SolarCitizens

ROOFTOP SOLAR POTENTIAL OF AUSTRALIAN HOUSING STOCK BY TENURE AND DWELLING TYPE

AUSTRALIAN PV INSTITUTE

UNSW SYDNEY

Published April 2024

Solar Citizens acknowledges the Traditional Owners of the lands on which we work. Their sovereignty was never ceded.

ACKNOWLEDGEMENTS

This report was produced by researchers in the School of Photovoltaic and Renewable Energy Engineering at UNSW Sydney for the Australian PV Institute and Solar Citizens.
More information on the APVI can be found at: www.apvi.org.au

The work is supported by the Australian Centre for Advanced Photovoltaics (ACAP) and received funding from the Australian Renewable Energy Agency (ARENA).

Please use the following citation for this document:
'Dehghanimadvar M, Roberts M, Bruce A, Egan R, Rooftop solar potential of Australian housing stock by tenure and dwelling type (2024). Solar Citizens / APVI.'

Executive summary

This report presents an assessment of the rooftop solar potential across Australia's housing stock. It has a particular focus on social housing, apartments and private rental housing, three sectors that are significantly underrepresented in Australia's world-leading penetration of residential solar.

The total potential for rooftop solar installation on residential buildings in Australia is estimated at approximately 60.9 Gigawatts (GW). As of June 2023, approximately 15.1GW of residential solar is installed in Australia [1], the majority on owner-occupied stand-alone and semi-detached houses, leaving an estimated 45.8GW of untapped photovoltaic (PV) potential exists across the country.

Our findings indicate that unlocking this untapped potential could yield significant economic, social, and environmental benefits for diverse Australian households in different types of dwellings, including:

- employ 48,000 people for 5 years
- save around 5.7 million households, currently without solar, an average of more than $1,300 per year
- generate total bill savings of $9.3 billion a year for over 20 years for an initial investment of around $9.8 billion per year for five years
- produce approximately 61 Terawatt-hours (TWh) of electricity each year (on top of the estimated 20TWh generated by existing residential solar)
- reduce greenhouse gas emissions by approximately 785 Megatonnes over 20 years.

Table of contents

List of figures

List of tables

1 Introduction

Over the past decade, PV deployment has seen substantial growth in Australia. As of 31st December 2023, the country boasts 3.68 million PV installations, with a combined capacity exceeding 34.2GW, of which an estimated 15.1GW is on residential rooftops and around 6.9GW on other buildings [1]. Australia remains a global leader in residential solar deployment, with 35% of all houses having installed solar [2].

However, residential solar adoption is unevenly distributed across demographics. Although the link between household income and solar installation is questionable [3], access to solar is dependent on dwelling type and tenure. More specifically, most residential solar is installed on owner-occupied houses, typically occupied by older residents with higher incomes.

The surge in wholesale energy costs in Australia and subsequent increase in retail electricity prices has put pressure on low-income households[1], as they typically allocate a more substantial share of their household income toward energy expenses, yet these households are the least likely to access the benefits of low-cost rooftop solar. Installing solar on social and community housing, as well as incentivising installation on rental properties and apartments, could help ease the financial burden on some of Australia's most vulnerable households, ensure more equitable access to renewable energy and contribute significantly to the urgent decarbonization of the electricity system.

This report aims to explore this opportunity through application of the methodology underlying the APVI's SunSPOT[2] tool, as described in Section 5. Previous studies have provided estimates of the rooftop solar capacity of Australia's housing stock [4], of Australia's entire building stock, broken down by planning zone [5], and of Australia's social housing stock [6]. This report is based on similar methodology to these previous studies, but uses updated data and assumptions.

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1 https://www.theguardian.com/australia-news/2023/may/25/power-bills-to-rise-by-up-to-a-quarter-in-parts-of-australia-after-regulator-issues-market-default-decision

2 https://www.sunspot.org.au/

In particular, our analysis adds to previous studies by:

- combining a new, granular dwelling-level solar potential assessment of residential buildings across the City of Sydney (using 2022 City of Sydney FSE survey and 2020 LiDAR data) with the City of Melbourne analysis used for previous reports;
- updating the underlying assumptions in the method to account for current and future solar photovoltaic efficiencies;
- applying these refined per-dwelling solar capacities to the latest residential building data from the 2021 ABS Census; and
- including a detailed analysis by housing tenure and dwelling type to identify potential opportunities for effective policy intervention across Australian states and territories.

This assessment of physical rooftop capacity on residential buildings excludes small roof planes and heavily shaded roof areas, but does not account for a range of issues that will affect the feasibility of installing solar PV on all these areas, including connection constraints imposed by distribution network service providers (DNSPs) and/or potential grid capacity issues.

Section 2 of the report presents our findings for the residential solar potential and associated benefits in each state and territory and the top 20 commonwealth electoral divisions.
Section 3 summarise the opportunity, costs and impacts of installing solar across Australia's social housing, rental, and multi-occupancy housing sectors, in light of the policy importance of these housing categories. Section 4 suggests some potential policy approaches aimed at increasing deployment of rooftop solar across social housing, rental properties and apartment buildings. Section 5 describes the methods and assumptions used in the analysis and Section 6 presents a brief comparison of the findings with those from previous studies.

2 Solar potential by jurisdiction

2.1 National potential and impacts

The rooftop capacity for installing solar PV on houses and apartments across Australia is estimated to be 60.9 GW, of which around 25% (15.1 GW) is currently realised[3].

This potential is not uniformly distributed across different dwelling types; 94% of the potential (and almost all of the current installed capacity) is on houses, including stand-alone, semi-detached, terraces and townhouses. Figure 1 illustrates the distribution of this rooftop potential between houses and apartments, across social housing, private rental, and owner-occupied properties.

The existing 15.1GW of PV is installed across the roofs of approximately 3.29 million houses, leaving 5.70 million households (in houses and apartments) without solar. Although, anecdotally, the majority of the 15.1GW installed capacity is on owner-occupied houses, there is no detailed national data available to describe the distribution of installed capacity across building types and housing tenure. For that reason, this report focuses on the *total* rooftop capacity for each housing type, although the *unrealised* capacity is also shown for the national and state data.

[3] There is no record of whether installed rooftop PV is residential or commercial, so the cumulative total installed capacity of systems smaller than 10 kW is used as a proxy for residential systems. As of December 2023, this is 15.1GW [7].

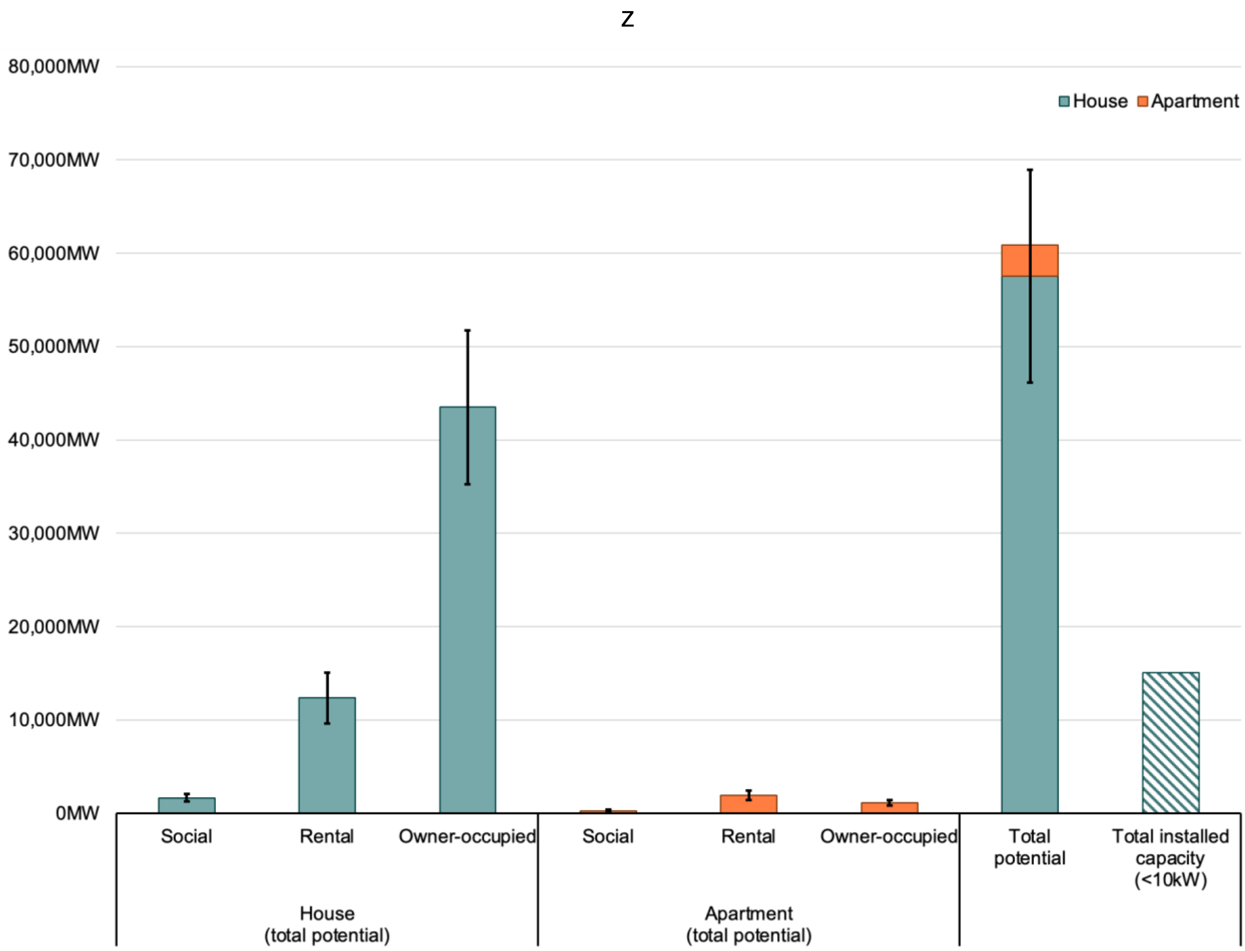

Figure 1 Solar potential of different dwelling types and tenures across Australia

The potential impacts of installing solar PV across this available rooftop capacity are shown in Table 1. There is approximately 46GW of unrealised solar potential on residential rooftops, which generate around 61 TWh of electricity annually which is approximately 22% of the total annual generation across Australia in 2022[4]. This is additional to the estimated 26GWh currently generated from residential solar.

Installing solar on the available and suitable rooftops of houses (including some unused roofspace on houses with existing, smaller PV systems) could save the residents around $8.6 billion[5] annually on their electricity bills, and realising the apartment potential could save another $0.7 billion.

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[4] https://www.energy.gov.au/sites/default/files/2023-08/Australian%20Energy%20Statistics%202023%20Table%20O_0.xlsx

[5] All financial information in this report is in Australian dollars (AUD)

Table 1 National impacts of solar deployment on Australian residential buildings

Building type	Tenure	Solar Potential (GW)	Annual energy (TWh)	Cost ($billion)	Job-years (1,000's)	Annual bill savings ($m)
Houses	Social Housing	1.7 (1.2 – 2.1)	2.2 (1.7 – 2.8)	1.8 (1.1 – 2.5)	8.7 (6.5 – 10.9)	360 (230 – 520)
	Private Rental	12 (9.7 – 15)	17 (13 – 20)	13.0 (8.6 – 18.0)	64 (50 – 79)	2,500 (1,700 – 3,600)
	Owner Occupied	44 (35 – 52)	58 (47 – 69)	45.0 (31.0 – 62.0)	230 (180 – 270)	8,900 (6,200 – 12,000)
Apartments	Social Housing	0.29 (0.2 – 0.38)	0.38 (0.26 – 0.5)	0.33 (0.22 – 0.47)	1.5 (1.0 – 2.0)	61 (36 – 93)
	Private Rental	1.9 (1.4 – 2.4)	2.5 (1.9 – 3.2)	2.5 (1.7 – 3.3)	10 (7.4 – 13.0)	400 (260 – 580)
	Owner Occupied	1.1 (0.84 – 1.4)	1.5 (1.1 – 1.9)	1.5 (1.0 – 2.0)	5.9 (4.4 – 7.4)	230 (150 – 340)
Total Potential		61 (49 – 73)	81 (65 – 97)	64 (44 – 89)	320 (250–380)	12,000 (8,600–18,000)
Existing installations		15.1	–	–	–	–
Unrealised potential		46 (34 – 58)	61 (44 – 77)	49 (31 – 71)	240 (170 – 300)	9,300 (5,900 – 14,000)

The potential social impacts include providing around 240,000 additional job-years of employment in the solar sales and installation industry, equivalent to employing 48,000 people for 5 years. Currently, almost all the solar panels and inverters installed in Australia are manufactured overseas, but there are signs of an emerging domestic industry, including the APVI's Silicon to Solar project [8] and the recent announcement of a polysilicon manufacturing facility [9]. Deployment of PV across the residential housing stock therefore has the potential to provide further employment in the manufacturing sector and support this emerging industry.

The realization of these economic and social benefits needs an estimated initial investment of $9.8 billion a year for 5 years across all building types and housing tenures. The appropriate allocation of these costs would vary by sector, but they would be returned in bill savings within 5.3 years, with the average annual household bill savings of $1,390 continuing for the operational lifetime of the solar PV systems, usually 20 years or more.

Furthermore, harnessing these unused rooftops could substantially reduce CO_2 emissions, contributing to Australia's emissions reduction targets. If all the solar potential of all Australia's houses were fully realised, approximately 726 Megatonnes (Mt) of CO_2 emissions could be avoided over 20 years, and a further 59 (Mt) of CO_2 emissions avoided by deploying solar on all apartment buildings. Figure 2 shows a break-down of these emissions reductions by tenure.

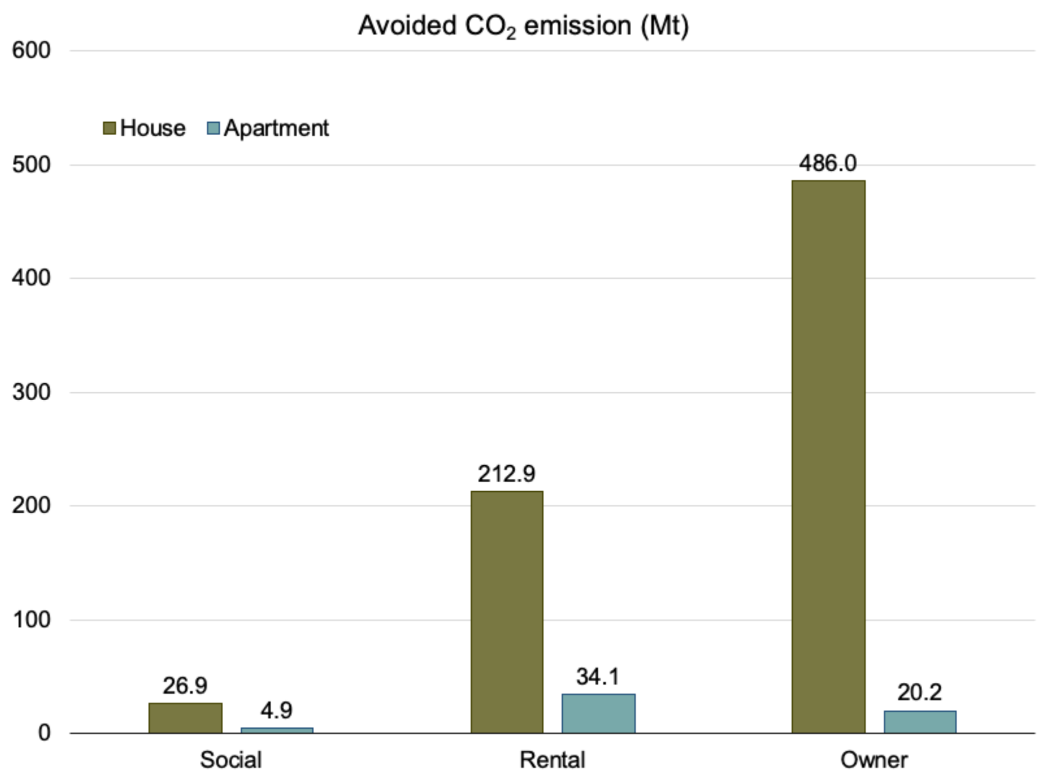

Figure 2 Potential avoided emissions over the 20-year operational lifespan of PV systems.

Two key metrics, the average payback time and bill savings per household serve as compelling evidence of the cost-effectiveness and financial advantages of solar system installation across various housing types (social, rental, and owner-occupied).

The average payback time and bill savings per household are shown below:

- House:
    - Social Housing:
        - Average Payback time: 4.9 years
        - Average annual bill savings per household: $1,358
    - Private Rental:
        - Average Payback time: 5.1 years
        - Average annual bill savings per household: $1,432
    - Owner Occupied:
        - Average Payback time: 5.2 years
        - Average annual bill savings per household: $1,560

- Apartment:
    - Social Housing:
        - Average Payback time: 5.5 years
        - Average annual bill savings per household: $680
    - Private Rental:
        - Average Payback time: 6.2 years
        - Average annual bill savings per household: $535
    - Owner Occupied:
        - Average Payback time: 6.3 years
        - Average annual bill savings per household: $524

2.2 State potential and impacts

Using data from the 2021 Census for the number of dwellings in each Australian state, the potential solar installation capacity for each tenure type (social housing, private rental and owner-occupied) for houses and apartments have been estimated, as well as annual energy generated, avoided CO_2 emissions and employment created.

The total unrealised residential solar potential for each state is shown in Figure 3

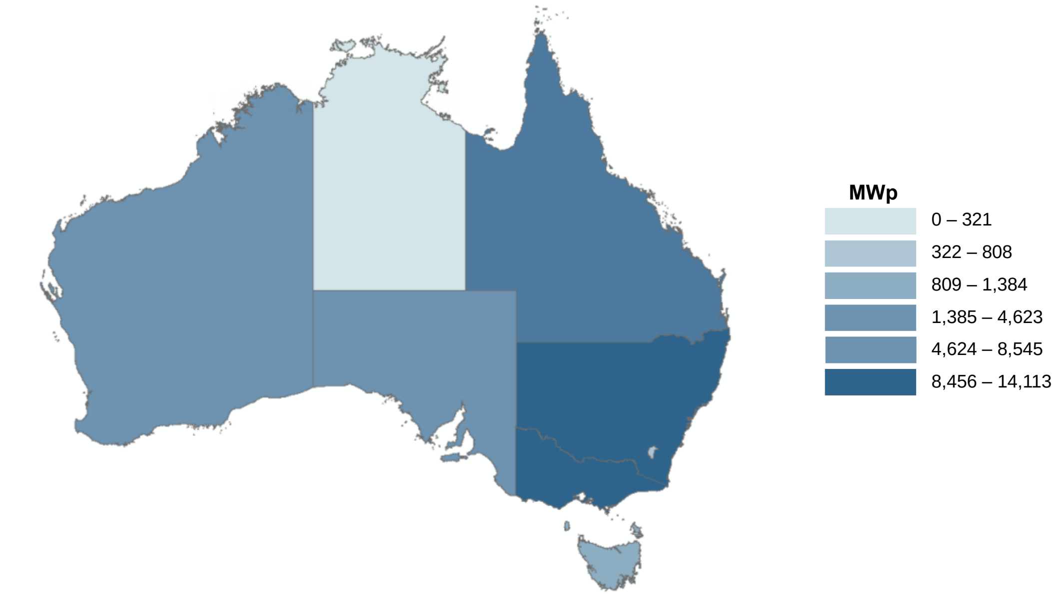

Figure 3 Estimated unrealised residential rooftop solar capacity by state

2.2.1 New South Wales

Table 2 illustrates the impact of solar potential installations in NSW. The estimated total residential solar potential in NSW is around 17.9 GW across all tenure and building types. The current installed capacity in NSW (3.82 GW [1]) has not been excluded from the figures presented in Table 2.

Table 2 Impacts of realising the total residential solar potential in NSW

Building types	Tenure	Solar potential (MW)	Annual energy (GWh)	Cost ($m)	Annual bill savings ($m)	Job-years	Lifetime avoided CO2 emissions (Mt)
House	Social Housing	510 (380 – 640)	660 (490 – 830)	470 (300 – 690)	110 (75 – 160)	2,700 (2,000 – 3,300)	9 (6.7 – 11)
	Private Rental	3,400 (2,600 – 4,100)	4,400 (3,400 – 5,300)	3,200 (2,100 – 4,400)	740 (520 – 1,000)	18,000 (14,000 – 21,000)	60 (47 – 73)
	Owner Occupied	13,000 (10,000 – 15,000)	16,000 (13,000 – 19,000)	12,000 (8,100 – 16,000)	2,700 (2,000 – 3,600)	65,000 (53,000 – 78,000)	220 (180 – 270)
Apartment	Social Housing	130 (89 – 170)	160 (110 – 210)	140 (92 – 190)	28 (18 – 40)	660 (460 – 870)	2.3 (1.6 – 3)
	Private Rental	850 (650 – 1100)	1,100 (830 – 1,400)	1,000 (740 – 1,400)	190 (130 – 260)	4,400 (3,400 – 5,500)	15 (11 – 19)
	Owner Occupied	520 (400 – 640)	670 (510 – 820)	640 (460 – 840)	110 (78 – 150)	2,700 (2,100 – 3,300)	9.2 (7 – 11)
Total		**18,000** (14,000 – 22,000)	**23,000** (18,000 – 28,000)	**17,000** (12,000 – 24,000)	**3,900** (2,800 – 5,200)	**93,000** (74,000 – 110,000)	**320** (250 – 380)
Unrealised potential		**14,000** (10,000 – 18,000)	**18,000** (14,000 – 23,000)	**14,000** (8,700 – 19,000)	**3,100** (2,100 – 4,300)	**73,000** (55,000 – 92,000)	**250** (190 – 310)

The average payback time and bill savings per household in NSW are presented in Table 3.

Table 3 Average payback time and annual bill savings per household in NSW

Building types	Tenure	Average Payback time (years)	Average annual bill savings per household ($)
House	Social Housing	4.3	1,372
	Private Rental	4.3	1,535
	Owner Occupied	4.3	1,658
Apartment	Social Housing	4.9	681
	Private Rental	5.6	532
	Owner Occupied	5.7	526

2.2.2 Victoria

VIC has the second-highest residential solar potential after NSW, estimated at around 15.9 GW. Table 4 provides an overview of the impact of unlocking the solar potential in VIC. The current installed capacity in VIC (3.07 GW [1]) has not been excluded from these figures.

Table 4 Impacts of realising the total residential solar potential in VIC

Building types	Tenure	Solar potential (MW)	Annual energy (GWh)	Cost ($m)	Annual bill savings ($m)	Job-years	Lifetime avoided CO2 emissions (Mt)
House	Social Housing	280 (210 – 350)	340 (260 – 430)	330 (200 – 500)	43 (27 – 61)	1,400 (1,100 – 1,800)	5.6 (4.1 – 7)
	Private Rental	3,200 (2,500 – 3,900)	3,900 (3,000 – 4,800)	3,800 (2,400 – 5,500)	490 (320 – 680)	16,000 (13,000 – 20,000)	63 (49 – 78)
	Owner Occupied	12,000 (9,400 – 14,000)	14,000 (12,000 – 17,000)	14,000 (9,000 – 20,000)	1,800 (1,200 – 2,400)	61,000 (49,000 – 72,000)	230 (190 – 280)
Apartment	Social Housing	51 (36 – 66)	63 (44 – 82)	69 (46 – 95)	7.9 (4.7 – 12)	270 (190 – 340)	1 (0.72 – 1.3)
	Private Rental	430 (320 – 550)	540 (390 – 680)	620 (420 – 840)	67 (41 – 97)	2,300 (1,600 – 2,900)	8.7 (6.3 – 11)
	Owner Occupied	270 (200 – 350)	340 (240 – 430)	380 (260 – 520)	42 (26 – 61)	1,400 (1,000 – 1,800)	5.4 (3.9 – 7)
Total		**16,000** (13,000 – 19,000)	**20,000** (16,000 – 24,000)	**19,000** (12,000 – 27,000)	**2,400** (1,700 – 3,400)	**83,000** (66,000 – 99,000)	**320** (250 – 380)
Unrealised potential		**13,000** (9,600 – 16,000)	**14,000** (8,700 – 19,000)	**15,000** (9,400 – 23,000)	**2,000** (1,300 – 2,800)	**67,000** (50,000 – 83,000)	**260** (190 – 320)

The average payback time and bill savings per household in VIC are presented in Table 5. Payback periods in VIC are higher than in NSW and most other states, across all sectors. This is due to a combination of higher PV installation costs, low electricity prices, and lower PV yield. However, payback periods across all dwelling types and housing sectors are all considerably below expected system lifetimes.

Table 5 Average payback time and annual bill savings per household in VIC

Building types	Tenure	Average Payback time (years)	Average annual bill savings per household (AUD)
House	Social Housing	7.7	978
	Private Rental	7.7	1,065
	Owner Occupied	7.7	1,169
Apartment	Social Housing	8.8	442
	Private Rental	9.2	405
	Owner Occupied	9.0	426

2.2.3 Queensland

QLD has an estimated solar potential of 12.5GW across all residential buildings. The impact of realising the total potential capacity in QLD is presented in Table 6. The current installed capacity in QLD (3.96 GW [1]) has not been excluded from these figures.

Table 6 Impacts of realising the total residential solar potential in QLD

Building types	Tenure	Solar potential (MW)	Annual energy (GWh)	Cost ($m)	Annual bill savings ($m)	Job-years	Lifetime avoided CO2 emissions (Mt)
House	Social Housing	310 (230 – 380)	430 (330 – 540)	330 (220 – 450)	67 (42 – 110)	1,600 (1,200 – 2,000)	6 (4.5 – 7.4)
	Private Rental	3,000 (2,300 – 3,600)	4,200 (3,300 – 5,200)	3,200 (2,200 – 4,300)	660 (420 – 1,100)	15,000 (12,000 – 19,000)	58 (45 – 71)
	Owner Occupied	8,600 (7,000 – 10,000)	12,000 (9,900 – 14,000)	9,200 (6,700 – 12,000)	1,900 (1,300 – 3,000)	45,000 (36,000 – 53,000)	170 (140 – 200)
Apartment	Social Housing	56 (37 – 74)	79 (53 – 110)	68 (42 – 98)	12 (6.6 – 22)	290 (190 – 390)	1.1 (0.72 – 1.4)
	Private Rental	370 (270 – 470)	520 (380 – 670)	500 (340 – 690)	81 (48 – 140)	1,900 (1,400 – 2,400)	7.2 (5.2 – 9.2)
	Owner Occupied	190 (140 – 240)	270 (210 – 340)	270 (190 – 370)	43 (26 – 71)	1,000 (750 – 1,300)	3.8 (2.8 – 4.7)
Total		**13,000** (10,000 – 15,000)	**18,000** (14,000 – 21,000)	**14,000** (9,700 – 18,000)	**2,700** (1,800 – 4,400)	**65,000** (52,000 – 78,000)	**240** (200 – 290)
Unrealised potential		**8,500** (6,100 – 11,000)	**12,000** (8,600 – 16,000)	**9,300** (5,900 – 13,000)	**1,900** (1,100 – 3,200)	**44,000** (31,000 – 57,000)	**170** (120 – 220)

The average payback time and bill savings per household in QLD are shown in Table 7.

Table 7 Average payback time and annual bill savings per household in QLD

Building types	Tenure	Average Payback time (years)	Average annual bill savings per household (AUD)
House	Social Housing	4.9	1,459
	Private Rental	4.9	1,539
	Owner Occupied	4.9	1,701
Apartment	Social Housing	5.6	767
	Private Rental	6.2	603
	Owner Occupied	6.4	555

2.2.4 South Australia

The total solar potential of residential buildings in SA is estimated at 4.8GW. The potential impacts are shown in Table 8. The current installed capacity in SA (1.58 GW [1]) has not been excluded from these figures.

Table 8 Impacts of realising the total residential solar potential in SA

Building types	Tenure	Solar potential (MW)	Annual energy (GWh)	Cost ($m)	Annual bill savings ($m)	Job-years	Lifetime avoided CO2 emissions (Mt)
House	Social Housing	200 (140 – 250)	270 (190 – 350)	190 (110 – 290)	54 (36 – 74)	1,000 (740 – 1,300)	1.1 (0.81 – 1.4)
	Private Rental	890 (690 – 1100)	1,200 (950 – 1,500)	850 (530 – 1,200)	240 (170 – 320)	4,600 (3,600 – 5,700)	5 (3.9 – 6.1)
	Owner Occupied	3,500 (2,900 – 4,200)	4,800 (3,900 – 5,700)	3,400 (2,200 – 4,800)	960 (720 – 1,200)	18,000 (15,000 – 22,000)	20 (16 – 24)
Apartment	Social Housing	23 (14 – 31)	31 (19 – 42)	20 (12 – 29)	6.1 (3.6 – 9)	120 (74 – 160)	0.13 (0.081 – 0.17)
	Private Rental	90 (58 – 120)	120 (79 – 160)	41 (26 – 58)	24 (15 – 35)	470 (300 – 630)	0.51 (0.33 – 0.68)
	Owner Occupied	44 (29 – 60)	60 (40 – 81)	41 (26 – 58)	12 (7.3 – 17)	230 (150 – 310)	0.25 (0.16 – 0.34)
Total		**4,800** (3,800 – 5,800)	**6,500** (5,200 – 7,800)	**4,600** (2,900 – 6,500)	**1,300** (950 – 1,700)	**25,000** (20,000 – 30,000)	**27** (21 – 32)
Unrealised potential		**3,200** (2,200 – 4,200)	**4,400** (3,000 – 5,700)	**3,000** (1,700 – 4,700)	**870** (560 – 1,200)	**17,000** (12,000 – 22,000)	**18** (13 – 24)

The average payback time and bill savings per household in SA are shown in Table 9.

Table 9 Average payback time and annual bill savings per household in SA

Building types	Tenure	Average Payback time (years)	Average annual bill savings per household (AUD)
House	Social Housing	3.4	1,623
	Private Rental	3.5	1,895
	Owner Occupied	3.5	2,081
Apartment	Social Housing	3.3	1,056
	Private Rental	3.4	958
	Owner Occupied	3.4	922

The higher electricity prices in SA (averaging at $0.454 per kWh, compared to $0.282 per kWh in VIC) as well as high PV yield and low PV installation costs contribute to significantly lower payback time.

2.2.5 Western Australia

Table 10 shows the impact of solar potential in WA. The current installed capacity in WA (2.10 GW [1]) has not been excluded from these figures.

Table 10 Impacts of realising the total residential solar potential in WA

Building types	Tenure	Solar potential (MW)	Annual energy (GWh)	Cost ($m)	Annual bill savings ($m)	Job-years	Lifetime avoided CO2 emissions (Mt)
House	Social Housing	200 (150 – 250)	290 (210 – 360)	170 (110 – 250)	41 (25 – 61)	1,000 (750 – 1,300)	2.9 (2.1 – 3.7)
	Private Rental	1,400 (1,100 – 1,700)	2,000 (1,600 – 2,400)	1,200 (830 – 1,700)	290 (190 – 410)	7,200 (5,600 – 8,700)	20 (16 – 25)
	Owner Occupied	5,000 (4,000 – 5,900)	7,300 (5,900 – 8,600)	4,400 (3,100 – 5,800)	1,000 (700 – 1,400)	26,000 (21,000 – 31,000)	73 (59 – 87)
Apartment	Social Housing	15 (10 – 20)	22 (15 – 29)	14 (9.1 – 21)	3.1 (1.8 – 4.9)	78 (53 – 100)	0.22 (0.15 – 0.29)
	Private Rental	98 (71 – 120)	140 (100 – 180)	100 (68 – 140)	20 (12 – 30)	510 (370 – 650)	1.4 (1 – 1.8)
	Owner Occupied	52 (38 – 66)	76 (55 – 97)	53 (36 – 73)	11 (6.6 – 16)	270 (200 – 350)	0.76 (0.55 – 0.97)
Total		**6,700** (5,400 – 8,100)	**9,800** (7,900 – 12,000)	**5,900** (4,200 – 8,000)	**1,400** (930 – 2,000)	**35,000** (28,000 – 42,000)	**98** (79 – 120)
Unrealised potential		**4,600** (3,300 – 6,000)	**6,700** (4,800 – 8,700)	**4,100** (2,600 – 5,900)	**960** (570 – 1,400)	**24,000** (17,000 – 31,000)	**68** (48 – 87)

The average payback time and bill savings per household in WA are shown in Table 11.

Table 11 Average payback time and annual bill savings per household in WA

Building types	Tenure	Average Payback time (years)	Average annual bill savings per household (AUD)
House	Social Housing	4.2	1,292
	Private Rental	4.2	1,468
	Owner Occupied	4.2	1,599
Apartment	Social Housing	4.6	711
	Private Rental	4.9	570
	Owner Occupied	4.9	556

2.2.6 ACT

Table 12 shows the impact of solar potential in ACT. The current installed capacity in ACT (0.23 GW [1]) has not been excluded from these figures.

Table 12 Impacts of realising the total residential solar potential in ACT

Building types	Tenure	Solar potential (MW)	Annual energy (GWh)	Cost ($m)	Annual bill savings ($m)	Job-years	Lifetime avoided CO2 emissions (Mt)
House	Social Housing	52 (39 – 64)	71 (54 – 89)	57 (37 – 80)	11 (5.6 – 18)	270 (200 – 330)	1.1 (0.82 – 1.4)
	Private Rental	170 (130 – 210)	240 (180 – 290)	190 (120 – 270)	36 (19 – 61)	890 (670 – 1,100)	3.6 (2.8 – 4.5)
	Owner Occupied	740 (600 – 890)	1,000 (820 – 1,200)	830 (580 – 1,100)	160 (86 – 260)	3,900 (3,100 – 4,600)	16 (13 – 19)
Apartment	Social Housing	6 (4 – 7.9)	8.3 (5.6 – 11)	7.7 (5 – 11)	1.3 (0.58 – 2.3)	31 (21 – 41)	0.13 (0.085 – 0.17)
	Private Rental	39 (30 – 48)	54 (42 – 66)	63 (46 – 81)	8.3 (4.4 – 14)	200 (160 – 250)	0.83 (0.65 – 1)
	Owner Occupied	30 (23 – 36)	41 (32 – 50)	47 (34 – 61)	6.3 (3.3 – 10)	150 (120 – 190)	0.63 (0.49 – 0.77)
Total		**1,000** (820 – 1,300)	**1,400** (1,100 – 1,700)	**1,200** (820 – 1,600)	**220** (120 – 360)	**5,400** (4,300 – 6,600)	**22** (17 – 27)
Unrealised potential		**810** (590 – 1,000)	**1,100** (810 – 1,400)	**960** (570 – 1,400)	**170** (85 – 290)	**4,200** (3,100 – 5,300)	**17** (12 – 22)

The average payback time and bill savings per household in ACT are shown in Table 13.

Table 13 Average payback time and annual bill savings per household in ACT

Building types	Tenure	Average Payback time (years)	Average annual bill savings per household (AUD)
House	Social Housing	5.2	1,372
	Private Rental	5.2	1,397
	Owner Occupied	5.3	1,568
Apartment	Social Housing	6.1	726
	Private Rental	7.6	483
	Owner Occupied	7.5	483

2.2.7 Northern Territory

Table 14 shows the impact of solar potential in NT. The current installed capacity in NT (0.12 GW [1]) has not been excluded from these figures.

Table 14 Impacts of realising the total residential solar potential in NT

Building types	Tenure	Solar potential (MW)	Annual energy (GWh)	Cost ($m)	Annual bill savings ($m)	Job-years	Lifetime avoided CO2 emissions (Mt)
House	Social Housing	67 (53 – 81)	100 (80 – 120)	120 (83 – 160)	16 (12 – 21)	350 (280 – 420)	1 (0.79 – 1.2)
	Private Rental	110 (87 – 140)	170 (130 – 210)	200 (140 – 270)	27 (20 – 35)	580 (450 – 710)	1.7 (1.3 – 2)
	Owner Occupied	230 (180 – 270)	340 (280 – 400)	400 (290 – 530)	55 (42 – 69)	1,200 (950 – 1,400)	3.4 (2.7 – 4)
Apartment	Social Housing	3.6 (2.4 – 4.9)	5.4 (3.6 – 7.3)	7 (4.4 – 9.9)	0.88 (0.54 – 1.3)	19 (12 – 25)	0.054 (0.035 – 0.073)
	Private Rental	22 (16 – 28)	34 (24 – 43)	46 (31 – 62)	5.4 (3.7 – 7.4)	120 (84 – 150)	0.33 (0.24 – 0.43)
	Owner Occupied	9 (6.3 – 12)	13 (9.5 – 18)	18 (12 – 25)	2.2 (1.4 – 3)	47 (33 – 61)	0.13 (0.094 – 0.17)
Total		**440** (350 – 530)	**660** (520 – 800)	**780** (550 – 1,100)	**110** (80 – 140)	**2,300** (1,800 – 2,800)	**6.6** (5.2 – 7.9)
Unrealised potential		**320** (230 – 410)	**480** (350 – 620)	**580** (370 – 820)	**78** (53 – 110)	**1,700** (1,200 – 2,100)	**4.8** (3.4 – 6.2)

The average payback time and bill savings per household in NT are shown in Table 15.

Table 15 Average payback time and annual bill savings per household in NT

Building types	Tenure	Average Payback time (years)	Average annual bill savings per household (AUD)
House	Social Housing	7.2	1,755
	Private Rental	7.2	1,689
	Owner Occupied	7.2	1,878
Apartment	Social Housing	7.9	843
	Private Rental	8.4	641
	Owner Occupied	8.2	691

2.2.8 Tasmania

Table 16 shows the impact of solar potential in TAS. The current installed capacity in TAS (0.23 GW [1]) has not been excluded from these figures.

Table 16 Impacts of realising the total residential solar potential in TAS

Building types	Tenure	Solar potential (MW)	Annual energy (GWh)	Cost ($m)	Annual bill savings ($m)	Job-years	Lifetime avoided CO2 emissions (Mt)
House	Social Housing	67 (52 – 83)	82 (63 – 100)	87 (58 – 120)	14 (9.6 – 19)	350 (270 – 430)	0.21 (0.16 – 0.26)
	Private Rental	300 (240 – 360)	370 (300 – 440)	390 (270 – 530)	62 (45 – 82)	1,600 (1,300 – 1,900)	0.94 (0.75 – 1.1)
	Owner Occupied	1,200 (980 – 1,400)	1,500 (1,200 – 1,700)	1,500 (1,100 – 2,000)	250 (180 – 320)	6,200 (5,100 – 7,300)	3.7 (3 – 4.4)
Apartment	Social Housing	7.1 (4.5 – 9.7)	8.6 (5.4 – 12)	9.4 (5.5 – 14)	1.5 (0.83 – 2.2)	37 (23 – 50)	0.022 (0.014 – 0.03)
	Private Rental	24 (15 – 33)	29 (19 – 40)	32 (19 – 48)	5 (2.8 – 7.5)	130 (80 – 170)	0.075 (0.047 – 0.1)
	Owner Occupied	11 (7.1 – 15)	14 (8.7 – 19)	15 (8.7 – 22)	2.3 (1.3 – 3.5)	59 (37 – 80)	0.035 (0.022 – 0.048)
Total		**1,600** (1,300 – 1,900)	**2,000** (1,600 – 2,300)	**2,100** (1,500 – 2,800)	**330** (240 – 430)	**8,400** (6,800 – 10,000**)**	**5** (4 – 5.9)
Unrealised potential		**1,400** (1,100 – 1,700)	**1,700** (1,300 – 2,100)	**1,800** (1,200 – 2,500)	**280** (200 – 380)	**7,200** (5,600 – 8,800**)**	**4.3** (3.3 – 5.2)

The average payback time and bill savings per household in TAS are shown in Table 17

Table 17 Average payback time and annual bill savings per household in TAS

Building types	Tenure	Average Payback time (years)	Average annual bill savings per household (AUD)
House	Social Housing	6.3	1,394
	Private Rental	6.3	1,540
	Owner Occupied	6.3	1,633
Apartment	Social Housing	6.5	801
	Private Rental	6.5	804
	Owner Occupied	6.5	797

2.3 Potential by Commonwealth Electoral Division (CED)

2.3.1 Top 20 electorates

Utilizing ABS census data, the table below highlights the top 20 CEDs in Australia with a high solar potential. Additionally, estimates for the potential annual generation, job creation per year, and avoided CO_2 emissions throughout the lifespan of solar panels are provided for these capacities. The existing installed capacities are not excluded.

Table 18 The 20 CEDs with the high solar potential

CED	State	Solar PV Capacity (MW)	Annual Energy (GWh)	Avoided CO2 Emissions (kt/ 20 years)	Job-years
Mayo	SA	500 (410 – 590)	680 (560 – 810)	2800 (2300 – 3300)	2200 (1800 – 2600)
Blair	QLD	500 (400 – 590)	710 (570 – 840)	9700 (7900 – 12000)	1700 (1400 – 2000)
Barker	SA	490 (400 – 580)	670 (540 – 790)	2800 (2200 – 3300)	2000 (1600 – 2300)
Grey	SA	490 (390 – 580)	670 (540 – 800)	2800 (2200 – 3300)	1900 (1500 – 2200)
Spence	WA	490 (390 – 580)	660 (530 – 790)	2700 (2200 – 3300)	1700 (1400 – 2100)
Sturt	VIC	480 (380 – 590)	660 (510 – 800)	2700 (2100 – 3300)	1800 (1500 – 2200)
Brand	SA	480 (390 – 570)	700 (570 – 830)	7100 (5800 – 8400)	1900 (1500 – 2200)
Mallee	SA	480 (390 – 570)	590 (480 – 700)	9600 (7800 – 11000)	1900 (1600 – 2300)
Kingston	SA	480 (390 – 570)	650 (530 – 770)	2700 (2200 – 3200)	1900 (1600 – 2300)
Longman	NSW	480 (380 – 570)	680 (540 – 810)	9300 (7500 – 11000)	1800 (1400 – 2100)
Paterson	NSW	470 (380 – 570)	610 (490 – 730)	8400 (6800 – 10000)	1800 (1500 – 2100)
Makin	QLD	470 (380 – 560)	640 (520 – 760)	2700 (2200 – 3200)	1900 (1600 – 2300)
Gilmore	WA	470 (380 – 560)	610 (490 – 720)	8300 (6700 – 9900)	1900 (1500 – 2200)
Macarthur	NSW	470 (380 – 560)	610 (490 – 720)	8300 (6700 – 9900)	1700 (1400 – 2000)
Cowan	NSW	470 (370 – 570)	680 (540 – 830)	6900 (5400 – 8300)	1800 (1500 – 2200)
Page	NSW	470 (380 – 560)	600 (490 – 720)	8300 (6700 – 9900)	1900 (1500 – 2200)
Petrie	NSW	470 (370 – 560)	660 (530 – 800)	9100 (7300 – 11000)	1600 (1300 – 1900)
Burt	WA	470 (380 – 560)	680 (550 – 810)	6800 (5500 – 8100)	1800 (1500 – 2200)
Hunter	VIC	470 (380 – 550)	600 (490 – 720)	8300 (6700 – 9800)	1800 (1500 – 2200)
Calare	NSW	470 (380 – 550)	600 (490 – 720)	8300 (6700 – 9800)	1800 (1500 – 2100)

3 Solar potential by housing sector

Because the majority of existing residential solar is installed on owner-occupied houses and deployment in this sector remains high, it is useful to focus on the harder-to-reach sectors, specifically social and community housing, private rental properties, and apartment buildings.

3.1 Social and community housing

Table 19 presents a comparison of the state-wide solar potential of social housing in Australia, based on data from the AB. The estimated total solar potential (including existing installations) of social and community housing properties across Australia is approximately 2GW. Notably, NSW, QLD, and VIC have the highest shares of this solar potential.

Table 19 Impact of realising the total residential solar potential on social housing

State	Solar potential (MW)	Annual energy (GWh)	Lifetime avoided CO2 emissions (Mt)	Cost ($m)	Job-years	Annual bill savings ($m)
NSW	640 (470 – 810)	820 (600 – 1,000)	11 (8.3 – 14)	610 (390 – 880)	3,300 (2,400 – 4,200)	140 (92 – 200)
ACT	58 (43 – 72)	80 (59 – 100)	1.2 (0.91 – 1.5)	65 (42 – 91)	300 (220 – 380)	12 (6.2 – 21)
QLD	360 (270 – 450)	510 (380 – 640)	7 (5.3 – 8.8)	390 (260 – 540)	1,900 (1,400 – 2,400)	79 (48 – 130)
NT	71 (55 – 86)	110 (83 – 130)	1.1 (0.83 – 1.3)	130 (87 – 170)	370 (290 – 450)	17 (13 – 22)
SA	220 (160 – 290)	300 (210 – 390)	1.2 (0.89 – 1.6)	210 (120 – 310)	1,200 (820 – 1,500)	60 (39 – 83)
WA	210 (160 – 270)	310 (230 – 390)	3.1 (2.3 – 3.9)	190 (120 – 270)	1,100 (810 – 1,400)	44 (27 – 66)
VIC	330 (240 – 420)	410 (300 – 510)	6.6 (4.8 – 8.3)	400 (240 – 590)	1,700 (1,300 – 2,200)	51 (32 – 73)
TAS	74 (56 – 93)	91 (68 – 110)	0.23 (0.17 – 0.29)	97 (64 – 140)	390 (290 – 480)	15 (10 – 21)
Total	**2,000** (1,400 – 2,500)	**2,600** (1,900 – 3,300)	**32** (23 – 40)	**2,100** (1,300 – 3,000)	**10,000** (7,500 – 13,000)	**420** (270 – 610)

Harnessing this solar potential not only has the potential of saving an average of $420 million annually on electricity bills. Realising these benefits requires an initial investment of $420 million per year for 5 years. This investment is expected to generate approximately 10,000 job-years – or employ 2,000 people for 5 years - across Australia.

3.2 Private rental properties

The private rental properties throughout Australia have an estimated solar potential of 14GW, largely unrealised. The impacts are summarised in Table 20.

Table 20 Impact of realising the total residential solar potential on rental properties

State	Solar potential (MW)	Annual energy (GWh)	Lifetime avoided CO2 emissions (Mt)	Cost ($m)	Job-years	Annual bill savings ($m)
NSW	4,200 (3,300 – 5,200)	5,500 (4,300 – 6,700)	75 (58 – 92)	4,200 (2,800 – 5,800)	22,000 (17,000 – 27,000)	920 (650 – 1,300)
ACT	210 (160 – 260)	290 (220 – 360)	4.5 (3.4 – 5.5)	250 (170 – 350)	1,100 (830 – 1,400)	44 (23 – 74)
QLD	3,300 (2,600 – 4,100)	4,800 (3,700 – 5,800)	65 (51 – 80)	3,700 (2,600 – 5,000)	17,000 (13,000 – 21,000)	740 (460 – 1,200)
NT	130 (100 – 160)	200 (150 – 250)	2 (1.5 – 2.5)	240 (170 – 330)	700 (540 – 860)	33 (24 – 43)
SA	980 (750 – 1,200)	1,300 (1,000 – 1,600)	5.5 (4.2 – 6.8)	930 (580 – 1,400)	5,100 (3,900 – 6,300)	270 (190 – 350)
WA	1,500 (1,200 – 1,800)	2,200 (1,700 – 2,600)	22 (17 – 26)	1,300 (900 – 1,800)	7,700 (6,000 – 9,400)	310 (200 – 440)
VIC	3,600 (2,800 – 4,400)	4,500 (3,400 – 5,500)	72 (55 – 89)	4,400 (2,800 – 6,400)	19,000 (14,000 – 23,000)	560 (360 – 780)
TAS	330 (260 – 400)	400 (310 – 480)	1 (0.8 – 1.2)	420 (290 – 580)	1,700 (1,300 – 2,100)	67 (48 – 89)
Total	**14,000** (11,000 – 18,000)	**19,000** (15,000 – 23,000)	**250** (190 – 300)	**15,000** (10,000 – 22,000)	**74,000** (58,000 – 91,000)	**2,900** (2,000 – 4,200)

Unlocking this substantial solar installation potential needs an initial investment of $3 billion a year for 5 years and would result in an estimated annual saving of $2.9 billion on bills. With the right mechanism, these savings could benefit tenants and generate return on investment for landlords and investors. Over the 20-year lifespan of solar PV systems, in addition to significant bill savings across states, the avoided CO_2 emissions could potentially reach an average of 250 Mt. Moreover, if this solar potential is realized, it has the capacity to create 74,000 job-years across Australia.

3.3 Apartment buildings

According to the data presented in Table 21, the average solar installation capacity for apartments across Australia can reach up to 3.3 GW.

Table 21 Impact of realising the total residential solar potential on apartment buildings

State	Solar potential (MW)	Annual energy (GWh)	Lifetime avoided CO_2 emissions (Mt)	Cost ($m)	Job-years	Annual bill savings ($m)
NSW	1,500 (1,100 – 1,900)	1,900 (1,500 – 2,400)	27 (20 – 33)	1,800 (1,300 – 2,400)	7,800 (5,900 – 9,700)	330 (220 – 450)
ACT	75 (57 – 92)	100 (79 – 130)	1.6 (1.2 – 2)	120 (85 – 150)	390 (300 – 480)	16 (8.3 – 26)
QLD	620 (450 – 790)	880 (640 – 1,100)	12 (8.8 – 15)	840 (570 – 1,200)	3,200 (2,300 – 4,100)	140 (81 – 230)
NT	35 (25 – 45)	53 (37 – 68)	0.52 (0.37 – 0.67)	71 (47 – 96)	180 (130 – 230)	8.5 (5.7 – 12)
SA	160 (100 – 210)	210 (140 – 290)	0.88 (0.57 – 1.2)	140 (90 – 200)	810 (530 – 1,100)	43 (26 – 62)
WA	170 (120 – 210)	240 (170 – 310)	2.4 (1.7 – 3.1)	170 (110 – 230)	860 (620 – 1,100)	34 (21 – 51)
VIC	760 (550 – 970)	940 (680 – 1,200)	15 (11 – 19)	1,100 (720 – 1,500)	3,900 (2,800 – 5,000)	120 (72 – 170)
TAS	43 (27 – 58)	52 (33 – 71)	0.13 (0.083 – 0.18)	57 (33 – 84)	220 (140 – 300)	8.7 (5 – 13)
Total potential	**3,300** (2,500 – 4,200)	**4,400** (3,200 – 5,600)	**59** (44 – 75)	**4,300** (2,900 – 5,800)	**17,000** (13,000 – 22,000)	**690** (440 – 1,000)

4 Policy implications

More than a third of Australian houses have rooftop solar installed and the low cost, significant bill savings and consequent short payback periods [10] mean that, for owner occupiers, deployment on stand-alone, semi-detached, terrace houses and townhouses is likely to continue. However, there are potential policy measures that would improve household decision-making around solar (and battery) installation and therefore increase deployment and utilisation of available roof areas, as well as targeted policies that could support deployment specifically on rental dwellings, apartments and social housing. The federal government's proposed DER / CER roadmap [11] offers an opportunity to develop suitable policies to increase equitable access to rooftop solar and enable efficient and effective use of residential roofs.

4.1 General residential solar deployment

There is a need for impartial, accurate information about the costs and benefits of installing solar and batteries, and resources to support households in decision making about distributed energy resources (DER). This is being addressed by consumer decision-making tools like the APVI's SunSPOT [12] and information sites such as the federal government's Solar Consumer Guide, as well as state government resources.

- Further development of these resources, to include the impacts of electrification of space and water heating, cooking and transport, would support households in installing solar PV systems sized to suit future electrified loads, and likely result in bigger PV systems and better utilisation of available roof areas.

Connection limits and fixed export limits imposed by distribution network service providers (DNSPs) to address grid constraints. In many areas, households with single-phase grid connections are limited to 5kW inverters – even if most of their solar generation is consumed onsite. These 'blunt instrument' fixed limits risk forcing households to install smaller systems than are technically possible and economically beneficial. Some DNSPs are developing more sophisticated approaches, such as Dynamic Operating Envelopes, that only restrict solar exports at times when it is necessary to maintain grid security [13].

- Wider roll-out of dynamic grid management, as an alternative to fixed connection and export limits, would enable more efficient use of the distribution network and – by increasing network hosting capacity – better utilisation of building rooftops.

While government solar subsidy schemes targeting low-income house owners, such as NSW's Rebate Swap for Solar[6] help to address inequities in solar ownership, specific policies are needed to extend widespread deployment to apartment buildings and the rental sector.

4.2 Apartment buildings

There is potential to install an estimated 3.3GW of solar PV on Australia's apartment buildings, but the sector faces specific challenges, which include technical constraints, additional costs, and organisational and governance issues. While installation of solar PV to supply common property loads is relatively straightforward and is becoming more common, deployment of shared PV systems to meet apartment loads is still challenging.

Apartment owners and residents are often excluded from State government subsidies for solar and/or batteries, either explicitly or implicitly. Moreover, the diversity of the apartment buildings stock, and the complexities of decision-making within strata bodies, mean that appropriate system design is very building-specific, apartment owners and residents need additional support and advice to explore and cost available options. Additionally, solar installation on apartment buildings is likely to be more expensive than on houses for a number of reasons.

- Targeted subsidies for solar on apartment buildings, to support both feasibility studies and installation costs, are therefore needed to address the shortfall in this building sector. This could include extension of the Community Solar Banks scheme [14], with the explicit inclusion of strata properties, as well as jurisdictional initiatives such as the ACT's Solar for Apartments programme [15].

Governance arrangements for strata title are legislated by state and territory governments, and the voting threshold required to install solar (or other environmental upgrades) therefore varies by jurisdiction. NSW's Strata Schemes Management Amendment (Sustainability Infrastructure) Act 2021 [16] reduced the threshold required to implement 'sustainable infrastructure' upgrades from 75% to a simple majority, aligning with WA's 2019 update [17] to the state's Strata Titles Act.

- Harmonisation of strata regulation across all Australian jurisdictions with a 50%. Voting threshold for sustainability upgrades (including installation of solar or batteries, electrification of space and water heating and installation of electric vehicle charging infrastructure) would remove a significant barrier to strata decision making.

One way to distribute solar generation to multiple apartments from a shared rooftop system is through an Embedded Network. However, there are significant administrative hurdles to

[6] https://www.energy.nsw.gov.au/households/rebates-grants-and-schemes/rebate-swap-solar-offer

establishing an embedded network and to selling electricity through it. In Victoria, exemptions are available only where the embedded network supplies customers with 100% renewable electricity [18], a positive intent but a very high bar.

- The AER is currently consulting on its own exemptions framework [19], presenting an opportunity to allow exemptions (and reduce the administrative hurdle for establishing embedded networks) where the purpose is to distribute renewable electricity to apartments from a shared PV system to benefit residents.

4.3 Rental sector

The challenges of deploying solar on rental accommodation, including the significant issue of split incentives between landlords and residents, mean that the 14GW solar potential of this sector (of which 12.1GW is on houses) is largely untapped.

- Giving tenants visibility of the financial and other benefits of solar (as well as other sustainability upgrades) could allow these benefits to be reflected in rental rates, enabling landlords to recoup their investment costs. This could be achieved through mandatory disclosure of energy bills and/or of energy efficiency ratings.
- As well as through targeted subsidies, such as Solar Victoria's Solar Rebates for Rentals scheme [20], landlords could be incentivised to invest in solar (as well as other sustainability upgrades) if the associated capital costs could be offset through instant tax write-offs.

4.4 Social housing

Installing 2GW on the available rooftops of Australia's Social Housing stock would provide direct cost-of-living relief by reducing the energy costs of low-income households. Additionally, social and community owned apartment buildings provide a unique opportunity to develop and deploy solutions for shared solar in multi-occupancy housing, without the additional decision-making complexity of strata governance.

As with other sectors, installation of rooftop solar on social housing should be accompanied by broader sustainability upgrades, including installation of efficient lighting and appliances, and improving insulation and building fabric to reduce energy consumption. This is particularly important for buildings with very poor thermal performance, such as is common in remote First Nations communities.

- Additional funding to meet the rooftop solar potential of social housing Australia-wide can be met by extension of the Commonwealth Household Energy Upgrades Fund, with co-contributions from state and territory governments, ongoing until the solar potential of all social housing has been realised.

5 Methodology

5.1 Method outline

The method used for this study involved 3 steps.

Firstly, 2020 LiDAR data [21] for the City of Sydney local government area (LGA) was analysed to determine the slope, orientation and shading of building roof surfaces, and thence the solar insolation falling on each roof plane over a typical year was estimated. This process is based on the method underlying the APVI's SunSPOT tool [12] and has been used in prior research assessing solar potential of major Australian cities[4, 22, 23]. Discrete solar roof planes were identified and areas over 10m^2 in area and exposed to 80% of the annual insolation on an unshaded horizontal surface were designated as suitable for solar PV installation.

These roof areas were then mapped to specific buildings using building footprint data derived from the City of Sydney 2022 Floor Space and Employment (FSE) survey [24]. Buildings were filtered for residential primary use, and sorted by dwelling type (detached house, semi-detached, townhouse or terrace, and apartment) and by number of storeys. Using the rooftop solar potential and the number of dwellings for each residential building, the PV capacity per dwelling was calculated for different dwelling types.

Finally, the per-dwelling solar potential was applied to Australian Bureau of Statistics (ABS) census data on different dwelling structures and tenures. Based on the ABS census data, five types of dwelling structures are considered in this research: separate houses, semi-detached or townhouses, apartments with one or two storeys, apartments with three storeys and apartments with four or more storeys.

The method is illustrated in Figure 4.

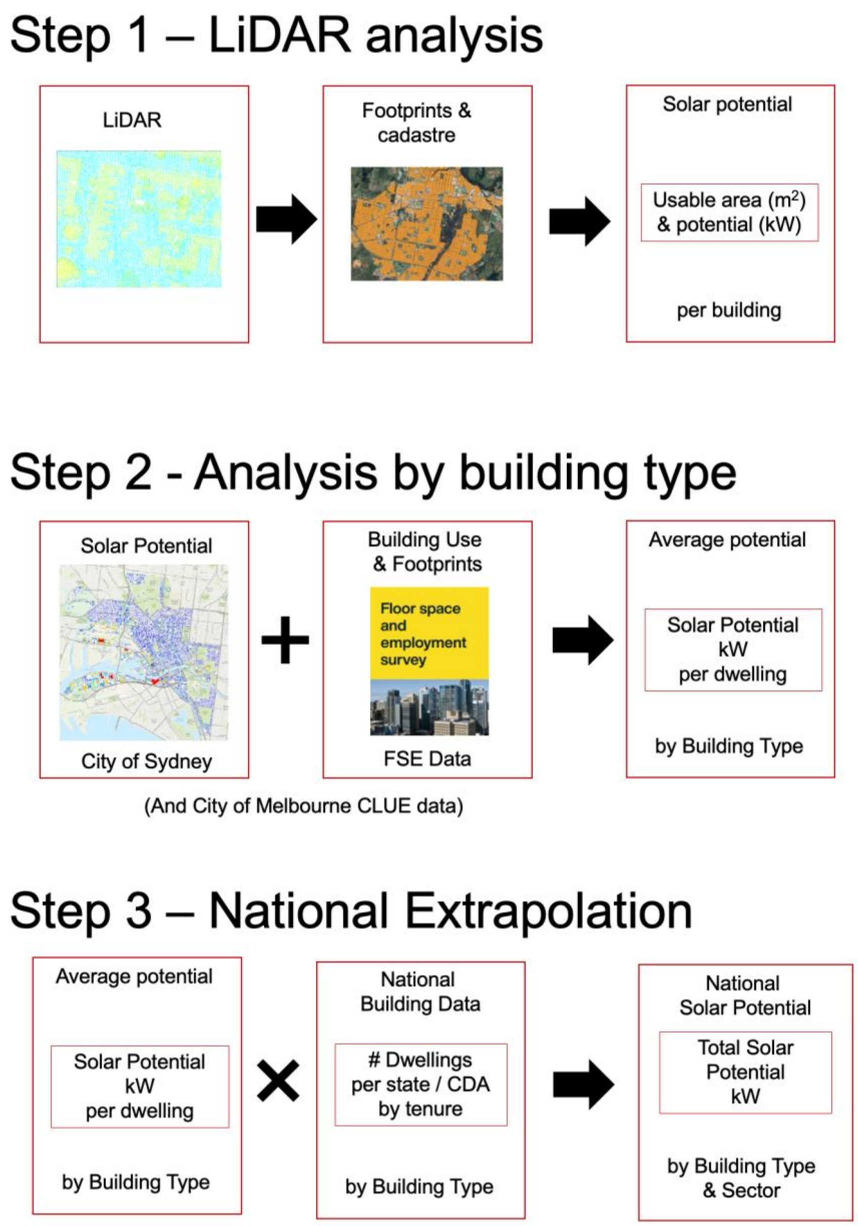

Figure 4 Method overview

5.2 Detailed LiDAR analysis

5.2.1 LiDAR methodology

The LiDAR methodology involves using LiDAR data as an input for ESRI's ArcGIS tool. The process is summarised in Figure 4. The LiDAR data is used to generate separate raster layers for slope and orientation. Areas of similar slope and orientation are then identified and divided into roof areas, which are mapped to individual buildings and properties using building footprints and property cadastres. The annual insolation incident on each roof plane is calculated using the ArcGIS Hillshade tool and a Typical Meteorological Year (TMY) weather file [25].

Two methods are used to determine suitable roof areas for PV installation. The widely-recognized NREL method [26] compares the number of hours each plane is exposed to the sun over four representative days of a year with a minimum threshold, and excludes any planes facing southeast through the southwest. In the second method, roof areas that receive over 80% of the annual insolation on an unshaded horizontal plane, are designated as 'usable', i.e. suitable for PV installation. For both methods, roof planes with less than 10m^2 contiguous surface area are considered unsuitable (ensuring that any identified suitable plane can support a minimum 2 kWp PV system). Although these criteria are somewhat arbitrary, they exclude heavily shaded roofs and align with previous studies. The average of the 2 methods is used to estimate the total solar PV potential of each building, assuming a power density of 200W/m^2 and a PV module size of 1.75 m^2. Any roof plane with a slope of less than 10 degrees was treated as flat and a north-facing, rack-mounted system with tilt of 15º and suitable spacing to avoid self-shading was assumed.

Previous studies [27, 28, etc.] have compared the results obtained using high resolution Digital Surface Models (DSMs) to those obtained using publicly-available LiDAR data, and shown that the results from LiDAR data are typically lower than those from the DSM as the relatively low resolution results in over-estimation of roof obstructions and variations to slope and orientation, and therefore under-estimation of usable roof area. For this reason, a multiplying factor of 1.29 is applied to the LiDAR results for Sydney, equivalent to averaging the results derived from LIDAR and DSM estimates [27].

5.2.2 Results – City of Sydney

Table 22 shows the results of the City of Sydney analysis.

Table 22 Total usable area, PV system size and energy generation for each residential building type in the City of Sydney

Dwelling Type	# Buildings	80% Insolation method			NREL Method		
		Usable Area (Ha)	Potential Capacity (MWp)	Annual Energy (GWh)	Usable Area (Ha)	Potential Capacity (MWp)	Annual Energy (GWh)
House	1255	6.6	12.6	15.1	5.7	11.0	13.3
Townhouse	15501	19.0	35.9	42.8	18.3	34.7	41.2
1 or 2 storey apartment	262	4.5	8.8	11.0	4.5	8.8	11.0
3 storey apartment	392	8.1	15.9	19.4	7.0	13.7	16.9
4 or more storey apartment	1158	33.7	66.0	83.9	33.8	66.3	82.8
Total	**18568**	**71.9**	**139.2**	**172.1**	**69.3**	**134.4**	**165.1**

The total solar potential of the City of Sydney is estimated at 139 MWp across various residential building categories. Notably, the 4 or more storey apartment account for the highest share of this capacity, some 47%.

5.2.3 Building classification

Using the City of Sydney FSE survey [24] dataset attached to building footprints (which includes dwelling numbers in multi-occupancy buildings), the building footprints were mapped to the categories of dwelling type used in the ABS census.

Previous analysis [4] used a similar method and data from the City of Melbourne: the 2015 City of Melbourne building footprint [29]and the 2017 Census of Land Use and Employment (CLUE) [30], and the resulting per-dwelling data has been used for a number of reports[5, 6]. This City of Melbourne analysis is included here for comparison.

Table 23 shows the numbers of *dwellings* in each LGA according to the ABS 2021 Census of Population and Housing [31]. Note that, except for separate houses, these figures are not expected to align with the *building* numbers generated from the FSE and CLUE datasets for Sydney and Melbourne respectively. However, the analysis found the building categorisations from CLUE and FSE data are not fully aligned with the census data. In particular, the Melbourne CLUE data identified larger numbers of stand-alone houses, and lower numbers of semi-detached and terraces.

Table 23 Numbers of each dwelling type in Cities of Sydney and Melbourne LGAs

STRD Dwelling Structure	Sydney	Melbourne
Separate house	2,377	1,871
Semi-detached, row or terrace house, townhouse etc.	21,119	10,043
Flat or apartment in a one or two storey block	3,365	2,563
Flat or apartment in a three storey block	10,962	5,998
Flat or apartment in a four or more storey block	84,276	81,918

5.2.4 Synthesis – per-dwelling solar potential

Using the number of dwellings in each building, from the FSE data, the usable roof area per residential building in the City of Sydney was converted to usable area per dwelling. This is shown in Figure 5, as well as the usable area per dwelling from the City of Melbourne analysis [4].

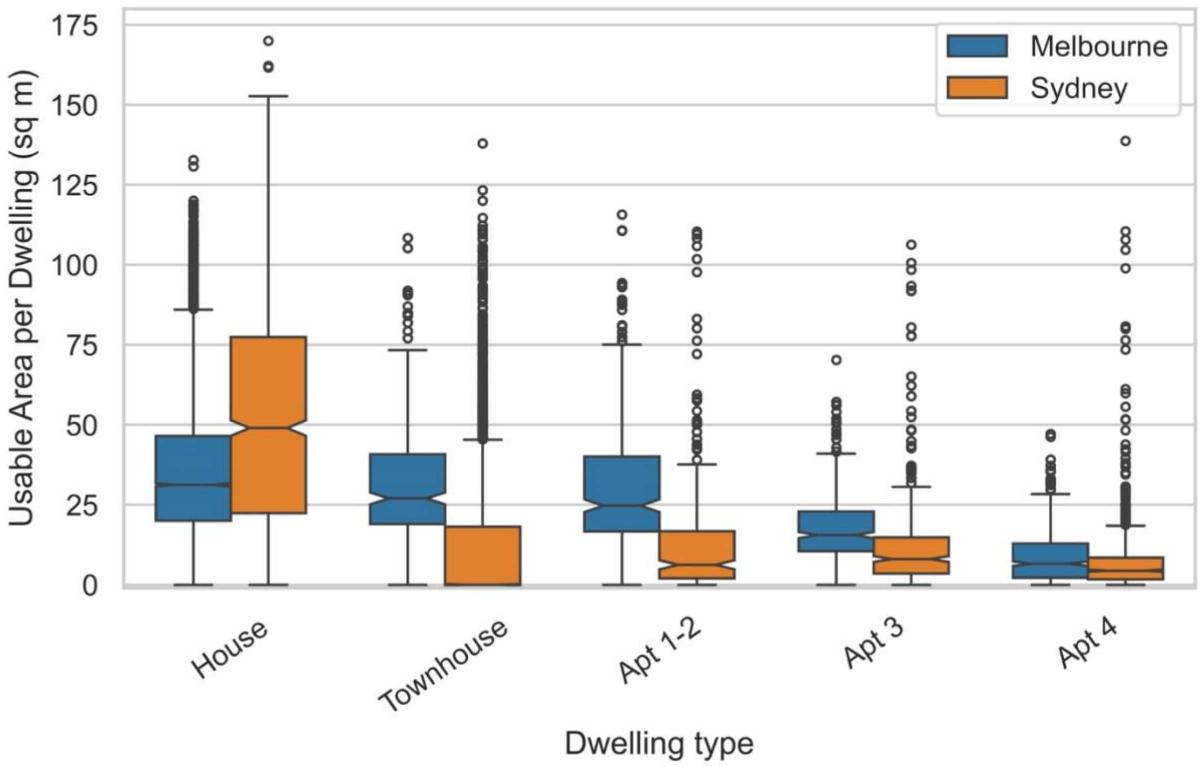

Figure 5 Usable roof area per dwelling in Cities of Sydney and Melbourne compared[7]

The usable area per dwelling derived from the 2 analysis is similar for stand-alone houses. However, the City of Sydney analysis suggests lower usable area for other dwelling types. In

[7] Horizontal lines show median area

particular, semi-detached, terraced and townhouses, as well as 1-3 storey apartment buildings, show much lower usable roof areas than suggested by the City of Melbourne study.

This discrepancy is likely due to a combination of different architectural characteristics of residential buildings in the two LGAs, different resolutions of LiDAR data used in the 2 studies. Anomalies in the CLUE and FSE datasets may also play a part.

For example, the relatively high PV capacity per dwelling for semi-detached and terraced houses derived from the Melbourne data may be partly attributed to miscategorisation of stand-alone houses as terraces. Conversely, the very low median usable area for value for semi-detached and terraced houses derived from the Sydney data may be due, in part, to some miscategorisation of apartments as terraces.

Because of the uncertainty in the results derived from both datasets, the kW-per-dwelling values used for the national, state and LGA analysis, as well as the breakdown by tenure and landlord type, use the *average* of the Sydney and Melbourne results shown in Table 24. The study revealed great diversity between buildings, so these values represent the average capacity across multiple buildings rather than the typical capacity for an individual building.

Table 24 Average solar PV potential kW per dwelling

Dwelling Structure	City of Sydney	City of Melbourne	Average
House	9.4	6.6	8.0
Terrace/Villa	2.0	5.9	4.0
1 or 2 storey Apartment	2.6	5.8	4.2
3 storey Apartment	2.3	3.5	2.9
4 or more storey Apartment	1.4	1.8	1.6

5.3 Application to national dwelling statistics

The 2021 Australian Bureau of Statistics (ABS) [31] Census of Population and Housing provides information on dwelling types in Australia, enabling an assessment of the solar potential of social housing, rental and owner-occupied properties and by geographic location. The average of solar potential per dwelling (from Table 24) was applied to these dwelling numbers to provide estimated solar potential for each state and LGA, by tenure and landlord type.

Table 25 shows the number of houses and apartments within social housing, private rental and owner-occupied categories across Australia. For simplicity, the ABS dwelling types have been combined into 2 categories: houses (including stand-alone, semi-detached, terraces and town houses) and apartments (including low, medium and high-rise buildings).

Table 25 Number and type of dwellings in Australia

	House		Apartment			
Residential groups	Separate house	Semi-detached or townhouse	Flat or apartment in a one or two storey block	Flat or apartment in a three-storey block	Flat or apartment in a four or more-storey block	Total
Social Housing	154,657	108,434	45,635	21,118	22,615	352,459
Private Rental	1,315,875	454,489	203,338	172,957	364,441	2,511,100
Owner Occupied	5,139,904	549,639	112,487	107,003	221,536	6,130,569
Total	**6,610,436**	**1,112,562**	**361,460**	**301,078**	**608,592**	**8,994,128**

5.4 Calculation of impacts

The annual energy that could be generated from solar PV installations on the available roofspace was calculated using the average yield (MWh per KW installed PV) for each state, derived from a previous study [5] which used NREL's System Advisor Model (SAM) [32] and typical year weather data files from Exemplary Energy [25], and assumptions about the distribution of orientation and slope of roof forms for each type of dwelling, and an average shading factor derived from the City of Melbourne LiDAR analysis.

The cost of systems was calculated based on average costs of quotes provided through Solar Choice [33] in August 2023 for standard and premium systems, sized according to the average rooftop capacity of each dwelling type. To account for the specific challenges associated with solar installation on apartment buildings, including roof access, and the additional infrastructure needed to enable sharing of solar systems between apartments, whether 'behind the meter' [31] or through an embedded network [32], an additional cost was added as follows:

- Apartment (1 or 2 floors): +25%
- Apartment (3 floors): +37.5%
- Apartment (4 or more floors): +50%

Table 26 Per-kW solar system cost in each state

State	House	Semi-detached	Apartment (1 or 2)	Apartment (3 floors)	Apartment (4+ floors)
SA	$958 ($770 – $1,145)	$900 (4710 – $1,090)	$848 ($808 – $888)	$1,244 ($1,140 – $1,348)	$1,305 ($1,140 –$1,470)
QLD	$1,068 ($960 – $1,175)	$1,074 ($950 – $1,197)	$1,090 ($993 – $1,188)	$1,578 ($1,438 – $1,719)	$1,656 ($1,438 – $1,875)
ACT	$1,119 ($970 – $1,268)	$1,065 ($920 – $1,210)	$1,078 ($1,005 – $1,150)	$1,749 ($1,643 – $1,856)	$1,834 ($1,643 – $2,025)
NT	$1,765 ($1,560 – $1,971)	$1,780 ($1,570 – $1,991)	$1,879 ($1,795 – $1,963)	$2,137 ($1,992 –$2,283)	$2,241 ($1,992 – $2,490)
TAS	$1,290 ($1,130 – $1,450)	$1,303 ($1,110 – $1,496)	$1,269 ($1,151 – $1,388)	$1,897 ($1,703 – $2,090)	$1,992 ($1,703 – $2,280)
VIC	$1,190 ($960 – $1,420)	$1,179 ($940 – $1,418)	$1,105 ($1,035 – $1,175)	$1,692 ($1,554 – $1,829)	$1,775 ($1,554 –$1,995)
NSW	$940 ($800 – $1,079)	$901 ($750 – $1,053)	$872 ($807 – $938)	$1,367 ($1,276 – $1,458)	$1,433 ($1,276 – $1,590)
WA	$877 ($770 – $984)	$876 ($760 – $992)	$868 ($785 – $950)	$1,145 ($1,080 – $1,210)	$1,200 ($1,080 – $1,320)

Household bill savings from rooftop solar depends on the proportions of generation self-consumed on site (avoiding payment for grid electricity) and exported (in return for a feed-in-tariff or FiT).

The analysis assumes a value of 32% self-consumption, derived from analysis of export data for 300 solar households. Retail prices paid for grid electricity vary by distribution network and retailer. For each state, the rates charged by the 3 largest retailers for each DNSP from July 2023, were used to calculate minimum, maximum and average rates for both imported electricity and feed-in-tariff (Table 27).

Table 27 Typical retail electricity usage and FiT rates by state from July 2023

	Electricity rate ($/kWh)			FiT ($/kWh)		
	min	**average**	**max**	**min**	**average**	**max**
NSW	0.331	0.364	0.408	0.070	0.077	0.084
QLD	0.288	0.311	0.333	0.050	0.081	0.148
VIC	0.227	0.282	0.329	0.049	0.051	0.054
NT	0.281	0.281	0.281	0.091	0.106	0.121
SA	0.435	0.454	0.473	0.066	0.080	0.094
WA	0.308	0.308	0.308	0.030	0.065	0.100
ACT	0.199	0.301	0.412	0.060	0.083	0.110
TAS	0.245	0.281	0.300	0.109	0.116	0.132

Annual avoided CO_2-e emissions reductions from deployment of these solar PV systems was calculated by multiplying the indirect (Scope 2) emissions factor for consumption of electricity purchased from the grid in each state [34] by the expected annual energy generation from the systems over the 20 year module lifetime, and subtracting the estimated embodied carbon emissions from the manufacture, installation, operation and decommissioning of the PV system (0.045kg CO2-e/kW) [35].

The employment generated by solar PV deployment is primarily in sales and installation, as most manufacture is currently offshore and solar is low maintenance. Nevertheless, it is estimated that each MW of rooftop solar requires 5.8 person-years of employment [36] and this factor was applied to the solar potential for each state to give the employment impact.

In order to accommodate the uncertainty within our dataset, we have incorporated a range of values to represent the variability in the outputs. While our discussion primarily focuses on the mean value, the tables and figures depict the mean, lower bound, and upper bound as Mean (lower - upper).

6 Comparison with previous estimates

Table 28 compares some key findings of this study – solar potential of all Australian residential buildings, apartment buildings and social housing, as well as NSW social housing – with findings from previous studies.

Table 28 Key findings compared with previous studies

	All residential buildings (total capacity)	All residential buildings (unused capacity)	Apartment buildings	Social housing (Australia)	Social housing (NSW)
This study	61 GW (49 – 73)	46 GW (34 – 58)	3.3 GW (2.5 – 4.2)	2.0 GW (1.4 – 2.5)	640 MW (470 – 810)
Analysis of rooftop solar potential on Australian residential buildings (2018) [4]	43 – 61 GW	–	2.9 – 4.0 GW	–	–
How much rooftop solar can be Installed in Australia? (2021) [5]	96 GW		–	–	
Solar Potential of Australian Social Housing Stock (2021) [6]		**–**	**–**	1.8 GW	
Solar Potential of NSW Social Housing Stock factsheet (2023) [37]	–	–	–	–	650 MW

The findings from this study, though more comprehensive, are broadly aligned with those from previous analysis using similar methodologies, including previous analyses of solar potential on social housing [6, 37] and slightly higher than the earlier analysis of Australia's housing stock [4]. The small discrepancies can be accounted for by:

- use of updated dwelling data from the 2021 Census,
- assumed PV power density of 200 W/m^2 (compared to 156 W/m^2 used in earlier studies) to account for improved PV efficiencies, and
- use of the new LiDAR analysis of City of Sydney rooftops, combined with previous City of Melbourne analysis, to estimate solar potential per dwelling.

The last factor has resulted in a higher estimate of per-dwelling PV capacity for stand-alone housing and lower estimates for apartments, terraces and semi-detached housing. To further refine these estimates, there is a need for granular analysis to better understand the discrepancies in both sets of spatial and building use datasets. Moreover, for a national analysis of the building stock, detailed LiDAR analysis of a range of geographic areas – including suburban and rural areas as well as urban - to better understand the diversity of rooftop potential. (Such a study is hampered by lack of linked building footprint and use data.)

The previous reports on social housing [6, 37] also included estimates based on 2019 dwelling numbers derived from the Australian Institute of Health and Welfare (AIHW) [38], which are higher than the numbers suggested by the 2016 and 2021 censuses. It is not clear which of the ABS or AIHW data is more accurate; however, the ABS census data has been used for this report as it is more recent and allows comparison across all housing sectors.

The 2018 CEFC-funded report "*How much rooftop solar can be Installed in Australia?*" [5] gives a much higher estimate of total residential solar potential (91GW) than that suggested by this report (61GW). However, the CEFC analysis used all buildings in residential planning zones as a proxy for residential buildings, and so likely included some non-residential buildings in the analysis. Additionally, the roof area data used for the study was based on building footprints derived from photogrammetry of aerial imagery [5]. Being a nationwide dataset, this would have included likely larger building footprints in regional and rural areas (compared to using roof areas from Cities of Melbourne and Sydney) and would therefore be expected to suggest a higher potential. However, the accuracy of these footprints is unclear as they were not able to be validated.

7 About the APVI

This report was produced by researchers in the School of Photovoltaic and Renewable Energy Engineering at UNSW Sydney for the Australian PV Institute and Solar Citizens.

The Australian PV Institute (APVI) is a not-for-profit, member-based organisation providing data analysis, reliable and objective information, and collaborative research to support the uptake of solar photovoltaics and related technologies. APVI promotes PV through its live solar mapping platform (http://pv-map.apvi.org.au), organises Australia's national solar research conference, and coordinates Australia's participation in two International Energy Agency programs: Photovoltaic Power Systems and Solar Heating and Cooling.

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

Please use the following citation for this document: 'Dehghanimadvar M, Roberts M, Bruce A, Egan R, *Solar for all?* Rooftop *solar potential of Australian housing stock by tenure and dwelling type (*2024). Solar Citizens / APVI.'

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