Griffith UNIVERSITY
Griffith Business School
Queensland, Australia

Centre for Applied Energy Economics & Policy Research: Working Paper Series 2021-06

Australian household adoption of solar photovoltaics: A comparative study of hardship and non-hardship customers

Tim Nelson and Tracey Dodd§
Level 6, 144 Edward Street
Brisbane, QLD, 4001.
October 2021.

Abstract
Australian hardship electricity customers, used in this study as a proxy for low-income tenants, have a higher electricity consumption and potential rate of solar energy self-consumption than standard customers: 36% and 26% respectively. Economic modeling, completed through this analysis, shows that deploying solar Photo Voltaic (PV) for low-income tenants could reduce annual grid-based electricity consumption by approximately 40% and lower greenhouse emissions by 1.6 tCO2e per household. Policy makers could overcome the split incentive problem that prevents the wide-scale installation of solar PV by low-income tenants through a new organizational and financial structure to account for the net present value of installing solar PV systems. The novel modeling method established through this paper advances international energy policy by providing a framework that can be used to analyze other electricity markets, with different service usage and pricing patterns.

Keywords: Electric Utilities, Energy Prices, Customer Hardship.
JEL Codes: D61, L94, L11 and Q40.

A peer reviewed version of this working paper was subsequently published as: Dodd, T. and Nelson, T. (2022), 'Australian household adoption of solar photovoltaics: A comparative study of hardship and non-hardship customers', Energy Policy, Vol. 160.

§Tim Nelson is an Associate Professor at Griffith University. Tracey Dodd is a Senior Lecturer at the University of Adelaide.

Centre for Applied Energy Economics and Policy Research

1. Introduction

Through the United Nations (2015) Framework Convention on Climate Change, 197 countries have agreed to work together to limit anthropogenic climate change to no more than 2 degrees Celsius above pre-industrial levels. For Australia, as a minimum, this requires greenhouse gas emission reductions of around 60% by 2030 and complete decarbonization by midcentury (see Climate Action Tracker, 2020; Meinshausen et al., 2021 for further information). To achieve this, Australia must transform the energy sector (both stationary energy and transport), which comprises 74% of net emissions, away from coal, toward renewable alternatives (Australian Government, 2020). Stationary energy, including household electricity use, accounts for the largest share of Australia's greenhouse gas emissions at 53.4%. These emissions include electricity generation (33.4%) and fuel combustion (20%). Thus, reducing greenhouse gas emissions produced through household electricity consumption remains critical for Australia to meet international climate change commitments.

Small-scale (or household) solar photovoltaics (PV) adoption is currently the most cost-effective means to reduce greenhouse gas emissions related to household electricity use in many parts of Australia (Australian Energy Regulator, 2021). This is because producing electricity at the point of consumption reduces transmission and distribution energy losses and can decrease infrastructure costs by 30% to 46% (Alshahrani et al., 2019; Australian Energy Regulator, 2021; Farrell, 2015). Increasing PV penetration beyond its current levels of around 33% of households (Clean Energy Regulator, 2020) is likely to require continued focus by governments. Scholars suggest that to increase household PV adoption; further research is required to understand the consequences of people who are currently excluded (Nelson et al., 2019; Zander, 2020).

In countries such as Australia, research shows that two cohorts are most disadvantaged in accessing household PV. This includes renters who would like access to solar PV but have low adoption due to "uncertainties about the costs and benefits" (Zander, 2020, p. 1). It also includes energy customers, known as "hardship customers", who have limited access to capital, which results in difficulty paying energy bills and investing in infrastructure to lower energy costs, including household PV (Nelson et al., 2019, p. 262). One of the considerations of existing policy design that warrants attention is the requirement for individuals to partially fund the installation of PV, which has led to low adoption. The capital outlay of PV installation, which in 2020 was estimated at approximately $4,000 for a 5 kW solar PV system (Australian Energy Market Operator, 2020), inhibits household PV adoption for both cohorts (Australian Competition and Consumer Commission [ACCC], 2021; Nelson et al., 2019).

However, renters face other barriers, such as approval from the landlord to install the system, as well as confidence that they will reside in the property for a period of time that would enable them to recover the costs of the system (Gillingham et al., 2012; Wood, Ong, & McMurray, 2012). This problem arises in relation to renters who are excluded from household PV as landlords have a low incentive to bear the economic cost of the system, as renters gain the financial benefit of lower electricity bills (Wood, Ong, & McMurray, 2012). This is an example of the split-incentive problem. While landlords who install solar on their property may increase the value of their asset, including the potential rental yield (Best et al., 2021), Australia faces a housing affordability challenge with 1 million low-income households (defined as <$22,760 income per annum) reporting housing stress (defined as a financial commitment of more than 30% of gross household income on housing costs) (Australian Institute of Health and Welfare, 2020). Hence, rental increases for low-income households may not be feasible, and the consequences of low PV adoption on rental properties have not been sufficiently explored (Charlier, 2015; Melvin, 2018). Initiatives have emerged to assist low-income renters to access the environmental and financial benefits of PV in Victoria, New South Wales and South Australia, through solar gardens (Rutovitz et al., 2018) and shared PV on community housing properties (Filatoff, 2020), yet these are not available at scale across Australia. Consequently, low-income households continue to be excluded from household PV, and spend approximately 8% of total disposable income on electricity each year, compared to 3.5% for average income households (Australian Energy Regulator, 2019; Dodd, Rai, & Caught, 2020). Thus, many people who are excluded from household PV are at risk of facing energy hardship, defined as an inability to pay energy bills (Daniel et al., 2020).

While the division of non-renters within the hardship cohort is not known, Simshauser and Nelson (2012) show that 62% of hardship customers in their Australian dataset were concession cardholders and thus in the lowest quintile of equivalised disposable income. Based on this, as well as recent data from the Australian Bureau of Statistics (ABS) (2019), which shows that 88% of households in the lowest quintile of equivalised disposable income rent, we use the hardship cohort as a proxy for low-income renters. This is also supported by Nelson et al. (2019). Moore et al. (2020) add that in Australia, around 40% of renters report difficulty in paying their energy bills and are either part of, or at risk of joining, the hardship cohort. Moore et al. (2020, p. 2) expand that while access to solar panels is unevenly distributed across the five income quintiles, low-income renters remain the most disadvantaged in terms of access, with 2% of renters have access to solar PV. Zander (2020), and others (see Best, Burke, & Nishitateno, 2020a; Nelson et al., 2019) argue that renters remain overlooked in relation to solar PV adoption policies, which favor owner-occupiers over rental households. Energy bills of low-income households are also the leading cause of rental arrears, which places people at risk of homelessness (ACCC, 2018). Further, people who face financial barriers to accessing energy find it challenging to manage the internal temperatures of their homes, resulting in increased health risks, such as cardiovascular disease (Maidment et al., 2014; World Health Organization, 2011). Nelson et al. (2019) argue that further scholarly attention toward increasing solar PV uptake by hardship customers who have trouble paying their energy bills, as a proxy for further understanding the costs and benefits of increasing renter solar PV takeup, is warranted.

The gap in practice and knowledge related to hardship take up of solar PV is problematic due to the associated negative environmental and social implications. Solar is now the cheapest form of electricity production in many parts of Australia (Dodd & Nelson, 2019), thus beyond the environmental implications (i.e., failure to meet Australia's greenhouse gas emission reduction targets), those excluded from household PV face social problems due to higher electricity bills (Nelson et al., 2019). Customers (and other businesses and households) can purchase electricity produced by renewable sources (known as GreenPower); however, this adds up to 50% to electricity bills (Potter, 2017; Choice, 2021). This is because the energy is not generated behind the meter, and costs of transmission and distribution (which comprise of up to 48% of the bill) are added to the cost of generating electricity (Australian Energy Regulator, 2021).

To date, the problems that individuals face from being excluded from accessing household PV has not been expansively modeled (Best & Trück, 2020). As a result, the scale of economic, environmental, and social costs and benefits are poorly understood, hindering progress toward the design of effective policy solutions to encourage greater household

PV adoption. To expand the body of work that examines solar PV adoption, we ask: what are the potential net benefits of solar PV on hardship customer homes versus standard customers and how could a market or policy solution be designed to increase PV installation on hardship households?

To answer this, we analyze electricity consumption data from an Australian energy retailer and model benefits by contrasting the costs and expected returns of PV. We select Australia as a case study due to the high solar PV adoption on owner-occupied dwellings and the need to consider pathways to address the divide that has emerged (Best & Trück, 2020), particularly low PV installation on dwellings tenanted by individuals who have difficulty paying their energy bills (ACCC, 2021).

The phenomenon of energy hardship (also known as energy poverty) is not unique to Australia. Financial stress, caused by lack of access to affordable distributed energy, is experienced globally and has negative social consequences (Monyei et al., 2019). Ritchie and Roser (2019) show that approximately 940 million people across the world (13% of the population) do not have adequate access to electricity. Thus, while our findings are limited to Australia, they have implications for other countries with similar solar exposure, energy consumption patterns, and institutional characteristics.

Our paper is structured as follows. First, we provide an overview of existing studies that have examined low PV installation by individuals who have difficulty paying their energy bills, including findings related to adoption barriers. Next, we present our method and results, followed by a discussion and conclusion, including the limitations of our study.

2. Literature Review

Nelson et al. (2019, p. 262) find that different factors contribute to the capital constraints of hardship customers that may lead to low household PV adoption. These include larger family and household size, but more importantly, low-income and reliance on government financial benefits due to unemployment. While energy hardship is not universally associated with low-income and unemployed individuals, Nelson et al. (2019) find it is the leading contributor. Further, Best, Burke, and Nishitateno (2020b) show that low-income individuals are less likely than high income householders to install household PV. Specifically, the ACCC (2021) show that hardship customers are the least likely of all customers to have household solar, with 7% having access to solar, compared to around 20% of other energy customers. The ACCC (2021) finds that hardship customers thus face electricity bills that are on average 40% more than standard customers.

In Australia, over half of hardship customers are concession cardholders and are thus likely to be low-income renters, which creates solar PV adoption challenges. Prior research indicates that the low adoption of PV on rented properties, including those tenanted by individuals who have difficulty paying their energy bills, may occur because of the capital outlay required to install the system (Ameli & Brandt, 2015; Nelson et al., 2011). Australia is characterized by relevantly short rental tenures (approx. 2 years), which means that tenants are unlikely to recover the capital outlay (Australian Housing and Urban Research Institute, 2017). Studies also show that landlords are unwilling to make such investments in rental properties where the renter will gain financial benefit through lower electricity bills. Indeed, research by Hope and Booth (2014) of the United Kingdom, Melvin (2018) of the United States, and the International Energy Agency (2007) of Japan, the United States, the Netherlands, Norway, and Australia examine landlord willingness to invest in energy efficiency measures (including but not limited to PV and building insulation). They find low landlord support to invest in assets that would lower tenant energy bills. Second, research shows that many low-income individuals, including people who have difficulty paying their energy bills, do not have the financial means to purchase PV, including discretionary personal capital, as well as access to finance (Ameli & Brandt, 2015; Weller, 2007). Best and Trück (2020) also find support for this thesis, illustrating a negative association between average income and PV installation.

A lack of information is also presented as a barrier in prior research (Fuerst & Warren-Myers, 2018; Jaffe et al., 2004). For instance, Ambrose (2015) studied landlord perceptions in the United Kingdom, finding low awareness of the benefits of energy efficiency measures (including PV) for tenants. Thus, even socially or environmentally-minded landlords, who may be willing to install PV on rental properties for non-economic reasons, may lack sufficient information to inform action. In addition, Burfurd et al. (2012) find that in socio-economically disadvantaged areas, there is a disproportionately lower level of information disclosure that would assist tenants in understanding the energy-related costs associated with housing stock, such as energy efficiency and potential access to PV. To provide a sense of what may be possible if information asymmetry could be overcome, Fuerst and Warren-Myers (2018) find that mandatory disclosure of energy efficiency ratings in places such as the Australian Capital Territory increases sale and lease prices. Burfurd et al. (2012) also find that mandatory disclosure of energy efficiency ratings increased landlord investment in PV. In relation to the hardship cohort more generally, Nelson et al. (2019) and Simshauser and Nelson (2014) show that further scholarly attention is required to understand barriers and opportunities to household PV adoption. Given that a high proportion of hardship customers are likely to be low-income tenants, Nelson et al. (2019) argue that future research in this area should commence by examining hardship customers in the context of the challenges that low-income renters face in relation to household PV adoption.

Research in this vein shows that power asymmetry may contribute to lower PV adoption on tenanted properties (de T'Serclaes & Jollands, 2007; Karakaya & Sriwannawit, 2015). Most laws prevent tenants' from making changes to housing fixtures (including appliances) or modifying any part of the property (Overtoom et al., 2019; Wood, Ong, & McMurray, 2012). Dillon et al. (2010) also find that some tenants lack of knowledge of their rights and are anxious about asking landlords to add energy efficiency benefits such as solar PV. Energy efficiency improvements can also lead to increases in rent, offsetting any benefit to tenants. In particular, Weber and Wolff (2018) found that in Germany, despite a 70% decrease in energy consumption after energy efficiency retrofits, over 50% of the households incurred greater costs due to higher rents post-capital deployment. Charlier (2015) finds similar outcomes in France, concluding that tax credits for PV have increased both rent and energy prices.

In addition, prior work argues that government policies, particularly in developed countries, have poorly targeted solar PV subsidies with resulting in poor distributional outcomes for adoption (Best, Burke, & Nishitateno, 2020a; Best & Trück, 2020). This includes the United Kingdom (Grover & Daniels, 2017) and Australia (Johnson & Sullivan, 2012; Tidemann et al., 2019). Other studies, including Best and Trück (2020), Bondio et al. (2018) and Sommerfeld et al. (2017), show that government incentives primarily focus on reducing the costs of installation and thus benefit middle-class individuals who are more likely to own their home and have access to capital. Indeed, prior work shows that almost all policies adopted within both the Australian context and globally are not means-tested and support existing homeowners (as they are the only people who have the agency to install PV given they own the roof space being utilized).

The above barriers to PV installation on hardship households, who have difficulty paying their energy bills, is concerning because of the likely environmental and social consequences (Maidment et al., 2014; World Health Organization, 2011), which remain understudied (Nelson et al., 2019).

Past research has examined the efficacy of policy support to increase PV adoption (International Energy Agency, 2007; Melvin, 2018); however, this work focuses on owner-occupiers, with little attention paid to solutions that could increase PV adoption on hardship homes. In particular, there is a dearth of research studies that examine the environmental and social consequences of hardship customer exclusion from access to low transmission cost solar PV. It is not known whether the return to society would be greater (or lower) from redistributing solar PV policy support away from owner-occupiers to hardship households. As a result, policymakers lack information on how to use limited resources available to increase the adoption of PV. As such, to advance the body of work that examines solar PV installation on properties occupied by hardship individuals, we first analyze energy usage patterns, contrasting standard households and hardship individuals. We use the results of this analysis to explore a market structure that could overcome the aforementioned barriers.

3. Method

We analyze energy usage data based on consumption data from AGL Energy Ltd (AGL Energy), one of Australia's largest electricity retailers. This included two datasets: (1) half-hourly load profiles of 1,000 Victoria-based customers participating in AGL Energy's 'Staying Connected' hardship program for the 2017 calendar year; and (2) half-hourly load profiles of 1,000 randomly selected generic Victoria-based AGL customers. The chosen customers were randomly selected after all solar customers were excluded from AGL's broader customer base of 663,292 total residential customers and 11,702 total Staying Connected customers. The 1,000 randomly selected Staying Connected hardship program are from a total customer cohort of 30k nationally and 11,702 in Victoria. Income and housing tenure (e.g., % of renters) was not disclosed in the Staying Connected customers dataset.

We selected the Australian state of Victoria as Chester (2013) has established the prevalence of hardship customers in this jurisdiction. The electricity consumption of AGL Energy's hardship program cohort, which is comprised of customers experiencing difficulty paying their electricity and/or gas bills, was utilized. AGL define hardship customers as those who are willing but unable to pay their energy bills. This allows us to consider whether hardship customers would benefit more or less than standard customers through installing solar PV. Hardship customers may potentially be useful as a broad proxy for low-income tenant consumption (given hardship customers are often renters with low-income – see Nelson et al., 2019). While this hardship cohort may include high-income individuals who have difficulty paying their electricity bills because of demographics and/or household size, Nelson et al. (2019, p. 266) confirm hardship customers include a high proportion of individuals' reliant upon government income' and thus may be an appropriate proxy for low-income renters. The electricity consumption of AGL Energy customers not enrolled in the hardship program was used as a proxy for electricity consumption by a standard household. Standard energy customers were randomly selected from the subset of customers not enlisted in the hardship program for the 2017 calendar year.

Australia is an interesting jurisdiction to analyze because of: the high penetration of household solar PV; and the fact that historical and existing policy support has been the ‘deeming’ of future production as an upfront capital subsidy payable to the PV installer through the Renewable Energy Target (RET). The RET involves the creation of small-scale technology certificates in which liable entities (i.e., retailers) have a legal obligation to buy and surrender to the Clean Energy Regulator on a quarterly basis. Small-scale technology certificates are provided 'up front' for the systems' expected power generation over a 15 year period (although the deeming is reduced by one year in each year from 2016). Policy support has effectively been ‘skewed’ towards households that have control of the decision to install solar PV (i.e., owner-occupiers).

To examine potential market solutions, we developed a novel economic model. This model included half-hourly solar PV output (Y) contrasted with household consumption (C). When Y is higher than C, the excess is exported to the grid and the solar PV system owner is paid per kWh exported (EX) based on a feed-in tariff rate (FiT). When the variable solar PV output (Y) is lower than household consumption (C), the shortfall (SF) is imported from the grid at the weighted nominal cost of grid electricity (Price of Grid Sourced Electricity [PGE]). The average daily load profile of AGL’s hardship customers within Victoria was calculated for the summer, shoulder and winter periods. The half-hourly annual output profile for a standard 3kW solar PV system located in Melbourne (Victoria’s capital city) was derived from Clean Energy Regulator data utilized to assign Small-Scale Technology Certificates (STCs) by postcode (Clean Energy Regulator, 2019). We account for the amount of solar generation utilized for self-consumption by the household, using Equations 1 and 2.

$$Energy\ displaced\ (ED): \quad if\ C \begin{cases} < Y, ED = C \\ > Y, ED = Y \end{cases} \tag{1}$$

$$Value\ of\ grid\ electricity\ offset\ (VGE) = Energy\ displaced \times PGE \tag{2}$$

To account for imports from and exports to the grid, which are dependent upon whether the solar PV system is meeting or exceeding household consumption, we use Equation 3.

$$if\ Y \begin{cases} < C, SF = (C - Y) * PGE \\ > C, EX = (Y - C) * FiT \end{cases} \tag{3}$$

The overall benefit of a possible market structure is calculated as the net present value (NPV), accounting for the capital cost and the benefit of solar PV self-consumption and exports to the grid. The benefits are calculated over all half-hour intervals within the deeming period (Equation 4).

$$Total\ Benefit = NPV\,(-Upfront\ solar\ system\ cost + \sum VGE + \sum EX) \tag{4}$$

Key data inputs of our model are presented in Table 1.

Table 1: Key data input assumptions

Assumption	Value
Site postcode profile	3000
System size	3.0
Solar system cost per W	$1.60
STC price	$35
Deeming period[1]	10 years
PGE	$0.27
FiT	$0.09

The solar profile of Melbourne was used to generate the profile of solar PV output due to its relatively low solar irradiation. Another benefit of using Melbourne is that its relatively lower solar PV output is likely to be more comparable with other parts of the world where solar PV resources are less than the Australian average. This ensures the analysis is conservative and we can conclude that the potential value is likely to be greater in most other regions of Australia. In addition, we considered the policy interventions to encourage solar PV uptake (including subsidies for solar panels through the Commonwealth Small-scale Renewable Energy Target [SRES] and various State-based schemes). It should be noted that the Victorian Government currently provides a rebate of $1,400 for renters to install solar PV. However, the Government caps the number of rebates that can be paid and only announces these caps monthly. As such, the policy is not necessarily something that could be relied upon by all consumers. SRES pays a fixed upfront subsidy per MWh for output until 2030. The STC price is the fixed price of subsidy certificates for the installation of solar PV schemes under the Commonwealth Renewable Energy Target. The price has been discounted to a fixed $35 per certificate to reflect the fact that the SRES scheme has historically been oversubscribed with certificate prices reflecting this. The subsidy is paid as an upfront lump sum with an assumed output period of 15 years. We assume the system is productive for a period of 15 years and a weighted cost of grid electricity of $0.27/kWh within Victoria and a voluntary solar feed-in tariff of $0.09/kWh of energy exported to the grid. These assumptions were sourced from the AEMC's annual price trends analysis of the Australian energy market (see AEMC, 2017).

The benefits to the tenant accrue due to the 'arbitrage' that exists between the price previously paid for electricity from the grid $0.27/kWh, which includes the cost of transmission, distribution and large-scale generation output, and the cost of the behind-

[1] 10 years was selected as the deeming period to reflect a shorter timeframe than the original 15 years. This is because the deeming decreases by one year from each year after 2016.

the-meter solar PV output. It is important to note that our results would change if tariff design shifted from energy 'throughput' tariffs to capacity or demand-based pricing (see Simshauser, 2016 and Azarova et al., 2018).

To explore how market solutions could be designed to increase PV adoption by renters who have difficulty paying their electricity bills, we also develop a model that establishes a payment for landlords (a fixed upfront payment of $1,000). This model assumes the electricity consumed behind the meter is supplied at 'levelized cost', significantly benefiting the tenant. For illustrative purposes, we suggest that the upfront payment to landlords could be managed through a not-for-profit (NFP) intermediary (Dekker, 2010) . This NFP would effectively own the system 'behind-the-meter', rent the roof space with an upfront payment of $1,000 and supply the produced energy to the renter. Through our model in relation to the second research question, we examine whether the economics of solar PV in Australia is sufficiently superior to grid-based electricity supply that there is scope for a new business model to be deployed to 'share the value' between the landlord and tenant, thereby overcoming the barriers to solar adoption by low-income renters identified in Section 2.

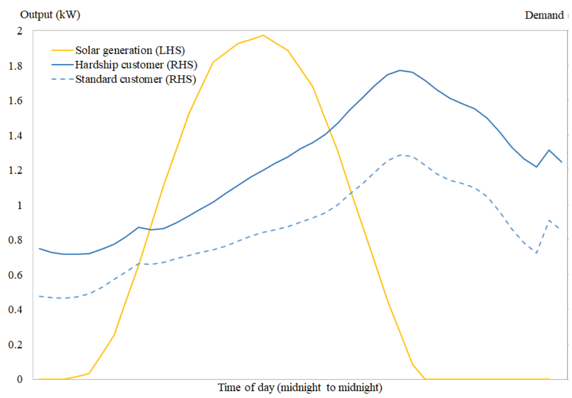
4. Results

To answer the central research question of what are the potential net benefits of solar PV on hardship customers (used as a general proxy for low-income renters) versus standard customers and how could a market or policy solution be designed to increase PV installation on hardship properties, we modeled outcomes for six scenarios. Two scenarios were modeled using the 'standard' household consumption profile: one with STC subsidy revenue included and one without. Four scenarios were modeled using the 'hardship' household consumption profile: STC revenue included and no payment to the landlord; STC revenue excluded and no payment to the landlord; STC revenue included and a landlord payment of $1,000; and STC revenue excluded and a landlord payment of $1,000.

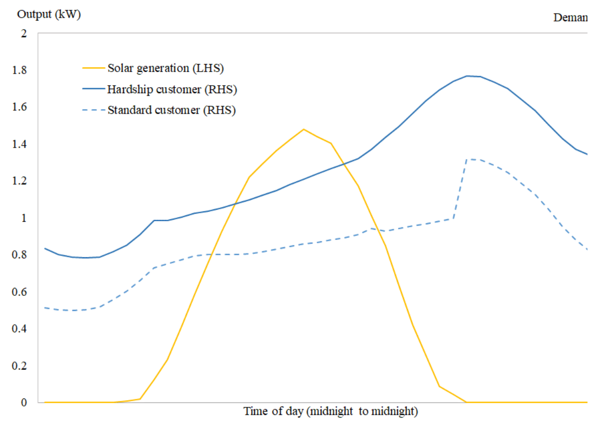
As shown in Figure 1, electricity consumption during the day (and therefore the rate of potential solar energy self-consumption) is consistently higher for hardship customers than standard customers. This is very consistent with the findings of Nelson et al. (2019) who found that hardship customers have higher usage due to a variety of factors, including greater numbers of home occupants. The degree of self-consumption was greatest during winter due to lessened solar exposure and higher average electricity usage (primarily for heating). The average annual rate of self-consumption for hardship customers and standard customers was determined to be 36% and 26%, respectively. Interestingly, these results demonstrate that deploying solar PV systems is likely to yield a greater rate of economic return for hardship households than standard households. This is because higher self-consumption results in more of the solar PV output being utilized and the tariff avoided (i.e. grid-based electricity) is significantly higher than the tariff paid if the energy is exported (i.e., the feed-in tariff).

Figure 1: Consumption profiles and solar PV system output for the winter, summer, shoulder, and annual periods

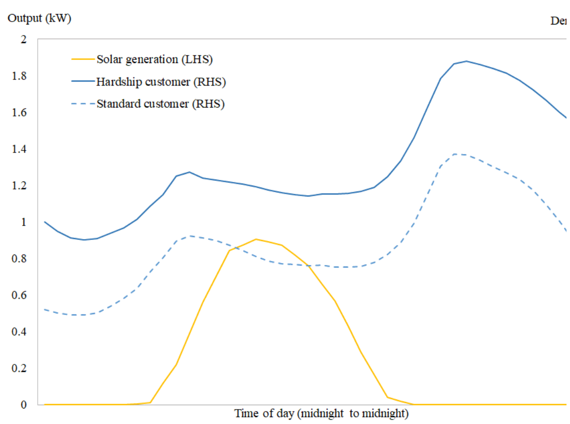
<u>Figure 1.a –Average summer output and consumption data</u>



<u>Figure 1.b – Average shoulder output and consumption data</u>



<u>Figure 1.c – Average winter output and consumption data</u>



<u>Figure 1.d – Average annual output and consumption data</u>

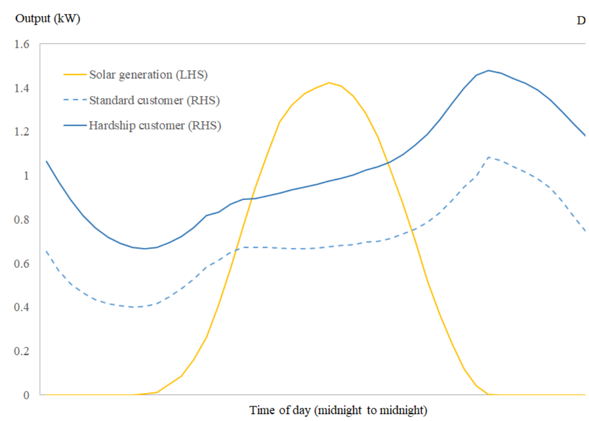


Table 2 shows that in every scenario modeled, the simple payback period is less than ten years. Importantly, this casts doubt over the efficacy of existing Australian subsidies, which use an output period of 15 years. From this evaluation, solar PV could now be considered as an economic investment after eight years for standard energy customers. For this cohort, the removal of SRES policy support would reduce the NPV of solar PV investment from $2,189.44 to $889.44 and result in a deterioration of the payback period from 5.8 to 8.1 years. But even without SRES policy support (which declines each year naturally due to the reduction of the output deeming period to 2030), the NPV of solar PV deployment for the standard customer is still positive and less than nine years. As we discuss in the subsequent section, this is an important finding as policy support is likely to be unnecessary. Therefore, redirecting subsidies to hardship properties is likely to be achievable without reducing overall PV uptake by owner-occupiers (without reducing overall PV uptake substantially).

Table 2 also shows that the economics of solar PV is superior for the 'hardship' customer profile. Materially higher self-consumption of 36%, compared to just 26% self-consumption based upon the ‘standard’ customer profile, results in more of the output of the PV system displacing relatively higher cost grid-based electricity, priced at $0.27 per kWh. The NPV for this customer cohort is $2,907.97, nearly $1,000 higher than the ‘standard’ customer cohort, and the payback period is only 4.7 years. Put simply, there is a better economic return on investment for society by subsidizing solar PV installations for hardship customers (used in this article as a proxy for low-income rental properties). The returns are likely to be even greater when broader benefits are considered, such as reduced overall household hardship and lower aggregated customer debt.

Table 2: Modeling results – Internal Rate of Return (IRR), NPV and payback period for installation of solar PV for NFP

Scenario Descriptors			**Modeling Results**		
Household cohort	Landlord payment	STC subsidies	Simple internal rate of return (%)	NPV ($ assuming 5% discount rate)	Simple payback period (years)
‘Standard’ household	N/A	Included	16%	$2,189.44	5.8
	N/A	Excluded	8%	$867.88	8.1
‘Hardship’ household	None	Included	19%	$2,907.97	4.7
	None	Excluded	11%	$1,586.41	7.1
	$1,000	Included	14%	$1,907.97	6.1
	$1,000	Excluded	7%	$586.41	8.8

In relation to the potential scale of the environmental and social benefits, using our modeling results, we estimate that deploying solar PV for the ‘hardship’ customer cohort could reduce annual grid-based electricity consumption by approximately 40%, reducing greenhouse emissions by 1.6 tCO2e per household annually (based on Victoria's average grid intensity) (Department of Environment and Energy, 2018).

In relation to the second element of our research question, which aimed to explore how a market solution could be used to increase PV installation on hardship properties, we tested NPV, including a $1,000 payment to the landlord. This payment could be made by a NFP who acts as an intermediary between the landlord and tenant to distribute the benefits of lower energy prices between a landlord (through the $1,000 payment) and the tenant (through the balance of solar offsets). Table 2 shows that the NPV for this model is positive. The NPV for the 'hardship' customer cohort with STC revenue still in place declines by around $1,000 to $2,119.75 with a payback period of 6.1 years. These results illustrate the scope for new market opportunities to deploy PV on hardship properties. As noted earlier, the poorly targeted and overly generous SRES policy could be redesigned to provide greater support to hardship households.

5. Discussion

This paper set out to contrast the potential net benefits of solar PV adoption on hardship households versus standard households. It also sought to explore a market solution that could address the dearth of PVs on hardship properties. Our results are novel in that we are one of the few studies to expansively model the net benefits of PV installation on hardship customer data compared to standard dwellings. In doing so we offer several contributions to the literature.

First, to our knowledge, we are one of the first studies to contrast the economic, environmental, and social costs and benefits of PV adoption by hardship customer data compared to standard dwellings. Unlike prior studies that have examined the barriers to household PV adoption by renters, we focus on the potential net benefits of the hardship cohort. Specifically, we examine energy consumers that face economic exclusion from society and energy poverty. We find that hardship households consume greater electricity than standard households and PV adoption would thus yield higher net economic, environmental, and social benefits. Our findings are not necessarily consistent with some other studies, such as Daniel et al. (2020, p.8), that hardship customers, who have difficulty paying energy bills, "may have lower energy consumption than owner-occupiers", we also call into question the efficacy of government policies that favor homeowners (Best, Burke, & Nishitateno, 2020a; Best & Trück, 2020).

While our data relates to hardship customers rather than strictly low-income tenants, consistent with prior work that shows hardship customers are more likely to be low-income renters, we thus highlight potential bias that may exist in prior conceptualizations of the policy problems and opportunities to increase household PV adoption. Notably, our research shows that prior assumptions regarding hardship customers using less energy than standard households do not necessarily apply in Australia. We also show that Australia could achieve greater net benefits if government PV subsidies were modified to provide targeted PV adoption incentives. This would see a revision of the current approach, which provides a standard rebate to all households, toward a structured mechanism that awards PV subsidies based on need and net reduction in energy drawn from the grid. Our results also expand prior work to quantify potential economic, environmental, and social benefits of greater household PV adoption, which can inform policy. We illustrate the superior economics of PV installations for hardship customers, which creates a compelling case for policy review and reorientation to examine how increased PV adoption could be achieved for this cohort.

Second, our results shed new light on the economics of PV in Australia. Specifically, we show that the cost of grid-supplied electricity and PV have advanced to a position in which standard customers receive a financial benefit from the system within 8.1 years without Government rebates. This payback period is even shorter for hardship customers at 7.1 years. Taken together, our results present a case for Australian policymakers to reconsider the allocation of solar PV rebates. Indeed, our results show that solar PV would yield higher benefits if installed on low-income tenant-occupied households and may no longer be required for owner-occupiers. Our results also show that Government rebates are theoretically no longer required as an incentive for homeowners who intend to reside in their property for more than eight years. Indeed, Australian federal and sub-national Governments may yield greater economic, environmental, and social benefits if current incentives, which have benefited households who no longer appear to require them, were reorientated toward other initiatives to create greater transparency about the financial benefits that households can achieve through the installation of PV.

Last, in relation to the barrier of the capital outlay required to install PVs system on hardship households (Ameli & Brandt, 2015; Nelson et al., 2011), we show a potential ‘shared value’ model that could stimulate greater investment in PV for properties without government intervention. This model involves a third party (in this case we use a NFP) that could deploy solar PV on hardship households and divide the economic benefits between resident and the landlord (in the case of renters). This model also makes the benefits of solar PV transparent and highlights ways in which the barrier of power asymmetry between renters and landlords (de T’Serclaes & Jollands, 2007; Karakaya & Sriwannawit, 2015) could be overcome. Based on this finding, Australian federal and sub-national Governments may thus also consider whether funding could be reorientated from solar PV rebates, in particular the SRES, toward other innovations to improve the economics of the transition to renewable energy. For instance, additional funding for research and development to decrease costs associated with household PV and storage facilities. Reorientation of policy support could also include greater research and development to accelerate the transition to other distributed energy network solutions, such as micro-grids and community-level storage.

6. Concluding Remarks

Our analysis shows that solar PV is now an economically advantageous technology for the ‘standard' household in Australia, even without subsidies due to the declining cost of solar PV technology and increasing grid-supplied tariffs. Our findings also reveal higher electricity use among hardship households, thereby increasing the economic, environmental, and social payback from deploying solar PV. As such, there is a case for reorientating solar PV policy support to hardship households. Further, we show a market solution that could unlock the shared value of PV adoption by low-income households, given the superior economics for this cohort.

Our study, however, has limitations that point to future research opportunities.
Our data show that hardship customers use more energy. While Nelson et al. (2019) point to reasons why this may be, showing that hardship customers generally have larger families and properties, further knowledge regarding hardship customers energy usage is required. Our research highlights a gap in finer grain detail on the hardship cohort, specifically, it is not yet known how many hardship customers rent. Gaps in knowledge also exist in relation to hardship customers' views and perceptions regarding energy use. Future research could, therefore usefully engage in qualitative inquiry to further understand the hardship cohort.

Our results are also limited to Australia, and further cross-national comparisons are needed. Extending work in this way could contribute to the growing body of work concerning the global transition to renewable energy. Further, our data was limited to hardship and standard customers. Future research could, therefore expand and test our model on broader customer cohorts, such as specific demographics within the broad rental group. Last, our research highlights a limitation of existing policy that favors owner-occupier dwellings. We explore one solution, the creation of a new market structure involving an NFP owning behind the meter systems and renting roof space from landlords.

Future research is required to examine if other solutions, such as alternative government policies to incentivize landlords to install PV could also yield net benefits. In addition, further research could examine policy avenues for different types of landlords, contrasting opportunities and challenges for government and community housing providers compared to the private rental market. Research in this vein would benefit from further quantitative modeling, as well as qualitative analysis to explore barriers to PV adoption not covered in our study, such as information asymmetry (Fuerst & Warren-Myers, 2018; Jaffe et al., 2004), as well as the perceptions of other actors, such as policymakers, energy retailers, and PV companies that could aid or hinder the reorientation of focus away from homeowners toward renters as a means to increase PV adoption in Australia.

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