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

2021

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 IEA carries out a comprehensive programme of energy cooperation among its 30 member countries and with the participation of the European Commission. The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the collaborative research and development agreements (technology collaboration programmes) within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems."

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

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

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What is IEA PVPS Task 1?

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. An important deliverable of Task 1 is the annual "Trends in photovoltaic applications" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2018. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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This Project received funding from the Australian Renewable Energy Agency (ARENA). The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

COVER PICTURE

35 MW Brigalow solar farm in Queensland. Image provided by Ideematec, Sentient Impact Group and GLSG Solar Australia.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

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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. Co-Operating Agent is Jose Bilbao (UNSW), 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)
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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) continued to grow through 2021, in both centralised (utility scale) and decentralised (rooftop) installs, with a new benchmark of 4.9 GW of new solar registered.

Additional annual rooftop installs on residential, commercial and industrial roofs exceeded 3 GW, with 1.7 GW on residential roofs and 1.3 GW on commercial and industrial roofs, shown in **Figure 1.**

New centralised, utility scale solar connections remain stable at around 1.7 GW annual installs, off a high of 2.4 GW in 2019.

The total installed capacity at the end of 2021 reached 26 GW, meaning Australia has a remarkable, and world leading installation rate of over 1 kW of solar per person, ahead of the Netherlands and Germany who both have less than 800 W per person. With continued growth in 2022, Australia looks set to maintain this lead.

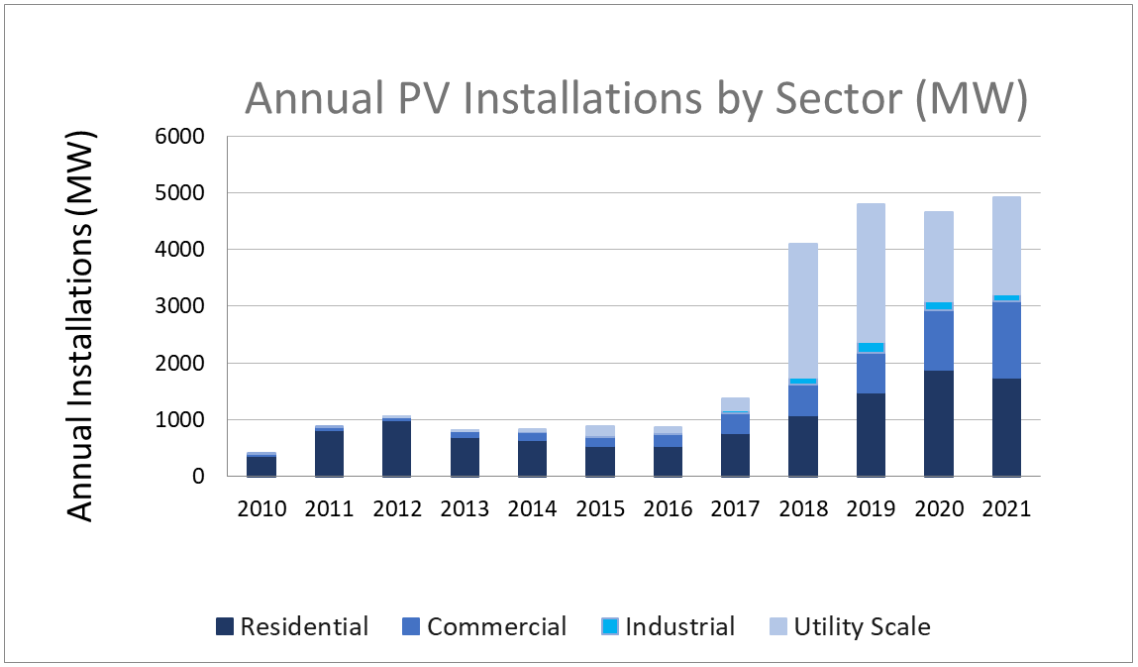

Figure 1. Annual PV installations by sector

By the end of 2021, the average penetration of solar on free-standing homes was 33%, and the average installation size exceeded 8.8 kW.

In the ten years, since 2011, the installation rate has grown nearly five-fold, from just under 1 GW/year to 4.9 GW/year in 2021.

In 2011, Australia had no centralised plant greater than 1 GW, and in just ten years, by the end of 2021, Australia had close to 9 GW of utility scale solar connected.

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

- With 16.5 GW on rooftops, Australia has seen a greater than ten-fold increase over ten years, from a total installed capacity of 1.3 GW in 2011.
- The total installed capacity across all sectors has more than doubled to 26 GW in three years from 11.5 GW in 2018.
- More solar was installed in the single year 2021 (4.9 GW) than the sum of all total installed to the end of 2014 (4.1 GW)

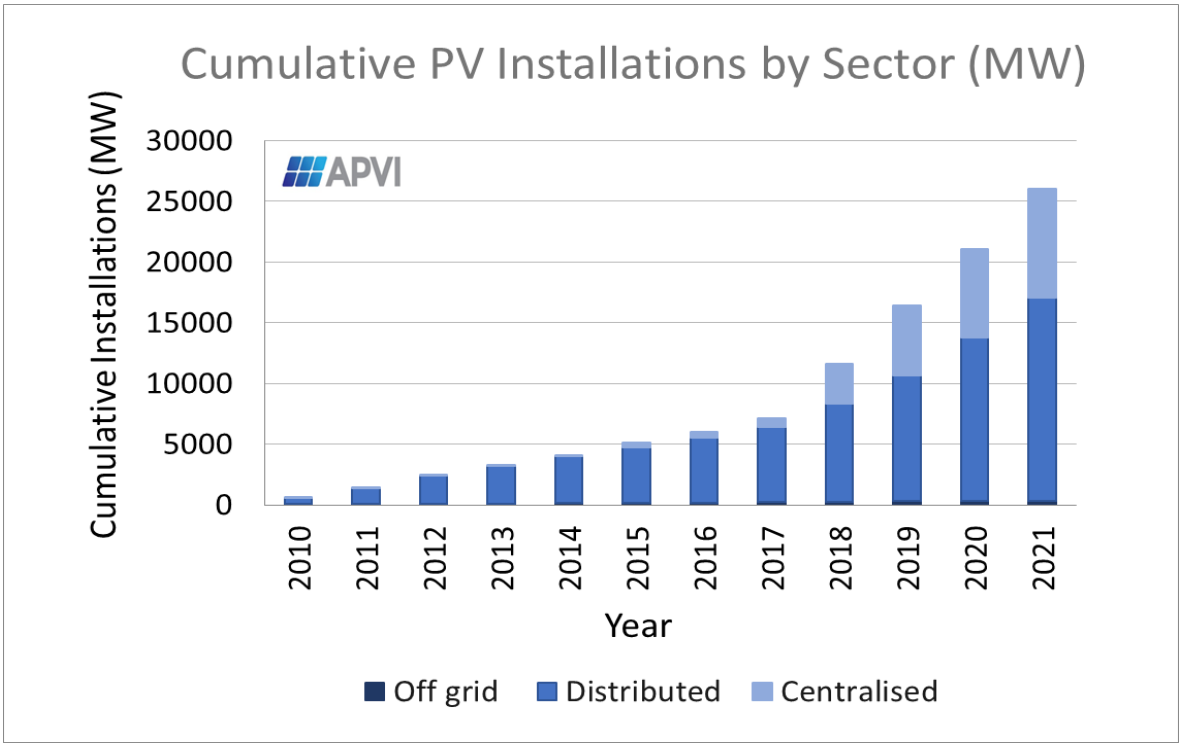

Figure 2. Cumulative Installs in Australia by Grid-Connection

The Australian market is very different to most world markets as it has been dominated by rooftop PV. The demand for rooftop solar PV 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 2021, Australia saw:

- The total number of rooftop installations exceed 3 million. This means over 33% of free-standing households across the nation are now powered with a PV system.
- In the states of Queensland and South Australia, achieve an average of close to 40% of free-standing homes being powered by solar. A significant number of localities now 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 in excess of 40%, with populations of 5.2 million and 1.8 million respectively.

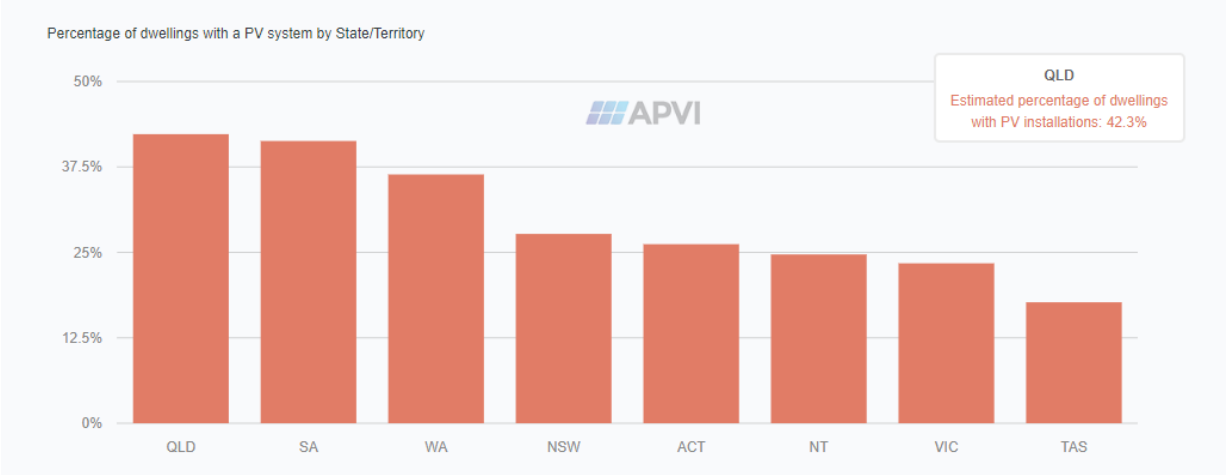

Figure 3. Percentage of residential dwellings with a PV system by state/territory

In 2021, the average size of rooftop installation (<100 kW) was 8.8 kW, up from 8.0 kW in 2020. 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. Prices then continued to drop, but less dramatically. In 2021, however, compounding factors of supply chain challenges associated with COVID-19 and growing demand has led to the first significant price increase in years. The evidence is that the situation will not improve over 2022. Despite this, demand remained high over 2021.

In contrast to other areas of global leadership, very little building-integrated PV (BIPV) was added in 2021, and no new 'Floatovoltaics' have been recorded beyond the single 100 kW installation in 2017.

In late 2021, Australia moved from a 30-minute settlement period in energy market transactions to a 5-minute settlement period, providing better returns for battery investment. We also recently saw the first wholesale demand response mechanism on the national electricity market (NEM).

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 in industrial and agricultural applications including power systems for telecommunications, signalling, water pumping and lighting. In Western Australia (WA), microgrids and stand-alone power systems (SAPS) 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, with increasing interest due to price pressures related to supply of coal and gas emerging in 2022.

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, designed to coordinate transmission, generation, firming and storage projects to deliver efficient, timely and coordinated investment in renewable energy.

A change of government in Australia in mid-2022 has resulted in 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 significant boost, with each of the prospective projects positioned to add 4 GW per year in demand if actioned.

Figure 4. 35 MW Brigalow solar farm in Queensland. Image provided by Ideematec, Sentient Impact Group and GLSG Solar Australia.

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 these statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2021 although commissioning may have taken place at a later date.

1.1 Applications for photovoltaics

Unlike other markets, Australian solar installations are dominated by rooftop demand, supported by a government mechanism that delivers an upfront capital cost reduction. Over 30% of Australian free-standing homes are now powered by solar, and over 12.5% of electricity demand, nationally, is met by solar energy.

The commercial and industrial rooftop market has shown consistent growth. Due to this continuing demand for rooftop solar, Australia has remained in the top ten markets world-wide for photovoltaics by annual installs and total installed capacity for over ten years, a remarkable outcome for a country of only 26 million people. The utility scale solar market grew with the benefit of incentives until 2020. With the removal of these incentives, the utility scale market initially contracted but has started to recover.

In Australia, there are only small activities that target BIPV, floating PV, AgriPV and VIPV, and they typically only operate at research or demonstration scale.

1.2 Total photovoltaic power installed

PV connected to the grid in Australia has benefitted from incentives and support from national government through a Renewable Energy Target (RET). The RET is delivered through the Small-scale Renewable Energy Scheme (SRES) for systems up to 100 kW and will continue to 2030. The Large-Scale Renewable Energy Target (LRET) for systems over 100 kW was met 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) are redeemable annually based on energy generated. These incentives come with a reporting obligation and are categorised into small (<100 kW) and large-scale systems (>100 kW). Within these categories residential solar is typically considered 0-10 kW while commercial and industrial installations are rated at 10-100 kW. Above 100 kW there is a mix of commercial, industrial, and ground mount up to 5 MW; installations above 5 MW are usually ground mounted. The

STC system will run to 2030, with an annual reduction in the support provided. 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 2021

		Installed PV capacity in 2021 [MW]	AC or DC
	Decentralized	3201	DC
	Centralized	1713	DC
	Off-grid	30	DC
	Total	4944	DC

Table 2: PV power installed during calendar year 2021

			Installed PV capacity [MW]	Installed PV capacity [MW]	AC or DC
Grid-connected	BAPV	Residential	3201	1737	DC
		Commercial		1355	DC
		Industrial		109	DC
	BIPV	Residential			
		Commercial			
		Industrial			
	Utility-scale	Ground-mounted	1713	1713	DC
		Floating			
		Agricultural			
Off-grid		Residential	29.6	24.2	DC
		Other			
		Hybrid systems			
Total			4943.6		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 plants 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 an official process 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

Figure 5. Rooftop mounted PV system, 5.4 kW capacity installed on a new house in suburban Australia. Credit: Tindo Solar.

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, etc)	Total [MW]
1992	7.3	0	0	7.3
1993	8.9	0	0	8.9
1994	10.7	0	0	10.7
1995	12.7	0	0	12.7
1996	15.6	0.1	0	15.7
1997	18.3	0.2	0.2	18.7
1998	21.2	0.9	0.5	22.6
1999	23.3	1.5	0.5	25.3
2000	26.3	2.4	0.5	29.2
2001	30.2	2.8	0.5	33.5
2002	35.2	3.4	0.5	39.1
2003	40.3	4.6	0.7	45.6
2004	46.2	5.4	0.7	52.3
2005	53	6.9	0.8	60.7
2006	60.5	9	0.8	70.3
2007	66.4	15	1	82.4
2008	73.3	29.9	1.3	105
2009	83.9	101	2.5	187
2010	87.8	479	3.8	571
2011	101	1268	7.4	1376
2012	118	2276	21.5	2416
2013	132	3070	24	3226
2014	148	3875	68.5	4092
2015	173	4580	356	5109
2016	210	5329	446	5985
2017	247	6145	740	7132
2018	284	8030	3272	11 586
2019	303	10 395	5701	16 399
2020	330	13 476	7285	21 091
2021	360	16 677	8998	26 035

*small changes to historical values reflect changes in the source data. Installs can be reported as much as a year later.

Table 5: Other PV market information

	2021		
Number of PV systems in operation in your country	Residential	3 066 748	2 798 782
	Commercial		266 299
	Industrial		1531
	Utility-scale		136
	Off-grid		na
Decommissioned PV systems during the year [MW]	Residential	1	1
	Commercial		
	Industrial		
	Utility-scale		
	Off-grid		
Repowered PV systems during the year [MW]	Residential	0	
	Commercial		
	Industrial		
	Utility-scale		
	Off-grid		

Table 6: PV power and the broader national energy market

	2020	2021
Total electricity demand [TWh]	265.2	267.4
Estimated total PV electricity production (including self-consumption) [GWh]	29.5	36

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.	12 977 sites	NA	Clean energy regulator data. The industry thinks it's nearly three times larger than the recorded value

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 2021 was from imported panels.

Module prices have increased due to supply chain challenges and increased shipping costs.

Table 8: Typical module prices

Year	Lowest price of a standard module crystalline silicon [$/W]	Highest price of a standard module crystalline silicon [$/W]	Typical price of a standard module crystalline silicon [$/W]
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
2021	0.3	1.15	0.55

2.2 System prices

The figures reported in the table below are an average price for a rooftop installation of 7 kW excluding subsidies which reduce the system cost by a further 40-50c/W, depending on insolation, averaged here at 0.45c/W

Residential and commercial prices are based on 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 costs including installation, connection and registration.

The utility-scale solar market grew rapidly between 2014 and 2020 with a steep decline in pricing. LGC system sizes average prices are not published as they are site dependent and commercial in confidence. The prices for systems connected in 2021 were negotiated some years ago.

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

Category/Size	Typical applications and brief details	Current prices [AUD/W]
Residential BAPV 5-10 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected households. Typically roof-mounted systems on villas and single-family homes.	1.55
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.	1.60
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.	1.60
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.	N/A
Large centralized PV >20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	N/A

Table 10: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV system 5-10 kW **[AUD/kW]**	Small commercial BAPV Grid-connected, roof-mounted, distributed PV systems 10-100 kW **[AUD/kW]**	Large commercial BAPV Grid-connected, roof-mounted, distributed PV systems 100-250 kW **[AUD/kW]**	Small Centralized PV Grid-connected, roof-mounted, centralized PV systems 10-20 MW **[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	na
2020	1.52	1.58	1.44	na
2021	1.55	1.60	1.60	na

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 2021 is 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 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 the customer. The “low” and “high” categories are the lowest and highest cost that have been reported within each segment. These costs are individual figures, i.e. summarizing these costs do not give an accurate system price.

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

Cost category	Average [AUD/W]	Low [AUD/W]	High [AUD/W]
Hardware			
Module	0.55	0.3	NA
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**		
Total (excluding VAT)			

2.4 Additional country information

With over 26 GW of solar and a population of 26 million, Australia now leads the world in installed solar per capita, with 3 million rooftop solar installations and 1 kW of solar per person. Germany and the Netherlands follow with less than 800W of installed solar per person.

With the current high energy prices and continued support for small-scale installations through the Small-scale Technology Certificates, we expect the small-scale market to remain strong 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]	0.2-0.42
Retail electricity prices for a commercial company [AUD/kWh]	0.23 – 0.42
Retail electricity prices for an industrial company [AUD/kWh]	0.20 – 0.30
Population mid 2022	26 094 037
Country size [km^2]	7.69 million
Average PV yield in [kWh/kW]	1400
PV yield value information	This value is a generalised average as conditions vary significantly across Australia.

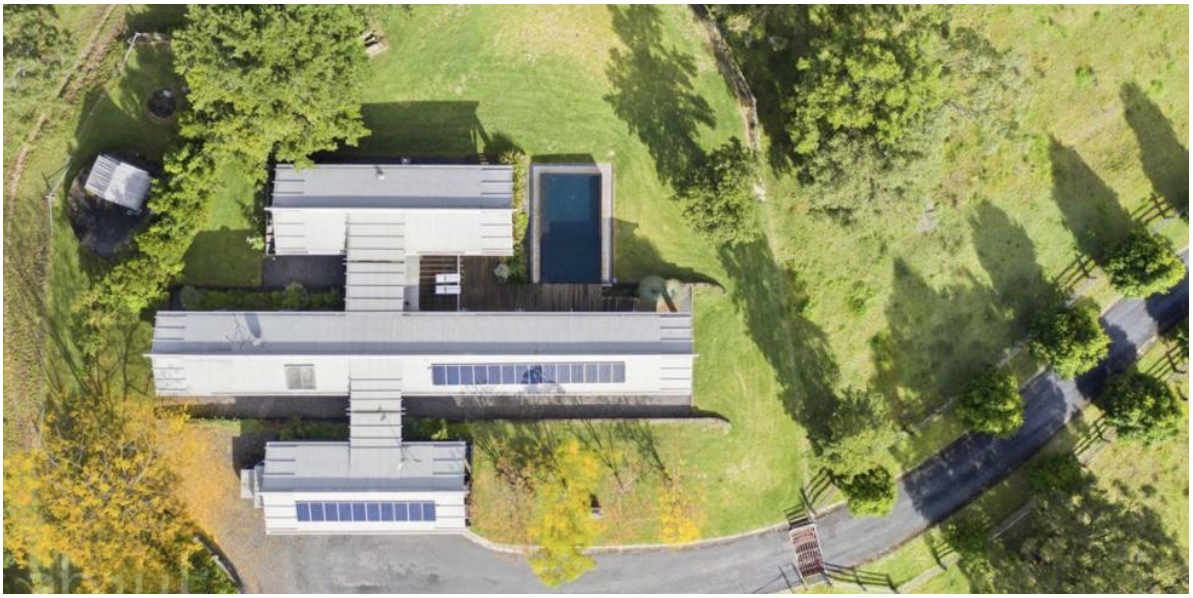

Figure 6: Rooftop solar panels on a rural property. Credit: APVI.

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivising, 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 2021	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	Yes	-	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	-	-	-	-	-	-
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	-	-	-	-	-	-
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 33,000 GWh (that was met before 2020), and the Small-scale Renewable Energy Scheme (SRES), with no set target. Details are 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 a cross-subsidy, leveraged upon all electricity consumption except for certain classes of industrial electricity consumers.

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, however the scheme has a completion date of 2030. Prior to 2015, up-front deeming arrangements meant that PV systems up to 100 kWp could claim 15 years' worth of STCs up front. Since 2015, PV installations receive one year less deeming each year, diminishing 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.

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 41 000 GWh, that was reduced in 2015 to 33 000 GWhr, which was then achieved in late 2019, ahead of the 2020 target date. Liable entities meet their obligations by acquiring and surrendering Large-scale Generation Certificates (LGCs), with 1 LGC created for each MWh of renewable electricity

3.2.2 National government agencies

The Australian Renewable Energy Agency (ARENA), Clean Energy Finance Corporation (CEFC), and Clean Energy Innovation Fund (CEIF) continued to operate throughout 2021 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)

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. We invest 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, principally through ongoing funding of the Australian Centre for Advanced Photovoltaics (ACAP), including, in 2021, the delivery of the first pieces of equipment supported by a $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
- 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://www.transparency.gov.au/annual-reports/australian-renewable-energy-agency/reporting-year/2020-21

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,

2021 project commitments related to solar photovoltaics include participation in a joint venture to accelerate the delivery of Gippsland's Perry Bridge and Fulham solar farms, where grazing and solar will co-exist;

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-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 gigawatts of additional renewable energy required to replace coal-fired generation and a further 6-19 gigawatts 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.

An updated Integrated System Plan was released on June 30 2022. More detail can be found at https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp

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.

3.2.3 Solar for communities

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

Examples of local initiatives include the Majura Community Solar Farm in the ACT, established by SolarShare, the Majura Community Solar Farm is part of the ACT government's Community Solar initiative whereby electricity is sold under a Feed in Tariff contract. SolarShare will be able to sell the energy into the energy network and receive 19.56c for each kWh of electricity generated.

https://www.solarshare.com.au/solar-farm-project/greenfield-project

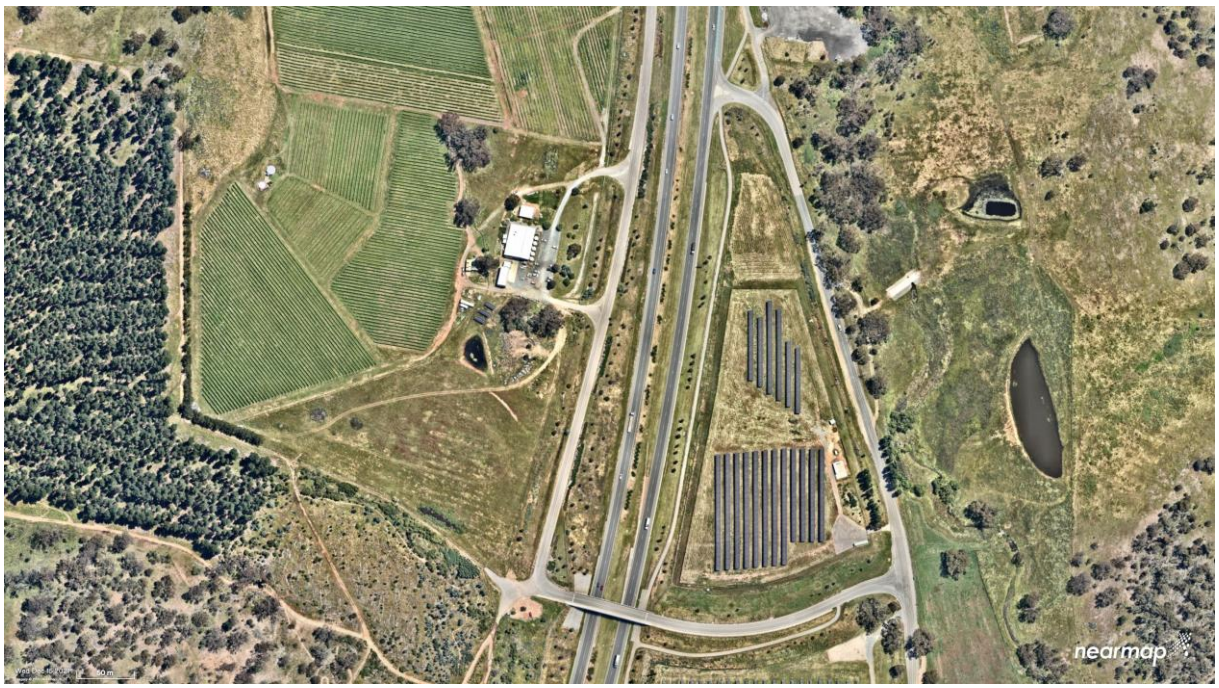

Figure 7: Majura Community Solar Farm. Credit: ITP Renewables.

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:

- The NSW Government is offering up to 3,000 free 3 kW 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 provides eligible Victorian households with a rebate of up to 50% of the purchase cost to install solar PV panels. The rebate is up to $1,850, currently about half the value of an average 4 kW solar PV system.
- The Victorian Government Small Business Rebate offers a rebate of 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.

3.2.4.2 Feed-in Tariff

Each of the State and Territory jurisdictions have run their own feed-in tariff (FiT) schemes. All now closed to new entrants but many are 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.

Table 16: Australian State and Territory feed-in tariffs in 2021

State	Start Date	Size Limits	Rate AUDc/ kWh	Scheme end	Type	Eligibility
Victoria						
Premium FiT (closed 1 Jan 2012)	1 Nov 2009	5 kW	60	2024	Net	Residential, community, small business
Comments	Customers lose their FiT if they change their system size or move house.					
South Australia						
Groups 1, 2 & 3 (closed 30 Sept 2011)	1 July 2008	10 kVA 1Ø 30 kVA 3Ø	44	30 June 2028	Net	A facility that consumes less than 160 MWh/yr
Comments	Groups 1, 2 & 3 differ according to the amount of electricity the FiT applies to and when the system was logged with the network operator.					
ACT						
Gross FiT (closed 31 May 2011)	1 March 2009	30 kW	50,05 (<10 kW), 40,04 (10-30 kW), after 1 July 2010 45,7 (<30 kW)	20 years after connection	Gross	Residential, business
Gross FiT (closed 13 July 2011)	1 April 2011	30-200 kW	34,27	20 years after connection	Gross	Residential, business
Comments	Although the Gross FiT (30 kW) was closed on 31 May 2011, <30 kW systems were made eligible for the Gross FiT (30-200 kW) from 12 July 2011 to 13 July 2011 to allow these systems to access the cap originally set aside for systems 30 kW to 200 kW.					
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 100 MWh/yr
Comments	Customers lose their SBS FiT if they change their system size or move house.					
Western Australia						
Residential FiT scheme (closed 1 Aug 2011)	1 July 2010	5 kW (city) 10 kW 1Ø 30 kW 3Ø (country)	40 to 30 June 2011 20 from 1 July 2011	10 years after installation	Net	Residential
RE Buyback Scheme	2005	Up to 5 kW	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 incentives

In 2021, 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 2021

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	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
	7	Number of participants (individual or collective self-consumption)	No collective self-consumption, distribution costs apply to all excess PV electricity
Other characteristics	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 30-minute 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-minute settlement scheme. The change was agreed to in 2017, giving generators sufficient notice to plan.

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 2021. There are no agriculture-specific large-scale solar plants. Two GW-scale solar projects are under development:

3.5.2 Ultra-large-scale solar

The Australian-ASEAN Power Link in the Northern Territory, is projected to be the world's largest solar farm and battery storage facility with 20 GW of solar, 42 GWhr of battery storage and 4,200 km of under-sea cable delivering power into Southeast Asia.

The Asian Renewable Energy Hub in Western Australia, which will see 26 GW 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 both domestic and export markets.

3.5.3 Social policies

In 2021, 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 3 kW 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.

3.6 Retroactive measures applied to PV

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

3.7 Indirect policy issues

3.7.1 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 1 MW solar PV installed to reduce the use of diesel power.

3.7.2 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 VPP products, testing different business models. There is around 300 MW of household VPP aggregated under all the schemes and around 350 MW in commercial and industrial VPP arrangements.

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

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

3.7.3 Support for electric vehicles and vehicle-integrated photovoltaics (VIPV)

In 2021, there was no national program to develop the electric vehicle market. Government support for electric vehicles (EVs) has instead been led by state governments.

State Governments offer a rebate of up to $3,000 as well as waiving Stamp Duty on Electric Vehicles. They are also supporting the roll out of charging stations.

One state (Victoria) 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 a road user charges

source: https://rac.com.au/car-motoring/info/electric-car-incentives#:~:text=NSW%20EV%20incentives,can%20be%20up%20to%20%243%2C000.

3.7.4 Curtailment policies

The Australian Energy Market Operator (AEMO) poses strict rules that limit total large-scale solar (and wind) output to protect what it calls system strength.

Curtailment happens when combined output reaches a pre-defined level and happens regularly in South Australia, where there is a rapidly growing large-scale solar capacity now standing at 110 MW and more than 1,800 MW of wind capacity.

Output of solar farms is also discounted using a Marginal Loss Factor (MLF). The MLF is a calculation used to estimate how much a plant's output reaches a destination and reflects distance to load. An MLF of 0.9, for instance, suggests losses of 10 per cent, so a solar plant will be credited for just 90 MWh out of every 100 MWh registered at the meter at the plant.

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

3.7.5 Other support measures

3.7.5.1 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 initiatives contrast with the position that the Australian Commonwealth Government held in 2021, where they preferred a technology led initiative and developed a Roadmap for low emissions technologies, with the then 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).

Australia has seen a change of government in mid-2022, which has already resulted in some significant changes including a commit to cut emissions by 43% by 2030.

3.7.5.2 Renewable Energy Zones (REZs)

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

- Queensland has announced plans for three REZs with 60 GW of projects proposed from the market.

- NSW has announced plans for a targeted AUD 32 billion investment in five REZs, calling for 12 GW of renewable energy to be built and an additional 2 GW 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.

3.8 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 2021 was by way of recuperable grants or equity.

Figure 8. Limondale Solar Farm in NSW 349 MW installation. Image provided by RWE Renewables Australia and Ideematec.

4 INDUSTRY

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

Australia has no solar feedstock, ingot or wafer production.

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.

In early 2021, Tindo secured funds to expand manufacturing capacity to 150 MW/yr, expected to be finished in 2022.

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 2021

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			30		60
Totals		**0**	**30**	**0**	**60**

4.3 Manufacturers and suppliers of other components

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

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

- Australian companies Latronics and Selectronics design and manufacture inverters for use in both grid and off-grid applications.
- Magellan Power is an Australian based manufacturer of power electronics including PV inverters designed for both residential and commercial applications.
- Redback Technologies is an Australian intelligent hybrid PV-storage inverter manufacturer.
- MIL Systems is an Australian power system engineering company that produces a residential grid-connected inverter.

4.3.2 Storage batteries

- Australian company RedFlow manufactures Zinc Bromine flow batteries. Its ZBM product delivers up to 3 kW of continuous power (5 kW peak) and up to 8 kWh of energy. RedFlow has launched a product to serve the residential market.
  There are large numbers of foreign manufactured battery companies supplying to the Australian market, some of whom are setting up local manufacturing.

4.3.3 Battery charge controllers and DC switchgear

A range of specialised fuses, switches and charge controllers are made locally. Here are a few examples of charge controllers & switchgear implementations in Australia:

- Magellan Power have a range of battery, control and switching technologies.
- Solari Energy – Solagrid Energy Storage System (ESS) a stand-alone energy storage system suitable for any sized solar energy installation. 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

With most solar going in on rooftops, there is some local industry including

- IXL who manufacture a range of mounting and tracking systems to suit local conditions.
- Capral Aluminium makes extruded aluminium for Clenergy mounting systems here in Australia. See https://www.clenergy.com/
- German company Schletter are also making roof top mounting systems

For large scale solar, 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.

Figure 9. 2.2 MW Large Scale PV array Port Bonython roll out of 5B Maverick Technology. Image courtesy of 5B

4.3.5 BIPV

Tractile Solar manufactures composite roof tiles that combine PV cells with Thermal Hot Water. 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/]

Melbourne-based architectural firm Kennon has announced the nation's first building to harness solar power via its facade is under construction. The revolutionary design conceived by Kennon in 2019 will be brought to life by a private developer, with the eight-storey office building to be located at 550 Spencer Street, West Melbourne.

With 1182 individual solar panels to be located on the facade, the building will produce more energy than it consumes, revolutionising sustainability outcomes for the future of architectural design. Construction is expected to be completed in mid-2023, with the developer seeking a long-term tenant motivated to uphold the building's sustainability values.

Figure 10. Schematic of planned BIPV on a commercial building at 550 Spencer St, Melbourne

Credit: CUUB/Kennon architecture firm

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), with accreditation 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 11. Rooftop Installation PV in progress. Credit: Tindo Solar.

5.1 Labour places

Through 2021 there were an estimated 25,370 full-time equivalent (FTE) labour places in the PV industry. 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 2021

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	120
Distributors of PV products and installations	25,000
System and installation companies	
Operation and maintenance companies	
Electricity utility businesses and government	
Total	**25 370**

5.2 Research development and innovation

Solar PV R&D is primarily funded by the Australian Renewable Energy Agency, with an annual research budget, averaged around 19 MAUD/yr over four years.

5.3 Business value

Table 21: Rough estimation of the value of the PV business in 2021 (VAT is excluded)

Sub-market	Capacity installed [MW]	Average price [AUD/W]	Value [AUD]	Sub-market [AUD]
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 2021				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.

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 and 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 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 2021, 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

Figure 12. Residential solar. Credit: APVI.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

Despite the challenges faced through 2021 posed by the COVID-19 pandemic, this year was another strong one for solar installations across the Australian market. The year saw a total installed capacity of 4.9 GW taking the country to a total cumulative capacity of 26 GW, more than doubling the total capacity at the end of 2018. With a population of 26 million people, Australia now has a world-class 1 kW per capita of solar installed.

The small-scale solar sector (<100 kW) had another incredible year despite COVID-19 and supply chain challenges, with over 3 GW of installed capacity. State, local government and community initiatives 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 33% of free-standing households now generating power from their rooftop, and well over 50% in many urban areas. At the end of 2021 there were more than 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. There are well established plans and commitments to invest in adapting 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 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 designing for 100% renewable penetration across the market by 2025, with evidence already of feasibility, and challenges, when on occasions, the entire state of South Australia (SA) is entirely powered by solar and wind, supported by batteries.
- New infrastructure connecting SA-NSW and VIC-NSW grids are under development. Project EnergyConnect was approved for construction in mid-2021.

- Network operators are looking at setting up autonomous micro and mini-grids and generator/retailers are investing in virtual power plants (VPPs).
- Storage capacity is 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 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 including by a redesign of tariffs to incentivise use of low-cost, low-emissions power, by investments in storage and investments 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.

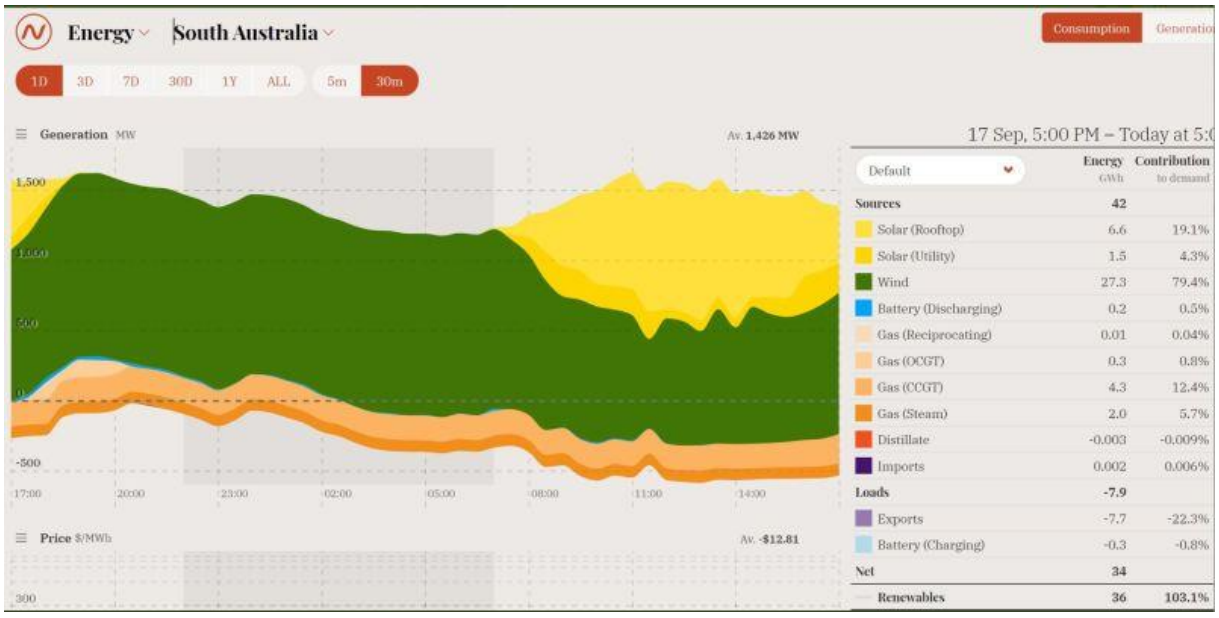

Fig 12: The state of South Australia is 100% renewables for a 24hour period for the first time on September 20 2021. Source: https://opennem.org.au/

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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The views expressed herein are not necessarily the views of the Australian Government. The Australian Government does not accept responsibility for any information or advice contained within this document.

Fig 13: Trundle Solar Farm – 6.4 MW Solar Farm, where ITP Renewables provided due diligence for the financiers and commissioning for Enerparc Australia. Image courtesy of ITP Renewables.