid	
Decommissioned PV systems during the year [MW]*		Unknown
Repowered PV systems during the year [MW]		Unknown

Table 6: PV power and the broader national energy market

	2021	2022
Total power generation capacities [GW]	267.4	267.4
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	36	42

These figures remain unchanged since 2022 as the data is yet to be updated.

1.3 Key enablers of PV development

Table 7: Information on key enablers.

	Description	Annual Volume	Total Volume	Source
Decentralized storage systems	Grid connected batteries registered	21 409 residential units, averaging around 7kWh	65 766 residential units, averaging around 7kWh	CER data for count :https://www.cleanenergyregulator.gov.au/DocumentAssets/Pages/State-data-for-battery-installations-with-small-scale-systems.aspx
Residential Heat Pumps [#]		423 075		https://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/Agents-and-installers/Small-scale-systems-eligible-for-certificates/Register-of-solar-water-heaters
Electric cars [#]		33 410	83 000	https://electricvehiclecouncil.com.au/
Electric buses and trucks [#]				
Other (up to you)				

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

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
	[$ /W]	[$ /W]	[$ /W]
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
2021	0.3	1.15	0.55
2022	0.35	1.3	0.57

Average price, inferred from system prices.

- The minimum price that has been achieved in 2022 was from imported panels.
- Module prices remain high due to supply chain challenges and increased shipping costs

2.2 System prices

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

Category/Size	Typical applications and brief details	Current prices [$ /W]
Off-grid 1-5 kW	A stand-alone PV system is a system that is installed to generate electricity to a device or a household that is not connected to the public grid.	NA
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	1.50
Residential BIPV 5-10 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity to grid-connected households. Typically, on villas and single-family homes.	NA
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.	1.55
Small commercial BIPV 10-100 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	NA
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.	1.55
Large commercial BIPV 100-250 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	NA
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	1.50
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	NA
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.	NA

The figures reported in the table above are an average price for a rooftops installation of 9kW excluding subsidies which reduce the system cost by a further 40c/W (on average), depending on insolation.

Residential and commercial prices are based upon a dataset provided by PV lead generator Solar Choice. Small-scale systems are eligible for an up-front subsidy that is excluded in the table below. Prices quoted are also exclusive of sales tax (GST).

Pricing is all inclusive for rooftop solar mounts including installation, connection, and registration.

Table 10: National trends in system prices for different applications

Year	Residential BAPV (Grid connected, roof-mounted, distributed PV systems 5-10 kW [$/kW]	Small commercial BAPV (Grid connected, roof-mounted, distributed PV systems 10-100 kW [$/kW]	Large commercial BAPV (Grid connected, roof-mounted, distributed PV systems 100-250 kW [$/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	
2015	2.45	2.07	
2016	2.42	2.08	
2017	2.22	2.01	
2018	1.72	1.77	1.77
2019	1.6	1.5828	1.44
2020	1.518	1.5828	1.44
2021	1.55	1.6	1.6
2022	1.5	1.55	1.55

2.3 Cost breakdown of PV installations

The cost breakdown of a typical 5-10 kW roof-mounted, grid-connected, 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 2022 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 [$/ W]	Low [$ /W]	High [$ /W]
Hardware			
Module	0.55	0.3	
Inverter	0.2		
Mounting material	0.22		
Other electronics (cables, etc.)			
Subtotal Hardware	0.97		
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)	1.56		
Average VAT			
Total (including VAT)	1.56		

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

Insufficient public data is available for grid-connected, ground-mounted PV systems as these are commercial installations.

Cost category	Average [$ /W]	Low [$ /W]	High [$ /W]
Hardware			
Module			
Inverter			
Mounting material			
Other electronics (cables, etc.)			
Subtotal Hardware			
Soft costs			
Planning			
Installation work			
Shipping and travel expenses to customer			
Permits and commissioning (i.e. cost for electrician, etc.)			
Project margin			
Subtotal Soft costs			
Total (excluding VAT)	0		
Average VAT			
Total (including VAT)	0		

2.4 Financial Parameters and specific financing programs

Table 13: PV financing information in 2022

Different market segments	Loan rate [%]
Average rate of loans – residential installations	4%
Average rate of loans – commercial installations	5-6%
Average cost of capital – industrial and ground-mounted installations	6-7%

Image: Commercial and industrial rooftops present a significant growth opportunity.

2.5 Additional Country information

Table 14: Country information

Retail electricity prices for a household [$/W]	AUD 0.2-0.42 $/kWh
Retail electricity prices for a commercial company [$/W]	AUD 0.23-0.42 $/kWh
Retail electricity prices for an industrial company [$/W]	AUD 0.20-0.30 $/kWh
Population at the end of 2022	25,750,198
Country size [km²]	7.69m
Average PV yield in [kWh/kW] and range	1400
PV yield value information	generalised average as conditions vary significantly across Australia

Image: Large Scale Solar, waiting for sunrise.

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 2022	**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 (RPS) with/without PV requirements						
Income tax credits						
Self-consumption	yes		yes			
Net-metering						
Net-billing						
Collective self-consumption and virtual 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						
Merchant PV/PPA facilitating measures						yes
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 that was met by 2020, and the Small-scale Renewable Energy Scheme (SRES) that has no set target and provides for a reduction in the upfront capital cost for systems under 100kW that is based on energy generated and reduces over time to 2030. Details are provided below.

3.2 Direct support policies for PV installations

3.2.1 The Renewable Energy Target

3.2.1.1 The Renewable Energy Target

The Renewable Energy Target works by allowing large-scale power stations and the owners of small-scale systems to create large-scale generation certificates and small-scale technology certificates respectively 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.

3.2.1.2 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, including heat pumps, 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 kW could claim 15 years' worth of STCs up front up to 2015, based on expected output at the system location. 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.

3.2.1.3 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 and had an initial target of 41 000 GWh, reduced in 2015 to 33 000GWhr, which was achieved in late 2019, ahead of the 2020 target. 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

3.2.2.1 National Government Agencies

The Australian Renewable Energy Agency (ARENA), Clean Energy Finance Corporation (CEFC), and Clean Energy Innovation Fund (CEIF) continued to operate throughout 2022 to support the deployment of renewable and clean energy technologies, with a reducing focus on solar PV in favour of higher risk projects including hydrogen electrolyser technologies and related projects.

The Australian Renewable Energy Agency (ARENA) is an Australian Government statutory agency, established in 2012 by the Australian Renewable Energy Agency Act 2011 (ARENA Act).

ARENA supports the global transition to net zero emissions by accelerating the pace of pre-commercial innovation, to the benefit of Australian consumers, businesses and workers. ARENA supports renewable energy technologies to become commercially viable by investing in innovation and knowledge. It invests throughout the innovation chain, balancing investment in emerging commercial technologies with earlier-stage research, development and demonstrations to address long-term needs.

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

- world-leading solar photovoltaic (PV) research, through ongoing funding of the Australian Centre for Advanced Photovoltaics (ACAP), including, in 2022 announcing a renewed commitment to support research out to 2030, and a suite of commercially driven research projects valued at AUD 40m, with a focus on driving cost reductions through world-leading solar PV research into both high efficiency solar cells and low-cost deployment.
- 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.
- 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/2022/10/arena-annual-report-21-22.pdf

3.2.2.2 Clean Energy Finance Corporation (CEFC)

The Clean Energy Finance Corporation (CEFC) is a Commonwealth Government initiative with a clear mission to accelerate investment in Australia's transition to net zero emissions. The CEFC invests to lead the market, operating with commercial rigour to address some of Australia's toughest emissions challenges.

With the increase in experience and competitive pricing for utility scale solar, CEFC investment is shifting away from solar to enabling technology, including increased transmission.

2022 project commitments related to solar photovoltaics include co-investment in the 200MW Blue-Grass Solar Farm, using bi-facial cell technology in the Darling Downs Renewable Energy Zone and the award-winning Blind Creek Solar (350MWac) and Battery Project (300MW / 600MWh) that, by co-locating with organic grass-fed lambs, regenerative agriculture and a soil carbon sequestration project, progresses experience with agri-PV.

Source: https://www.cefc.com.au/annual-report-2022/

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, including Australia's first Clean Energy Seed Fund.

3.2.2.4 Australian Energy Market Operator (AEMO)

AEMO develops and maintains an Integrated System Plan (ISP); a whole of electricity system plan that provides a roadmap for the efficient development of the National Electricity Market (NEM) over the next 30 years and beyond. The 2022 release reports an expectation that renewables in Australia's main grid is expected to surge from around 30 per cent now to a share of 83 per cent by 2030, with a fivefold increase in rooftop solar PV, an overall nine -times growth in large scale renewable capacity (wind and solar) and three times as much "firming" capacity, largely through storage. Much of this will be "distributed" storage, leaning on homes and business, much as Australia now relies on rooftop solar.

Source: https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp

3.2.3 Community Solar

Community Solar - No ongoing programs. The Federal Government Community Energy Efficiency and Solar Grants program closed in 2021.

3.2.4 State-Based Incentives Including Feed in Tariffs

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:

Image: APVI Social Media on assessing rooftop capacity for social housing. https://apvi.org.au/solar-potential-of-australian-social-housing-stock/

NSW:

- The NSW Government is offering up to 3,000 free 3kW solar systems, including installations, for low-income households.
  Find out more: https://www.energy.nsw.gov.au/households/rebates-grants-and-schemes/rebate-swap-solar-and-energy-efficient-upgrades

ACT

- The ACT government is offering a solar for low-income program which can provide low income houses up to AUD 2,500 to invest in a rooftop solar system. This involves an incentive for supply and installation and an added interest-free loan which you pay back within three years.
  Source: https://www.climatechoices.act.gov.au/policy-programs/home-energy-support-rebates-for-homeowners

VIC:

- Solar Victoria is providing a rebate of up to $1,400 for solar PV system installation, for homeowners with existing homes, homes under construction and rental properties.
  Find out more: https://www.solar.vic.gov.au/solar-panel-rebate
- Solar Victoria is supporting eligible Victorian households to install a solar battery by providing a point-of-sale discount up to a maximum of $2,950 for eligible customers.
  Find out more: https://www.solar.vic.gov.au/solar-battery-rebate

- Solar Victoria Not-for-profit community housing providers are eligible to apply for solar panel rebates on behalf of their renter with a rebate amount up to $1,400 per tenancy.
  Find out more: https://www.solar.vic.gov.au/solar-community-housing
- The Solar for Business Program offers rebates that cover up to 50% up to AUD 3,500 to reduce the upfront cost of installing a solar PV system on a business, and access to interest free loans.
  Find out more: https://www.solar.vic.gov.au/solar-business-program

NT:

- Under the Home and Business Battery Scheme the Northern Territory Government homes and businesses are able to purchase a battery to fit their needs with a grant of $450 per kilowatt hour of battery system capacity, up to $6,000.
  Find out more: https://territoryrenewableenergy.nt.gov.au/programs

SA:

- The Residential Solar PV program offers; 20% up to $1000 (1.5 kW to <10 kW), 20% up to $2,500 (10 kW to <20 kW), 20% up to $5,000 (>20 kW) rebates on solar PV systems.
- The Business Solar PV program offers; 20% up to $1,250 (10 kW to <20 kW), 20% up to $2,500 (>20 kW) rebates on solar PV systems for businesses.
- The Energy Storage Systems program offers; 50% up to $2,000 on Battery energy storage.
- The Shared Solar Program offers; 20% up to $20,000 per site (with a maximum of $500 per premise) Sharing of solar electricity between tenants in multi-storey premises (>20 kW). Minimum 25% shared to individual tenants, not common areas.
- The Energy Smart Building Program offers; 20% up to $25,000 Innovative, whole-building approaches that make a measurable impact to energy efficiency and electrification of the building.

  Find out more about these incentives at: https://www.cityofadelaide.com.au/about-council/grants-sponsorship-incentives/incentives-for-sustainability/#terms_4942717

WA:

- Distributed Energy Buyback Scheme (DEBS) offers eligible customers a time of export payment for electricity they export to the grid, including from rooftop solar PV systems, batteries and electric vehicles.
  Find out more at: https://www.wa.gov.au/organisation/energy-policy-wa/energy-buyback-schemes

Feed in Tariffs: 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. 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.

3.2.5 Local Government Incentives

Local Government Support: In 2022, local governments continued 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 https://www.sunspot.org.au/ .

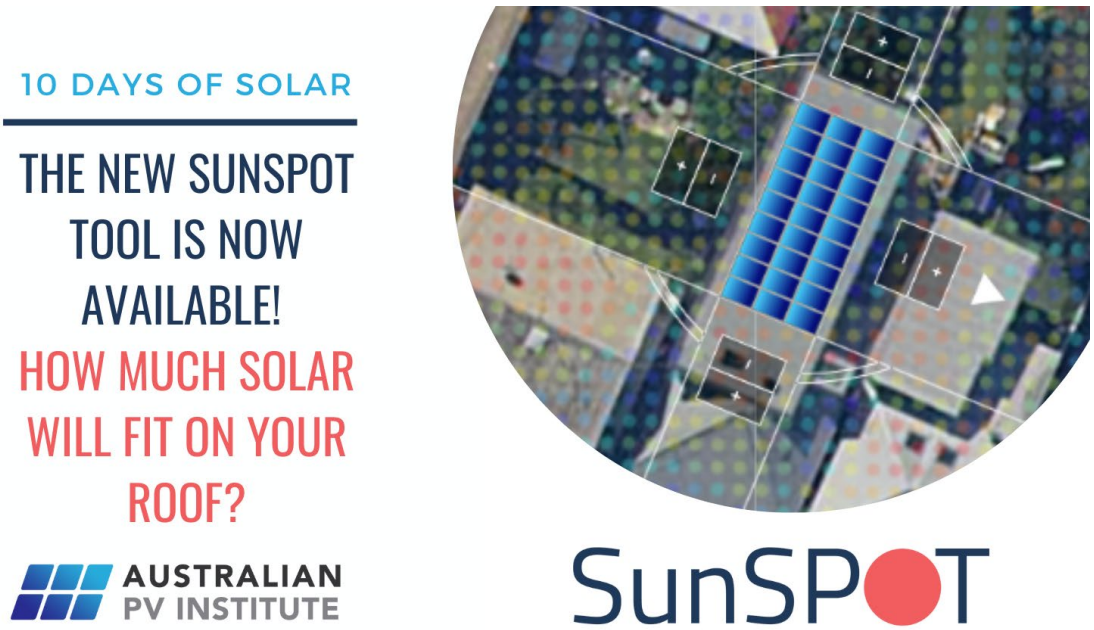

Image: APVI Social Media on Solar Mapping Tool, SunSpot
https://www.sunspot.org.au/

Some additional examples include:

Sydney's Randwick Council offers generous rebates of up to; $500 for a solar system, $1,000 for a home battery, $500 for an electric vehicle (EV) charger. And this is all within a single financial year.

Source: https://www.solarquotes.com.au/blog/randwick-council-sustainability-rebates/

Port Adelaide Enfield Council has begun a pilot scheme to support small to medium enterprises which allows them to apply for up to $500 for solar power and battery systems.

Source: https://www.solarquotes.com.au/blog/solar-port-adelaide-enfield-mb2431/

3.2.6 BIPV Development Measures

There are no additional measures in place to specifically promote BIPV development in Australia, though BIPV installations could qualify for some or all of the measures described above for residential and commercial PV systems.

3.3 Self-consumption measures

Table 16: Summary of self-consumption regulations for small private PV systems in 2022

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 and 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	In 2021, the market operator changed the settlement period from the former current 30-minute wholesale electricity spot market settlement period to five-minutes, providing a better price signal for investment in faster response technologies, such as batteries and gas peaking generators
	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	Number of participants (individual or collective self-consumption)	no collective self-consumption, distribution costs apply to all excess PV electricity
	8	Regulatory scheme duration	Premium FiTs differ between jurisdictions, and standard FiTs are revised annually
	9	Third party ownership accepted	Yes (for ex solar leasing)
	10	Grid codes and/or additional taxes, fees impacting the revenues of the prosumer	No
	11	Regulations on enablers of self-consumption (storage, DSM)	None

	12	PV system size limitations	Some regional limits on system size to connect. Some regional limits requiring self-consumption only.
	13	Electricity system limitations	None (except additional grid codes)
	14	Additional Features	None

3.3.1 Change to 5 Minute Settlement

The introduction of 5-minute settlement to the Australian Energy Market in 2021 has led to some significant changes in bidding practices for generators and batteries in the energy market, with some of the big-battery projects benefiting from arbitrage opportunities. In contrast to bidding under the 30min period, the market is not seeing a rush to negative price-bidding after a price spike by generators to secure offtake, which was a perverse outcome of the 30 min settlement scheme. The change was planned in 2017, giving generators sufficient notice to plan.

The 5-minute settlement is set to support renewable generators due to their extremely low operating costs whilst increasing the operating costs of coal-fired power, due to the inability of ageing power plants to compete during periods of fluctuating demand. This further encourages a market shift towards renewables.

More detail can be found here: https://aemo.com.au/initiatives/major-programs/nem-five-minute-settlement--program-and-global-settlement.

3.3.2 Collective Self Consumption

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.

3.4 Tenders, auctions & similar schemes

3.4.1 Solar Tenders

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 Other utility-scale measures including, floating and agricultural PV

3.5.1 Floating Solar

After the construction of one floating solar plant in 2017, there were no new connections in 2020.

3.5.2 Ultra Large Scale Solar

Australia has several mega-solar projects under development:

1) SunCable's Australian-ASEAN Power Link in the Northern Territory has survived a restructure and will be proceeding its goal to develop a 20GW solar farm and battery facility designed to deliver power to Singapore by under-sea cable.

2) The HyResource project (formerly the Asian Renewable Energy Hub) in Western Australia targets 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 is expected to be used for large scale production of green hydrogen products for domestic and export markets.

3) The North Queensland Super Hub under development aims to deploy 10GW of wind and solar over the next ten years, to support large-scale green hydrogen production.

3.5.3 Social Policies

Australia continues to build on initiatives for policy to support deployment of residential solar at a community and low-income level, as well as social licence for large scale solar.

Initiatives on social licence include an ARENA report on the social licence to operate large scale solar in Australia: https://arena.gov.au/knowledge-bank/establishing-the-social-licence-to-operate-large-scale-solar-facilities-in-australia/, a CSIRO study on how social licence shapes large scale solar (https://ecos.csiro.au/how-social-licence-could-shape-large-scale-solar/) and the development of a model (https://www.csiro.cl/en/research/social-license-to-operate/). In addition, the AEMC recently called for clarity around social licence to assist in transmission planning: https://www.aemc.gov.au/news-centre/media-releases/greater-clarity-around-social-licence-among-final-recommendations-improve-certainty-transmission

In 2022, 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.

- Victoria is also supporting not-for-profit community housing providers who are eligible to apply for solar panel rebates on behalf of their renter with a rebate amount up to AUD 1,400 per tenancy.
- The ACT government is offering a solar for low-income program which can provide low income houses up to AUD 2,500 to invest in a rooftop solar system. This involves an incentive for supply and installation and an added interest-free loan which you pay within three years.
- South Australia's Shared Solar Program offers; 20% up to AUD 20,000 per site (with a maximum of $500 per premise) Sharing of solar electricity between tenants in multi-storey premises (>20 kW). Minimum 25% shared to individual tenants, not common areas.

3.6 Indirect Policy Issues

3.6.1 Social or rural electrification measures

Some examples of rural electrification measures are: The

- 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 service them with 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.

3.6.2 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. There are currently about 20 commercially available Virtual Power Plant (VPP) products, testing different business models. There is around 300 MW of household VPP aggregated under all the schemes and around 350MW in commercial and industrial VPP arrangements. Most major energy providers in Australia have provisions for virtual power plants.

source: https://ieefa.org/wp-content/uploads/2022/03/What-Is-the-State-of-Virtual-Power-Plants-in-Australia_March-2022_2.pdf

- South Australia is making strides in VPP, currently holding the world's largest network of potentially 50,000 battery systems working together to make up a single VPP.

  Source: https://www.energymining.sa.gov.au/consumers/solar-and-batteries/south-australias-virtual-power-plant

  In addition to this, South Australia's Virtual Powerplant (SAVPP) is also undergoing an AUD 33 million expansion funded by Tesla to assist low-income households that aren't able to fit rooftop solar to fit a battery only option. This is set to bring an additional 3,000 households into the scheme.

Source: https://www.energymagazine.com.au/sas-virtual-power-plant-set-to-expand/

IKEA's Adelaide location microgrid has just gone live boasting Australia's largest VPP.

Source: https://www.microgridknowledge.com/distributed-energy/virtual-power-plant/article/33005727/ikea-commissions-the-largest-gridconnected-urban-virtual-power-plant-in-australia

- Western Australia's VPP 'Project Symphony' is set to enrol up to 900 DERs at around 500 homes and businesses.

  Source: https://www.energy-storage.news/project-symphony-western-australias-biggest-virtual-power-plant-goes-online/

- Victoria, the ACT, and South Australia all have solar rebates for battery installations. NSW Govt offers interest free loans to support household batteries.

In 2022, the Australian Government called for applications for community battery systems to support PV on distribution grids: https://www.dcceew.gov.au/about/news/community-battery-grant-guidelines-now-available. Systems are likely to be installed in 2023/24.

3.6.3 Support for electric vehicles and VIPV

In September of 2022 the Labour government launched its first ever electric vehicle strategy, and in November 2022 the Treasury Laws Amendment (Electric Car Discount) Bill passed which will provide AUD 2,000 off the purchase price of electric vehicles (plug in hybrid vehicles will be included until April 1 2025)

- NSW:
  - AUD 3,000 rebate
  - Stamp duty waived.
- VIC:
  - AUD 3,000 rebate
  - Reduced stamp duty and registration discounts
  - Introduced an EV specific tax. It charges electric vehicle owners 2.5 cents per kilometre to partially account for the declining fuel excise paid by those filling up with petrol or diesel. For a car travelling 15,000km annually, that means $375 in road user charges.
- QLD:
  - AUD 6,000 rebate in households earning less than AUD 180,000
  - AUD 3,000 on other households
  - Lower registration and stamp duty
- ACT:
  - Two years free registration
  - Stamp duty waived
  - Up to AUD 15,000 in interest free loans
- NT:
  - Cheaper registration and stamp duty
- TAS:
  - Two years free stamp duty
  - Two years free registration on EVs purchased by car rental companies and coach operators.

State Governments are also supporting the roll out of charging stations.

Source: https://www.whichcar.com.au/news/electric-vehicle-incentives-australia#new-south-wales

3.6.4 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 location-specific 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.

3.6.5 Other Support Measures

3.6.5.1 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. 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).

With a change of government in 2022, Australia has become significantly more progressive in a bid to reach net-zero by 2050, including a commitment to cut emissions by 40% by 2030.

3.6.5.2 Renewable Energy Zones (REZs)

State based Renewable Energy Zones (REZs) aim to motivate investment in specified regions 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.

3.7 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. Nevertheless, the bulk of financing for PV systems installed on the distribution grid comes for individual customers. Most solar installers offer finance.

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

3.8 Merchant PV – Large scale PV outside of support measure (merchant, PPAs, CPPAs)

3.8.1 Description of private (not backed by state) merchant/PPA/CPPA markets

In Australia, Variable Renewable Energy (VRE) projects are typically supported by run-of-plant Power Purchase Agreements (PPAs). However, there is a growing trend towards semi-merchant projects where a certain level of exposure to the spot market is retained. According to Simshauser and Gilmore (2022)*, over the past six years, 149 VRE projects (19,275MW, worth $37.7 billion) have secured financial close. Government support in the form of Contract for Difference (CfD) arrangements is widespread, with increasing volumes of corporate and utility-backed PPAs. However, out of the total 19,275MW of committed VRE capacity, at least 3,600 MW is exposed to the spot market, as highlighted by Simshauser and Gilmore in their research.

**Simshauser, P. and Gilmore, J. (2022) 'Climate change policy discontinuity & Australia's 2016-2021 renewable investment supercycle', Energy Policy, 160(August 2021), p. 112648. Available at: https://doi.org/10.1016/j.enpol.2021.112648.*

3.9 Grid Integration

Access reform remains a work in progress with the Energy Security Board being closed in May 2023. Each jurisdiction of the National Energy Market is designing their own approach to access, introducing complexity and creating potential administrative overlap. Access arrangement ultimately remain somewhat uncertain. Technology in Australia is moving faster than policy and regulation. To maintain the pace of renewable energy development, Australia needs to support National Energy Market reforms.

4 INDUSTRY

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

Table 17: Silicon feedstock, ingot and wafer producer's production information for 2022

Manufacturers (or total national production)	Process & technology	Total Production	Product destination	Price
Simcoa Pty Ltd – producers of metallurgical grade silicon	Silicon feedstock [Tonnes]	50,000	Predominantly USA	na
	sc-Si ingots. [Tonnes]	nil		
	mc-Si ingots [Tonnes]	nil		
	sc-Si wafers [MW]	nil		
	mc-Si wafers [MW]	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, doing module assembly and testing in Australia. Tindo's business model is to both sell modules to wholesalers and to the retail market through parent company Cool or Cosy.

In early 2021, Tindo secured funds to expand manufacturing capacity to 150MW/yr. This was completed in 2022 and production will gradually increase.

Total PV cell and module manufacture, together with production capacity information, is summarised in Table 18 below.

Image: Tindo Manufacturing Line rooftop. Image provided by Tindo Solar.

Table 18: PV cell and module production and production capacity information for 2022

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 manufacturers					
Tindo Solar	Sc-Si	nil	60MW	nil	150 MW
Thin film manufacturers					
		nil	nil		
Cells for concentration					
https://raygen.com/		nil	nil		
Totals			60 MW		

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 company Selectronics design and manufacture inverters for use in both grid and off-grid applications. Latronics exited the inverter industry in 2022, but continues to accept returns at end of life for recycling.
- 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.
- Ecoult batteries, ceased operation in 2022: The Ecoult UltraBattery was a CSIRO invention combines a lead-acid battery and a supercapacitor to provide a fast-charging, long-life battery.
- Gelion are developing a revolutionary zinc-bromide battery technology and additives for lithium ion batteries for the transport sector (https://gelion.com/)
- There are large numbers of foreign manufactured battery companies, particularly Li-ion batteries, 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. 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

Most large-scale systems in Australia now use trackers. The tracker market is dominated by Nextracker who are a US based company, recently listed on the US stock exchange. Other than that PV Hardware, FTC Solar (US company), Ideematec (German), Game change (US company) solar, Soltec, Archtech and others supply locally to the tracker market.

Fixed tilt suppliers are Schletter (German) and S Rack (German) and others. Local manufacturers include PV Hardware (https://pvhardware.com/australia/) and IXL (http://ixlsolar.com.au/) 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

The Australian solar supply chain is typically structured as follows:

- Wholesalers (Distributors) import modules 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.

Image: She Installs with Roland Electrical Pty Ltd. Image provided by APVI Ltd.

5.1 Labour places

Table 19: Estimated PV-related full-time labour places in 2022

Market Category		Number of full-time labour places [FTE]		
Upstream	Research and development (not including companies)	250		25,550
	Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	300		
Downstream	Distributors of PV products	25,000		
	System and installation companies			
	Operation and maintenance companies			
	Electricity utility businesses and government			

5.2 Research and development

Research, development and innovation is incentivised in Australian industry through a Federal Government tax incentive known as the R&D Tax Incentive by offsetting some of the costs of eligible research and development (R&D). Financial support for R&D is also possible for industry and research institutions through the Australian Renewable Energy Agency. Universities and the Commonwealth Scientific Industry Research Organisation are supported from Commonwealth funds directly and through competitive funding through organisations such as the Australian Research Council and Cooperative Research Centres to carry out research, development and innovation.

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.

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.

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 88 GWhr and 110 GWhr per year (respectively) of energy from new large-scale renewable energy facilities, with a ten year commmitment. 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 Community Power Group, Solar Citizens and the Yarra Energy Foundation.

6.4 States and Territories

In 2022, 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 and ACT governments leading progress having already achieved 100% renewables.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

At 4.2GW in 2022, Australia saw the first drop of more than 10% in new installs since 2013, brought on by supply chain challenges, price increases and, also reflecting a decade of inaction at a federal level on issues of energy security and climate change. With a change of government in 2022, Australia saw change and a renewed commitment to invest in energy security and to international goals to decarbonise. The industry is optimistic about growth in 2023 and beyond as investment returns.

The year saw a total install capacity of 4.2 GW (after 5GW in 2021), taking the country to a total installed capacity of PV 30 GW, growing more than ten times in ten years (with 2.5GW at the end of 2012). With a population of 26 million people, Australia now has a world-class 1.18 kW per capita of solar installed.

All sectors saw a decline in installations, delivering a drop of 15%.

Australia continues to build on its high per-capita rooftop install rate with over 37% of free-standing households now generating power from their rooftop, with well over 50% in many urban areas. At the end of 2022 there were more than 3.3 million household solar installations across the country.

7.2 Prospects

Building off a strong base, and with a change in government in mid-2022 leading to stronger and more ambitious commitments to net-zero emissions, Australia is likely to see ongoing growth in the solar PV market. Although progress is slow to date, there are well established plans and commitments to invest to adapt the electricity system to meet increasing solar deployment at utility scale through enhancing transmission, and to manage the significant decentralised generation investment.

- 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.
- 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 funded Australian Renewable Energy Agency (ARENA) has a budget to end 2030 of 1.6 BAUDs to support Australia in 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 planning for a resilient market with 100% renewable penetration across the national electricity market by 2025. This is happening at times already in South Australia (SA), when the entire state is powered entirely by renewables.

- New infrastructure connecting SA-NSW and VIC-NSW grids to help stability of the electricity market are under development. Project EnergyConnect was approved for construction in mid-2021. The further development of Renewable Energy Zones and AEMO's updated Integrated System Plan (2022) 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), all aimed at optimising costs and resilience in electricity supply.
- Storage capacity is set to increase with several 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 20 GW of solar in the Northern Territory, delivering power by under-sea cable into Southeast Asia, and the Asian Renewable Energy Hub, with up to 26 GW 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.

For utility-scale PV, challenges include access reform, with current arrangements leading to increased risk and uncertainty for investors as Australia lacks nationally consistent arrangements. Adding to this, the network continues to suffer grid and connection constraints for utility scale solar and changing economics for connected plant, including Marginal Loss Factors (MLF) that are adjusted annually to reflect co-location of supply and distance to load.

For behind-the meter PV, challenges include restrictions on system size, increasing network access costs and a regulatory focus on central generation, despite the high interest in and penetration of distributed PV. 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

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