Using electricity bills to shine a light on rooftop solar photovoltaics in Australia

A comparison of prices, volumes and socio-economic rank of households with and without rooftop solar photovoltaics (PV) based on information in electricity bills

A report for Solar Citizens

Associate Professor Bruce Mountain and Dr Asli Kars

November 2018

Victoria Energy Policy Centre

VICTORIA UNIVERSITY MELBOURNE AUSTRALIA

SolarCitizens

Funded by LORD MAYOR'S CHARITABLE FOUNDATION

Disclosure: Data used in the report has been provided for research purposes to the Victoria Energy Policy Centre (VEPC) by CHOICE TRANSFORMER. These data are derived from analysis of electricity bills and retail market offers using MISwitcher software that Carbon and Energy Markets (CME) licences for CHOICE TRANSFORMER's use. Bruce Mountain is the Director of CME and the VEPC and the principal author of this report.

Publisher: Victoria Energy Policy Centre, Victoria University, Melbourne, Australia.

ISBN: 978-1-86272-791-5

DOI: 10.26196/mjqx-4904

November 2018

Citation: Mountain, B., and Kars, A. (2018). Using electricity bills to shine a light on rooftop solar photovoltaics in Australia. Victoria Energy Policy Centre, Victoria University, Melbourne, Australia.

Cover: Adobe Stock Photography (under license).

Table of contents

Index of Figures

Index of Tables

Executive summary

This report presents results from the analysis of electricity bills for households with and without rooftop solar photovoltaics (PV). For the purpose of this study, CHOICE provided the Victoria Energy Policy Centre (VEPC) with processed electricity bills for 10,051 households of which 2,062 have rooftop PV. In addition, we matched this processed bill data, by postcode, to socio-economic data from the Australian Bureau of Statistics (ABS) and, by address, to publicly available house price data scraped from domain.com.au.

The main points from the analysis in this study can be summarised as follows:

1. On average, households with rooftop solar PV buy about nine percent less electricity from the grid than households without PV. However, households with PV consume, on average, a quarter more electricity than households without PV.
2. Households with rooftop solar PV in New South Wales, Queensland[1], and South Australia pay slightly higher average unit (cents per kWh) prices for their grid-supplied electricity than households without PV. By comparison in Victoria, households with PV pay appreciably higher prices. This is explained by the appreciably higher fixed charges in Victoria. The fixed component of residential electricity bills in Australia generally, and in Victoria, in particular, is higher than in any other country we know of.
3. While the median (and average) retailer feed-in rate for rooftop solar PV electricity exported to the grid is around the loss-adjusted value of the annual spot price, in fact around one third of households in all states sell their electricity to their retailers at a rate that is lower than it would cost their retailers to buy that electricity in the spot markets. Retailers profit from this to the extent that they do not pass this on to other customers in lower prices.
4. The average bill reduction that Australian households with rooftop solar PV can achieve by finding the cheapest offer in the market is only slightly lower than the average saving that households without rooftop solar PV can achieve.
5. Rooftop solar PV uptake is proportionately more common in households in the middle and lower socio-economic deciles than in the higher socio-economic deciles. Rooftop solar PV uptake is proportionately the highest in the lowest socio-economic decile and lowest in the highest socio-economic decile.
6. Rooftop solar PV is proportionately more popular with people who live in less valuable houses than it is with people who live in more valuable houses.

1. Please note that the references to QLD in this report are to South East Queensland (the distribution area of Energex where retail markets are deregulated).

1 Introduction

This report has been prepared for Solar Citizens. It uses processed electricity bills for 10,051 households of which 2,062 have rooftop PV. This data has been provided to VEPC by CHOICE for the purpose of this study. In addition, we matched this bill data, by postcode, to socio-economic data from the ABS and, by address, to publicly available house price data scraped from domain.com.au.

These data can provide answers to a variety of topical questions, including:

1. How much electricity households who install rooftop solar PV consume, and how this compares to households without rooftop solar PV?
2. For households with rooftop solar PV, how much is produced, how much is exported and how much is used in the house?
3. How the feed-in price that households with solar PV receive for the electricity they export, compares to the spot price that retailers would otherwise have paid for that electricity?
4. For the electricity bought from the grid, do households with solar PV pay a higher or lower price, per kWh, than households without solar PV?
5. How does the annual electricity bill for households with or without solar PV differ?
6. Can households with solar PV save more or less than households without, by finding the best offer in the market?
7. Is there a relationship between PV uptake and the value of the house on whose roof the solar is installed, or the socio-economic rank of the suburb that the household with PV is located?

Section 2 describes the study methodology, and Section 3 presents the findings.

2 Methodology

CHOICE provided the VEPC with processed electricity bill data from 10,051 unique households that provided copies of their most recent electricity bills to CHOICE in connection with the service provided by CHOICE TRANSFORMER, which was launched in May 2018. These households are all located in the contestable retail electricity markets of New South Wales, Victoria, South-East Queensland or South Australia.

The processed data that CHOICE provided to VEPC included billing address, postcode, retailer, network service provider, state, annual consumption, the estimated annual bill, the estimated volume of solar exported to the grid (where applicable), the solar feed-in price (where applicable), and the estimated annual saving if the customer switched to the cheapest publicly available offer (as estimated by CHOICE).

Of the 10,051 households, 2,062 have rooftop PV, distributed by state and network service provider as shown in Table 1.

Table 1: Data summary

State	Distributor	Without PV	With PV
NSW	Ausgrid	2,369	320
NSW	Endeavour	772	230
NSW	Essential	509	230
QLD	Energex	1,125	498
SA	SA Power Networks	470	248
VIC	Ausnet	639	168
VIC	Citipower	512	41
VIC	Jemena	381	69
VIC	Powercor	516	146
VIC	United	696	112

In addition to the CHOICE dataset, we matched the bills' postcode to the 2016 postcode-specific Rank Within Australia – Decile – of the Index of Relative Socio Economic Advantage and Disadvantage provided by the ABS.[2] We also scraped the domain.com.au website to obtain mid-point house price estimates for the addresses shown on the bills. These data existed for more than 80% of the addresses. These two data items provide additional and independent measures that can support conclusions on the wealth and socio-economic rank of households with solar relative to those without solar.

In order to establish the rooftop solar PV generation for each household, we used (in reverse) a model with MI Switcher and applied by CHOICE TRANSFORMER to estimate the annual PV exports based on PV system size and household grid purchases. The model applied by CHOICE uses a Gaussian process regression to establish a bivariate model of annual solar PV exports based on a dataset established using capital-city specific rooftop solar export data obtained from repeated simulation of NREL's System Advisor Model.[3] The accuracy of this solar model was tested by reverse engineering to estimate of the solar PV capacity, using data from 450 households that had provided PV capacity data to CHOICE. The R-squared score of the difference between the estimate of the predicted PV capacity and the known PV capacity is 99.9% providing very high confidence in the accuracy of the bivariate estimation model.

2. http://stat.data.abs.gov.au/Index.aspx?DataSetCode=SEIFA_SSC
3. This model is used by CHOICE TRANSFORMER in the estimate of the annualised solar exports from customers' bills.

We estimate the weighted annual spot price for rooftop solar produced by the 2,062 household with rooftop solar PV, to be compared with the feed-in rates they received from their retailers for exported solar PV produced electricity. To estimate the weighed annual spot price, the Bureau of Meteorology (BoM) Gridded Solar Irradiance dataset[4] provided the hourly-irradiance profile for each postcode in Australia from June 2012 to July 2018. Using the hourly-irradiance profiles, the Python Package, PVlib[5], simulated the AC PV generation output for 35 typical PV tilt and azimuth orientations for each postcode; this provided a profile that captures non-optimal roof angles on average PV production. An average of the 35 profiles, normalised by installed capacity, provided the average hourly generation for a 1kW system in each postcode. An average of all postcodes in each state provided the average state generation profile. A linear interpolation between known points allowed upsampling of the hourly data to estimate half-hourly PV production for all spot price intervals. The average spot price provided for each state was determined using (1).

$$R^{State}_{year} = \frac{\sum_{i \in year} G^{PV}_{i,State} \cdot P_{i,State}}{\sum_{i \in year} G^{PV}_{i,State}} \quad (1)$$

where

R^{State}_{year} is the average feed-in rate offered for small-scale behind the meter solar PV generation and year refers to all financial year data from 1st July to 30th June

$G^{PV}_{i,State}$ is the average generation profile for a 1kW system for each state at index i

$P_{i,State}$ is the sport price for each state and index i.

4. http://www.bom.gov.au/climate/how/newproducts/IDCJAD0111.shtml
5. https://github.com/pvlib/pvlib-python

3 Findings

This section presents the findings and draws out the main points and illustrates them in charts. The appendix contains more detailed tables of the analysis of the data in each area.

3.1 Annual electricity consumption with and without rooftop PV

We examined how the annual electricity consumption compares for households with or without solar PV. The methodology for the calculation of gross solar produced was explained earlier and we know how much solar PV relevant households exported and so it is possible to deduce how much solar-produced electricity the households consumed, as shown in Figure 1. This shows that on average households with solar PV use a little over a third more electricity than they buy from the grid.

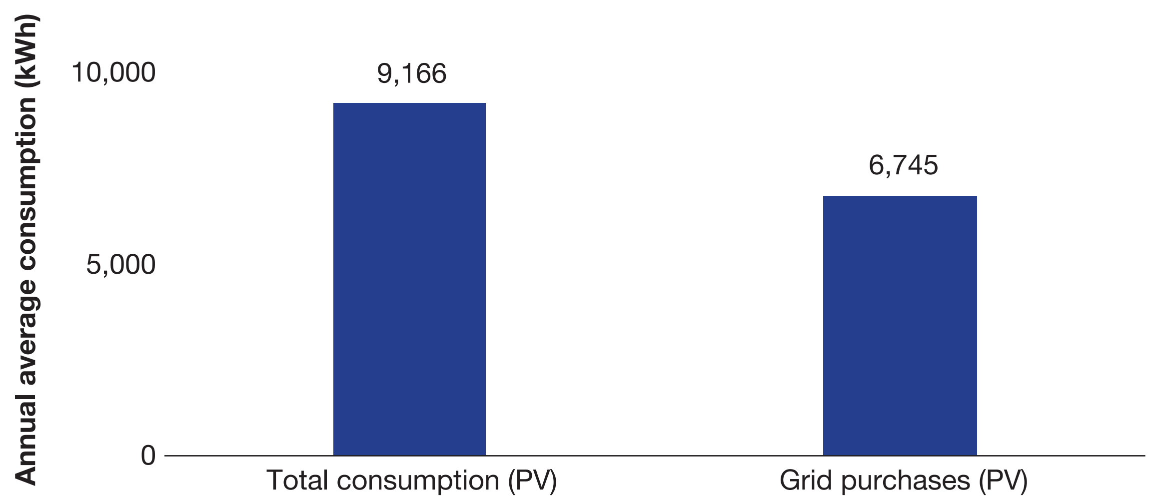

Figure 1: Annual average total consumption and grid purchases of households with PV

Using the bill data and the solar production estimator it is possible to compare the gross solar PV produced, the amount exported, and the amount used in the home where the solar PV is situated. The results of this are shown in Figure 2. This shows that households in SA use proportionately more of the solar PV produced than households elsewhere. This result suggests that consumers in SA seek to maximise their own use of their rooftop solar PV. Victoria has the lowest average PV production per household and also uses proportionately less relative to other households. This is as might be expected considering the relatively better feed-in rates in Victoria (relative to the variable charges in retail offers).

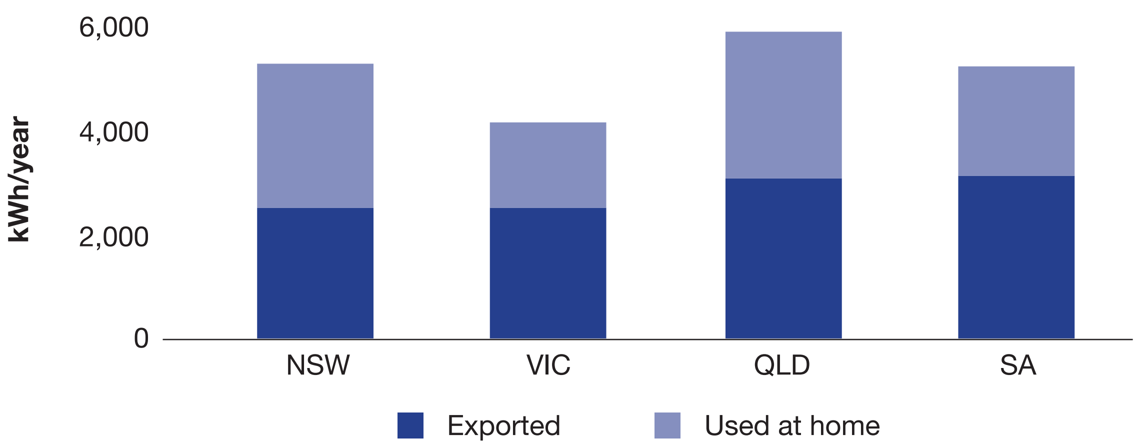

Figure 2: Residential PV production, export and self-consumption

Finally, Figure 3 compares how much electricity households with or without PV purchase from the grid. It shows that households without solar PV purchase about nine percent more electricity from the grid than households with solar PV.

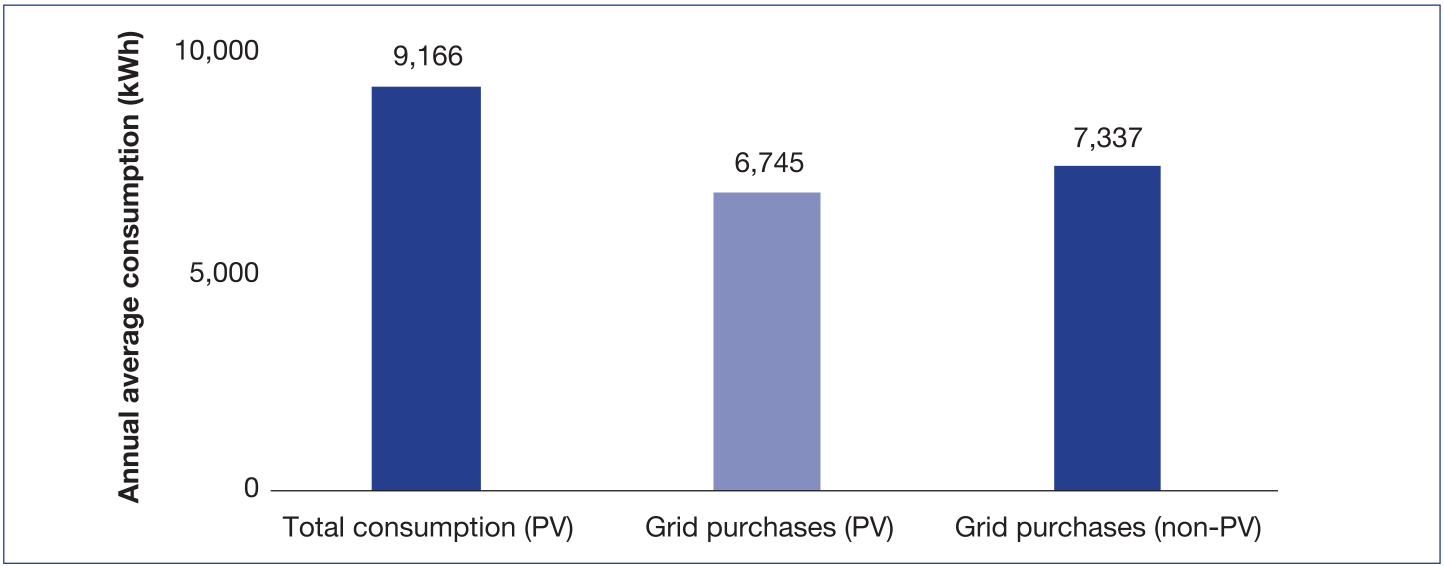

Figure 3: Purchases from the grid from households with or without PV

3.2 Average prices and bills with or without PV

Figure 4 shows the average unit price of electricity (before GST)[6] bought from the grid for households with and without PV in the four states. South Australia stands out as having appreciably higher pre-tax prices but other than in Victoria, households with rooftop solar PV pay slightly higher prices for their grid-supplied electricity than households without PV. By comparison in Victoria, households with PV pay appreciably higher prices. This is explained by the appreciably higher fixed charges in Victoria, relative to the variable energy charges. The fixed component of retail residential offers in Australia generally, and in Victoria, in particular, are higher than in any other country as far as we know.

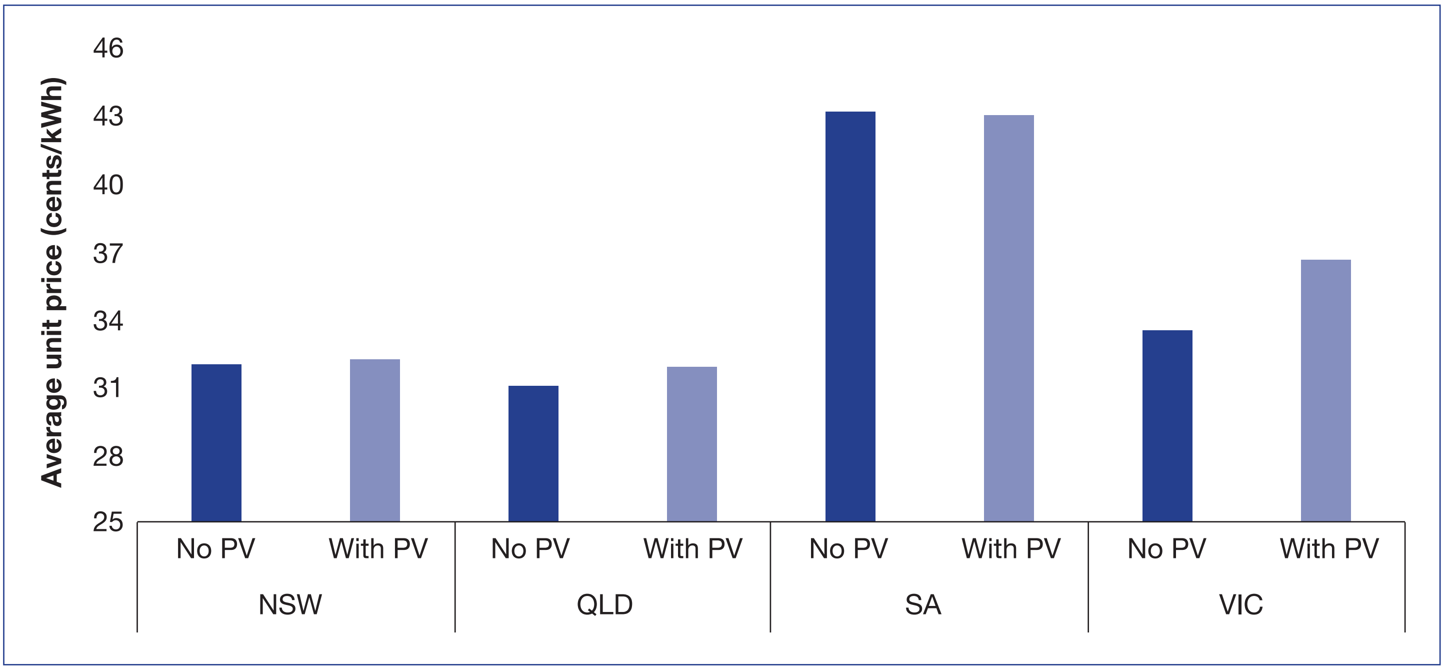

Figure 4: Average unit price for grid-supplied electricity (cents per kWh, before GST)

6. This is calculated as the total annual bill divided by the total annual consumption.

Figure 5 shows the distribution of prices across the dataset for households with or without solar PV. It shows the shift, as expected, to higher prices for grid-supplied electricity, as purchase volumes for households with PV are lower than households without solar PV. However, the shift is not large as the consumption of electricity from the grid for households with PV is in many cases comparable to the consumption of electricity in households without PV.

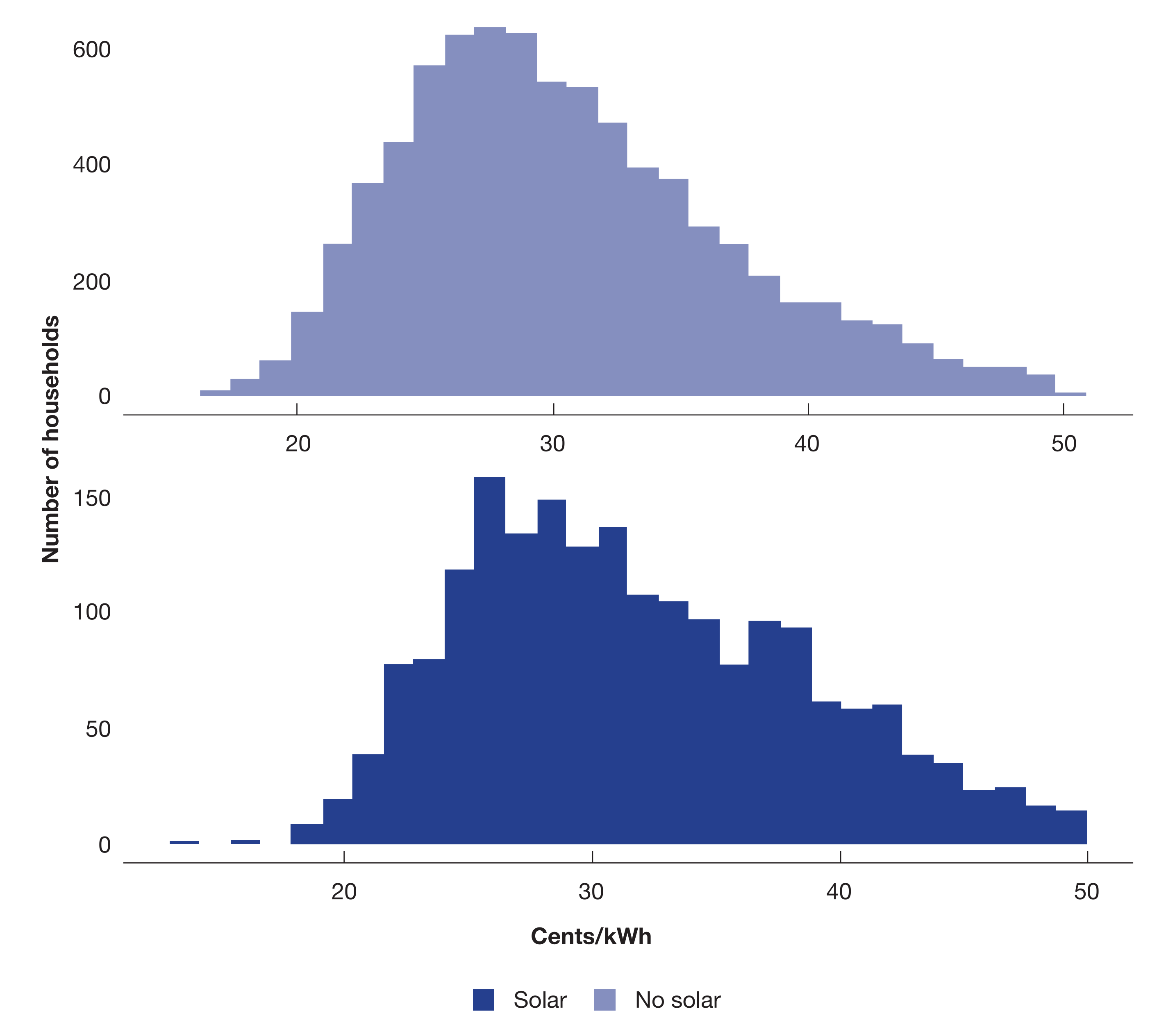

Figure 5: Distribution of prices for grid-supplied electricity (cents per kWh, before GST)

Figure 6 shows that on average households with solar PV have bills that are approximately 20% lower than households without solar PV. This is a consistent reduction across the states. Noting from Figure 3 that households with PV purchase from the grid on average about nine percent less than households without PV, part of the bill reduction shown in Figure 6 is accounted for by lower grid purchases. However, a large part of the bill reduction is accounted for by the export of electricity to the grid noting in Figure 2 that households with PV in NSW and QLD export about as much as electricity as they consume from their PV systems, and households in SA and VIC export more than they consume (from their own PV systems).

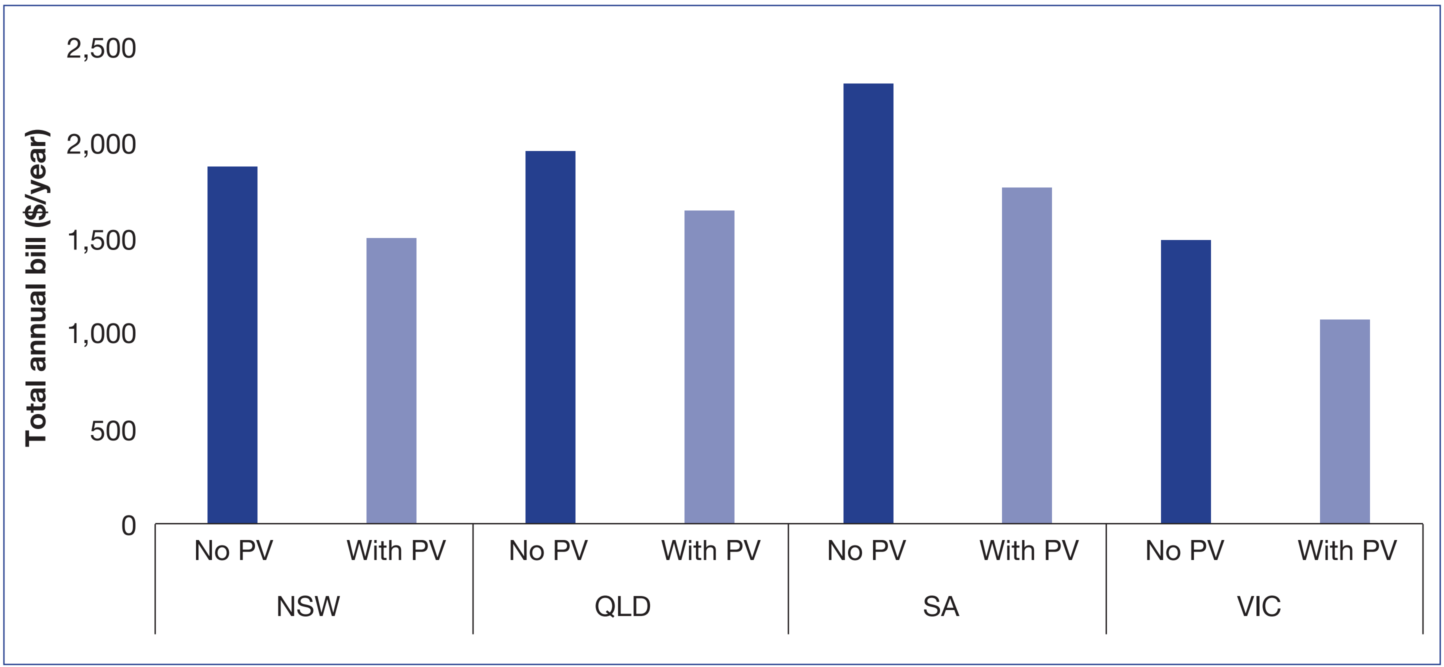

Figure 6: Total annual bill (after solar export but excluding cost of own-consumed PV, before GST)

3.3 PV export prices

Figure 7 presents histograms of the distribution of the retailer feed-in rates received by households with PV.

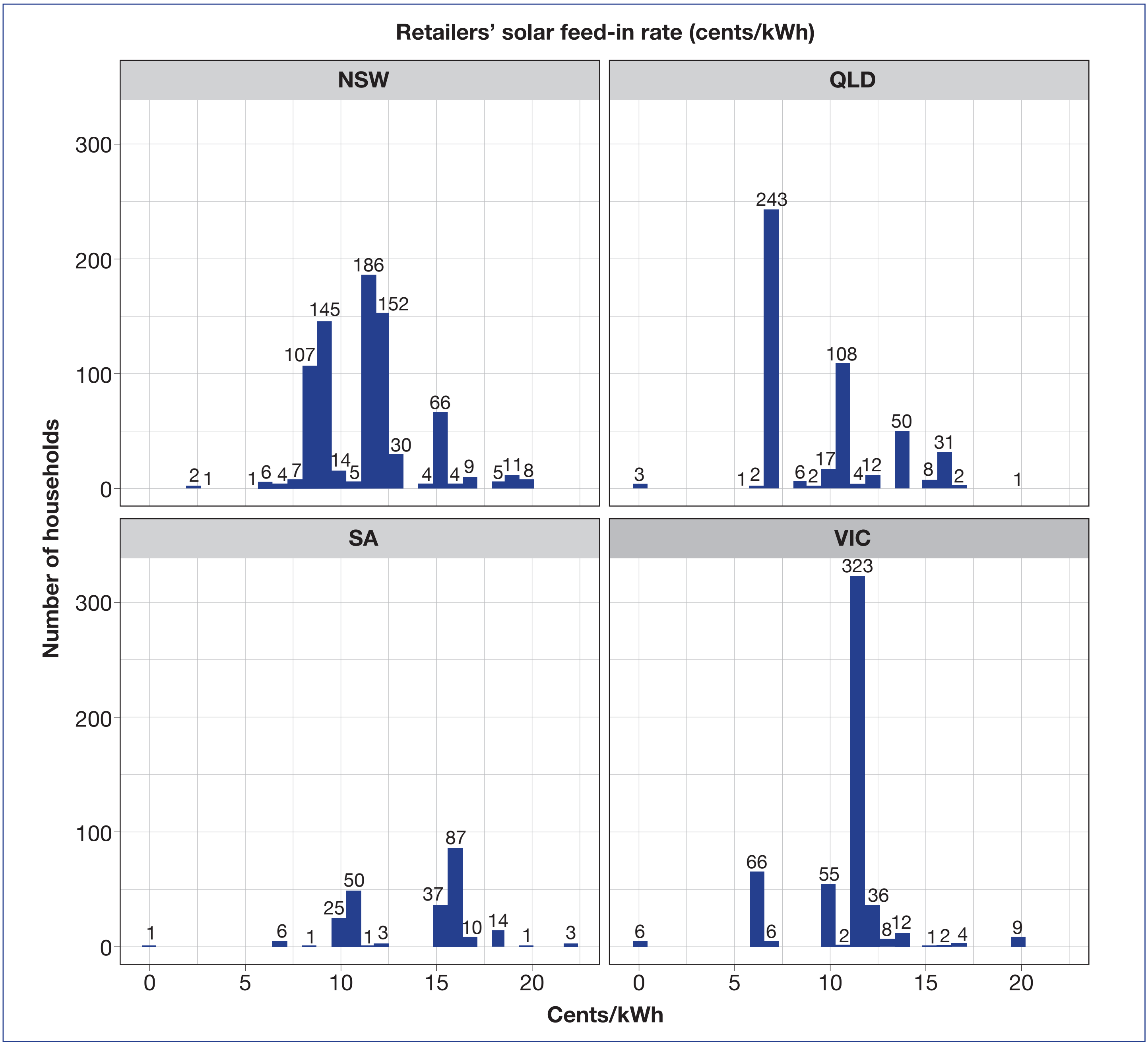

Figure 7: Export prices

The retailer feed-in prices in Figure 7 can be compared to the average distribution loss factor adjusted spot prices (using the methodology described earlier) in each state as shown in Table 2.

Table 2: 2017–2018 financial year profile adjusted spot prices before and after adjustment for Distribution Loss Factors (DLF)

State	Spot price before DLF	Spot price after DLF
NSW	8.2	8.7
VIC	10.7	11.5
SA	11.4	12.6
QLD	7.3	7.7

This comparison reveals that while the median (and average) retailer feed-in rate is around the loss-adjusted value of the annual spot price, in fact around one third of households in all states sell their electricity to their retailers at a rate that is lower than it would cost their retailers to buy that electricity on the spot markets. Retailers profit from this to the extent that they do not pass the benefit on to their other customers in the form of lower prices.

How should we interpret the information that some retailers are paying households considerably more than the demand-weighted spot price? It is plausible that retailers might value PV feed-in sourced? It is plausible that retailers might value PC feed-in sourced from retail contracts with households a bit more highly than the load-adjusted spot price since the retailers are getting a certain supply (measured over a period of several months) at a fixed price. Retailers expect to pay a premium for this (as they do in entering into price hedge contracts) as compensation for the greater certainty.

Some retailers, however, offer significantly higher feed-in rates than such certainty-adjusted spot prices. This raises the question of whether retailers are taking with one hand but giving with another (i.e. offering higher feed-in rates for energy purchased but also higher rates for the energy sold to these customers). We wished to subject the data to an econometric test to assess this, but the dataset is too small to draw statistically significant conclusions.

In some cases high feed-in rates are only achieved if the customer also installs a solar system supplied by the retailer. We can ignore these from the analysis since the rates need to be evaluated in the context of the solar installation deal. Our anecdotal examination of bills with premium feed-in rates is that they are associated with premium sales rates, and so anecdotally it is possible to conclude that the retailer is off-setting losses in the purchases of fed-in electricity with higher margins from the sale of electricity to those customers. However, even if this is not the case, it is not appropriate to conclude that retailers that choose to lose money in the prices they pay for fed-in electricity are imposing additional costs on other customers: there is a free market and retailers have no obligation to pay a premium for fed-in electricity relative to what they would pay to source the same electricity elsewhere.

3.4 Savings available by switching to the cheapest offers

The earlier analysis showed that households with solar PV have smaller electricity bills than households without, although they consume, on average about nine percent less. While the investment by households in solar PV typically reduce dependence on grid supplied electricity, households with solar have an additional point of commercial interaction with their retailers through the feed-in rate of the solar PV-produced electricity they export back to the grid. Moreover, the average saving that households with solar PV can achieve by finding the cheapest offer in the market is lower than the average saving that households without PV can achieve, as shown in Figure 8 (overleaf). The gap is not large (as expected) since the difference in grid consumption is, on average, also not large. However, as consumption from the grid increases available savings tend to increase.

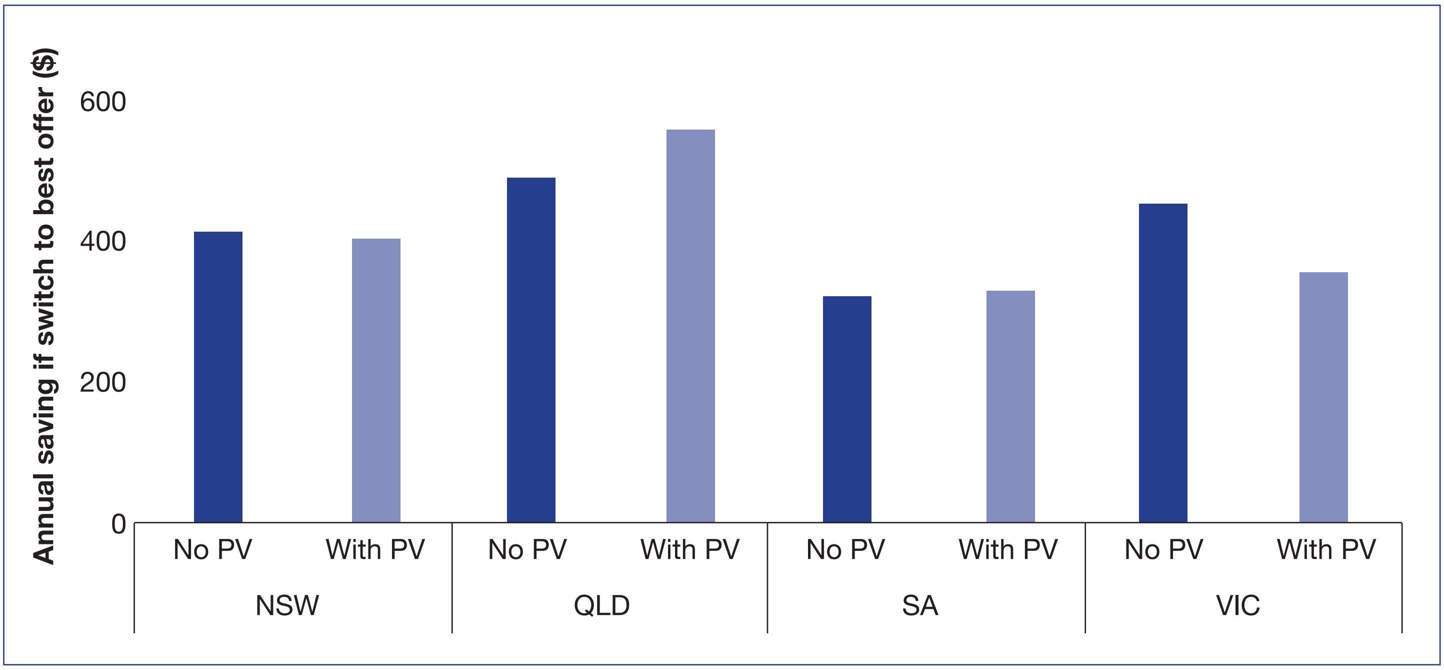

Figure 8: Average annual saving available by switching to the cheapest offer

3.5 PV uptake, socio-economic deciles and house prices

A prominent feature of Australia's[7] highly politicised energy policy debate is whether rooftop solar PV is positively associated with household wealth. It is argued that feed-in tariffs transfer wealth from lower-income residents to higher-income residents (on the basis of the assumption that households that install rooftop solar PV tend to be more affluent than households that don't) (Nelson, et al., 2011, Nelson, et al., 2012, Simshauser, 2016). However, Sommerfeld, et al. (2017) argues that PV owners cannot be categorised according to their income level. They also suggest that rooftop solar PV is positively associated with age and older people live in relatively lower socio-economic areas. Bondio, et al. (2018) stress that wealthy households are not interested in having residential solar PV, maybe because they are not concerned with uncertain future electricity prices. They support their argument with evidence that PV uptake is less likely in households with five or more bathrooms and as far as this suggests a wealthier household, PV uptake is less likely in wealthier households. They also note that retired consumers are more likely to adopt solar PV supported by evidence of disproportionately higher uptake amongst consumers who are more than 50 years old.

Our analysis of the CHOICE data suggest that PV uptake is more common in households in the middle and lower socio-economic deciles than in the higher economic deciles. Rooftop solar PV uptake is proportionately the highest in the lowest socio-economic decile and lowest in the highest socio-economic decile as shown in Figure 9 (overleaf).

7. Like the Australian literature, the international academic literature also shows a range of views on the relationship between rooftop PV uptake and household wealth. Belgian solar PV adopters are relatively wealthy, and they live in newer properties than non-adopters (Groote, et al., 2016). In Germany the percentage of residential consumers who own PV in the highest income band is 18% more than the consumers in the lowest income band (Grösche and Schröder, 2011). However, more recent studies claim that later German adopters are more likely to live in low-income areas (Müller and Rode, 2013, Rode and Weber, 2016). In Switzerland, PV adopters are upper-middle class consumers (Baranzini, et al., 2017). In Texas, households with PV have higher than average income (Rai and McAndrews, 2012). Similarly, Graziano and Gillingham (2015) find that it is the upper-middle class residents in Connecticut who install PV, although (Kwan, 2012) claim that middle-income households are more likely to install PV. Early British solar PV adopters, are upper-class consumers and likely to be home-owners (Keirstead, 2007). Caird, et al. (2008) argue that middle-class and older green consumers are interested in having solar PV, but only a small portion of them can afford the upfront cost. More recent studies suggest there is no correlation between household income and PV adoption in the UK (Richter, 2013), however a 2015 study also focusing on the UK argues that the effects of consumers' accumulated capital and financial savings are more important than income on the decision to install PV in homes (Balta-Ozkan, et al., 2015). Besides, Newbery, et al. (2018) state that even though poorer households are affected by higher electricity prices more strongly than richer households, the latter receive more PV subsidies in Europe.

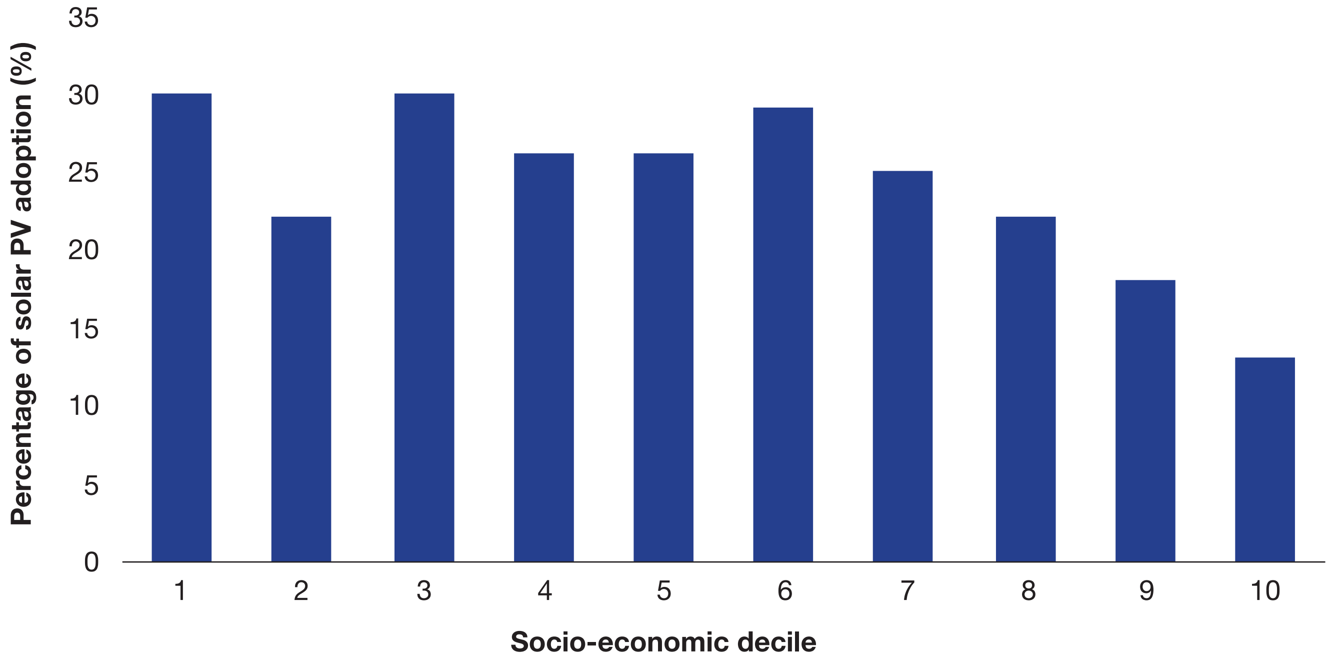

Figure 9: Proportion of households with PV within ABS socio-economic deciles

It might be argued that although households with PV tend to be proportionately higher in lower socio-economic postcodes, the households with PV might nonetheless be the wealthier households in those postcodes. An analysis of the estimated house value[8] of those houses with PV can provide additional information to test this argument. The result of this analysis is presented in Table 3. It shows the inverse relationship between rooftop solar PV uptake and socio-economic rank is similarly visible in the relationship between PV uptake and house value as shown in Table 3 below. These data show that proportionate rooftop solar PV uptake is inverse to the value of the house on whose roof it sits: rooftop solar PV uptake is more popular with people who live in less valuable houses than it is with people who live in more valuable houses.

Table 3: Relationship between house value, socio-economic decile and rooftop solar PV proportion

Socio-economic decile	Property value	Rooftop PV as percentage of all customers in decile
1	$465,089	30
2	$452,841	22
3	$477,171	30
4	$589,010	26
5	$582,951	26
6	$647,968	29
7	$770,425	25
8	$838,482	22
9	$1,015,555	18
10	$1,279,862	13

8. As noted earlier, the house values are the mid-point valuation as published on domain.com.au and the value shown in each row of Table 3 is the average value for households with PV in each decile.

Appendix A: Data tables

Table A1: Average annual saving available by switching to the cheapest offer

State	Has solar	Count	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
NSW	FALSE	3,650	$1	$148	$278	$414	$528	$6,609
NSW	TRUE	780	$2	$143	$269	$404	$514	$4,295
QLD	FALSE	1,125	$2	$191	$377	$491	$636	$8,732
QLD	TRUE	498	$2	$271	$481	$559	$763	$2,809
SA	FALSE	470	$2	$105	$219	$322	$434	$2,493
SA	TRUE	248	$1	$95	$204	$330	$445	$1,848
VIC	FALSE	2,744	$1	$198	$323	$454	$558	$5,449
VIC	TRUE	536	$11	$158	$270	$356	$444	$3,350

Table A2: Annual average total consumption and grid purchases of households with PV

Type	Min.	1st Qu.	Mean	Median	3rd Qu.	Max.
Actual use (PV)	142.7	4,787	9,166	7,618	11,690	50,850
Annual grid purchase (PV)	197	3,566	6,745	5,633	8,613	36,760
Annual grid purchase (no PV)	3	3,777	7,337	6,013	9,429	38,740

Table A3: Average unit price for grid-supplied electricity (cents per kWh, before GST)

Has solar	State	Count	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
FALSE	NSW	3,648	0.1522	0.2561	0.2904	0.3082	0.3354	3.1100
TRUE	NSW	780	0.1412	0.2541	0.2925	0.3118	0.3456	1.5100
FALSE	QLD	1,125	0.1932	0.2565	0.2817	0.3090	0.3203	8.0870
TRUE	QLD	498	0.1798	0.2588	0.2894	0.3040	0.3383	0.8388
FALSE	SA	470	0.2746	0.3590	0.3918	0.4020	0.4320	0.9480
TRUE	SA	248	0.2590	0.3616	0.3904	0.3991	0.4250	0.8570
FALSE	VIC	2,744	0.1683	0.2610	0.3040	0.3532	0.3554	15.8000
TRUE	VIC	536	0.1803	0.2809	0.3323	0.3636	0.4016	1.9910

Table A4: Total annual bill (after solar export but excluding cost of own-consumed PV, before GST)

Has solar	State	Count	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
FALSE	NSW	3,650	307	1,287.0	1,872	2,203	2,784	14,020
TRUE	NSW	780	-963	1,008.0	1,497	1,804	2,274	9,396
FALSE	QLD	1,125	372	1,456.0	1,953	2,255	2,688	10,960
TRUE	QLD	498	-2,807	1,072.0	1,642	1,802	2,362	7,390
FALSE	SA	470	419	1,538.0	2,308	2,614	3,285	13,420
TRUE	SA	248	-1,288	1,130.0	1,762	2,107	2,756	8,554
FALSE	VIC	2,744	314	1,089.0	1,486	1,770	2,116	9,265
TRUE	VIC	536	-1,057	671.8	1,070	1,246	1,597	8,006

Table A5: Export prices

State	Count	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
NSW	824	0.019	0.09	0.111	0.11170	0.125	0.20
VIC	563	0.000	0.10	0.113	0.10640	0.113	0.20
QLD	514	0.000	0.07	0.080	0.09601	0.110	0.20
SA	258	0.000	0.11	0.150	0.14180	0.163	0.22

Victoria Energy Policy Centre

Victoria University, PO Box 14428
Melbourne Victoria 8001 Australia
City Flinders Campus
Level 13, 300 Flinders St, Melbourne

vepc.org.au

Victoria Energy Policy Centre

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA