

# Factors Contributing to Energy-related Financial Stress in Australia\*

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*This paper quantifies factors affecting energy-related financial stress in Australia, a key economic challenge facing a minority of households. We find that low net wealth is a particularly important factor affecting difficulty in paying energy bills. Having insulation reduces reported difficulties in being able to heat and cool homes. The odds of not paying energy bills on time are doubled by households not having solar panels. Other important factors contributing to energy-related financial stress include being a renter, being a mortgage holder, having a large number of occupants in a household, and having a resident who requires energy-consuming medical equipment.*

## *1 Introduction*

Australia is facing its most challenging time in electricity markets. High prices and bills have placed enormous strain on household budgets and business viability. The current situation is unacceptable and unsustainable. (Australian Competition and Consumer Commission, 2018, p. iv)

Energy affordability has become a key economic issue in Australia. Figure 1 shows that real electricity prices for consumers were relatively stable for decades, before increasing rapidly from around 2008. As a proportion of average household expenditure, electricity expenditure increased by 50% from 2006 to 2016 (Phillips, 2017). A 2015–16 survey (Australian Bureau of Statistics (ABS), 2017) found that 10% of Australian households reported difficulty in paying

their energy bills on time. An earlier survey (ABS, 2013) found that 10% of households chose to restrict heating or cooling because they could not afford to pay for it. In some instances, not heating or cooling one's home can increase morbidity and mortality risks (Australian Council of Social Service (ACOSS), 2013); Barnett *et al.*, 2013).

Various dimensions of poverty have been the focus of considerable analysis in Australian economic discourse. For example, Wright *et al.* (2015) analysed poverty in the Latrobe Valley region, finding evidence of worsening poverty and inequality, even during the decade to 2006 when there was strong national economic growth. There is analysis of drivers of poverty persistence that has focused on a range of socioeconomic determinants (Buddelmeyer & Verick, 2008). Economic studies also assess policy effectiveness in reducing poverty, such as the degree of efficacy of public transfers (Rodgers, 2010). Many studies focus on income-related poverty measures (Chotikapanich *et al.*, 2013; Creedy & Gemmill, 2018). An alternative to analysing poverty is to use measures of inability to afford essential items (Saunders & Naidoo, 2009). Being unable to afford energy services is one dimension of a broader concept of economic disadvantage.

\*Funding was received from the Australian Government Department of Foreign Affairs and Trade through the Australian-German Energy Transition Hub, and from the Australian Research Council (DE160100750).

JEL classifications: D10, I32, Q40, Q48

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FIGURE 1  
*Real Electricity Price Index for Australian Consumers (Weighted Average of Eight Capital Cities).*



*Notes:* Calculated as the electricity price index divided by the consumer price index (all groups). 1980Q3 = 1. There are substantial increases in the real electricity price index after 2008 for each capital city.

*Sources:* ABS (2018), author calculations.

### *Definitions and Context*

'Energy poverty' fundamentally refers to an inability to obtain adequate energy services. Complete non-availability of high-quality energy such as electricity is a binding constraint in some developing countries (Li *et al.*, 2014; Best & Burke, 2018a). It can also be useful to consider energy poverty more broadly as a complex social problem that has many interrelated causes and effects (Baker *et al.*, 2018). This is helpful for a holistic understanding and because there is no single measure of energy poverty in common use (Chaton & Lacroix, 2018).

In a developed-country context, a lack of energy affordability and resulting financial stress is a crucial dimension of energy poverty. Financial stress relates to an imbalance between spending and income (Marks, 2007). It can be conceptualised as a different dimension of financial disadvantage from income poverty (Marks, 2007), while still relating to a lack of financial resources. Bray (2001) provided a general categorisation of dimensions of financial stress, including categories of cash-flow problems and hardship. Immediate implications of energy-related financial stress include some households

restricting energy use even though high-quality energy sources are available. This falls under the hardship category identified by Bray (2001). Some households also find it challenging to pay energy bills, which falls under the cash-flow problem category identified by Bray (2001).

A survey of Australian households by Members Equity Bank (2018) found that cost of living expenses, such as utility bills, were a key cause of worsening financial situations for households. This motivates analysis of energy-related financial stress in Australia. Possible rationales for substantial energy-related causes of financial stress include electricity bills being large and lumpy compared to costs of other essentials such as food, and energy bills being particularly salient expenditure items when they arrive in the mail.

Energy poverty, including energy-related financial stress, has received academic attention and policy focus in developed countries in Europe, especially in the United Kingdom, for a number of decades (Liddell *et al.*, 2012; Miniaci *et al.*, 2014; Legendre & Ricci, 2015).<sup>1</sup> There has

<sup>1</sup> The academic literature often uses the term 'fuel poverty' instead of 'energy poverty'.

been less empirical analysis for Australia (Azpiarte *et al.*, 2015), as electricity prices have been relatively low until recent years, and heating requirements are typically lower than in Europe. But energy poverty has begun to emerge in Australia over the last decade due to energy price increases (Simshauser *et al.*, 2011a,b; ABS, 2018).

#### *Dimensions of Energy Poverty Are Distinct from General Poverty*

Dimensions of energy poverty, such as energy-related financial stress, are distinct from poverty in general (Hills, 2012). This includes causes, effects and policy solutions. The prior literature suggests that three main causes of energy poverty are low incomes, poor housing quality and high fuel costs, underpinned by social, health and economic contributors (Baker *et al.*, 2018). In addition, Middlemiss and Gillard (2015) identified tenancy relations as contributing to energy poverty. Energy poverty also has distinct health implications that relate to home temperatures. Specific policy to target energy poverty includes home energy efficiency improvements and approaches to overcome tenant–landlord principal–agent problems. For instance, prior studies have concluded that insulation can substantially reduce energy poverty (Sovacool, 2015; Mohr, 2018).

Wealth is likely to be important in understanding vulnerability to energy poverty and energy-related financial stress. Prior work has found that wealth is important for various energy sector outcomes at the national level (Brunnschweiler, 2010; Best, 2017; Best & Burke, 2018b). At the household level, there may be binding wealth constraints that prevent purchases of energy-efficient appliances. A major influence of wealth constraints on consumer demand for energy could also be anticipated from a more theoretical standpoint. The general framework of Modigliani's (1966) life cycle model is useful for our paper because it includes wealth in the constraint function, not just income. It is interesting to assess the effects of both income and wealth, as many retirees may have high wealth but low income, while some young people are in the opposite situation.

Geographical factors are also likely to affect energy poverty differently than general poverty. Climate conditions have a direct influence on heating and cooling needs. Urban or rural location has also been investigated as a factor in explaining energy poverty; Robinson *et al.*

(2018) found that there is higher energy poverty in urban areas in England, for instance.

There are other household characteristics that may also influence the likelihood of being energy poor. These can act as a proxy for preferences in a constrained utility maximisation framework. Family structure may matter, such as the numbers of adults and of dependent children in a household (Middlemiss & Gillard, 2015). Being unemployed may lead to higher home energy use as unemployed people may be at home more. In France, renters have been found to be more likely to experience energy poverty, possibly due to worse energy efficiency in rented properties, as there may be a principal–agent problem that leads to landlords not having an appropriate incentive to make energy-efficiency improvements (Legendre & Ricci, 2015). Other population groups at elevated risk of energy poverty include single-parent households and households relying on government transfers (ACOSS *et al.*, 2018).

The distinct nature of energy poverty *vis-à-vis* poverty is evident in some households potentially being below general poverty lines but not experiencing energy poverty. In contrast, some households are unable to afford essential services, despite their income being above the poverty line (Bradshaw & Hutton, 1983). Rapidly rising energy prices make this possibility more likely. This possibility was already evident before the latest electricity price rises, as energy poverty had been found to have begun to spread to the second-lowest income quintile (see Chester & Morris, 2011).

#### *Contribution of This Paper*

Energy-related financial stress is a key dimension of energy poverty in Australia, a country with widespread energy availability. We seek to address the important question: what factors are associated with energy-related financial stress among Australian households? Specifically, we investigate the factors that lead some households to experience dimensions of energy-related financial stress in relation to use of electricity and natural gas. We use multiple measures of energy-related financial stress that focus on the key issue of affordability. These include both self-reported indicators and disconnection warnings from energy companies. We also combine measures of energy-related financial stress to incorporate multiple elements in single dependent variables.

Our focus on the role of net wealth is distinct from much of the relevant literature, which

typically focuses on the role of income. Our wealth focus also extends to energy-relevant physical capital additions to the home, such as solar panels and insulation. Our results are based on large surveys carried out by the Australian Bureau of Statistics in 2012 and 2015–16 (ABS, 2013, 2017), as outlined in Section II. We analyse the roles of variables that have not featured in studies of other countries, such as household net wealth, use of energy-consuming medical equipment, and solar panel installation. Solar panels have been installed by many Australian households, but the ability to install solar panels may be constrained by a lack of accumulated wealth (Best *et al.*, 2019). We use multiple methods to enhance causal interpretations of the results.

## II Method and data

We initially use a logit model,

$$\ln\left(\frac{p^j}{1-p^j}\right) = c + \mathbf{T}'_h \boldsymbol{\alpha}^j + \mathbf{R}'_h \boldsymbol{\beta}^j + \mathbf{O}'_h \boldsymbol{\gamma}^j + \mathbf{G}'_h \boldsymbol{\delta}^j + \mathbf{E}'_h \boldsymbol{\theta}^j + \varepsilon^j_h \quad (1)$$

to identify factors affecting energy-related financial stress. Logit models are appropriate for dichotomous dependent variables, especially when probabilities of outcomes are relatively close to zero. Logit models also allow for differing effects of explanatory variables on the absolute magnitude of the probability of energy-related financial stress, depending on the baseline probability.<sup>2</sup>

The dependent variable in our model is the log of the odds of each energy measure. Odds are defined as the probability ( $p$ ) of experiencing an outcome divided by the probability of not experiencing the outcome. We use data at the level of the household ( $h$ ) for each measure of energy-related financial stress ( $j$ ). Our analysis employs several measures of energy-related financial stress for the 12-month period prior to each survey. These include binary variables that assign values of 1 in cases of households:

- feeling unable to heat or cool their home due to a shortage of money;
- choosing to restrict heating or cooling because they could not afford the extra costs;
- not paying electricity, natural gas, or telephone bills on time due to a money shortage;
- often not paying these bills on time;
- receiving a disconnection warning from electricity or natural gas companies.

There is value in looking at multiple measures of energy-related financial stress as they are far from perfectly correlated. For example, the correlation between binary variables for being unable to heat or cool a home and not being able to pay a bill on time is 0.3 (ABS, 2013).<sup>3</sup> Factors affecting difficulty paying bills on time may differ from factors causing households to change their energy-use behaviour. We also investigate composite measures that combine energy outcomes.

The  $\mathbf{T}$  vector includes explanatory variables related to housing characteristics. We use binary variables for households that have solar panels and that have home insulation. One issue is that energy-related financial stress could motivate such energy investments. Accordingly, we look at installations that were in place 2 or more years prior to the survey taking place. We are thus assessing the impact of historical energy investments on subsequent energy-related financial stress. Housing characteristics also include the number of bedrooms, a binary variable for apartments, a binary variable for houses that were built at least 20 years ago, binary variables for renters, and a binary variable for owners who have mortgages (as opposed to owners who own their residence outright).

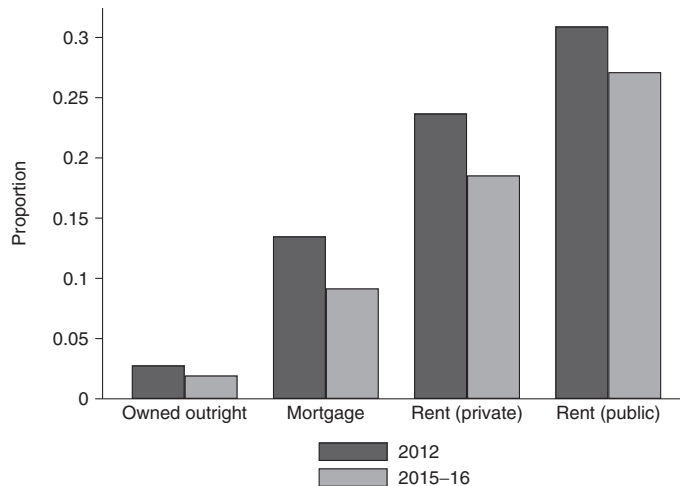
Figure 2 compares the energy-related financial stress experienced by housing tenure type. Public renters – those who have a state or territory housing authority as their landlord – are most likely to face difficulty paying energy bills on time, followed by private renters and then mortgage holders. It is particularly important to assess possible renter effects as the private renter sector

<sup>2</sup> For example, being in the lowest wealth quintile rather than the second lowest has a larger unconditional absolute effect on energy-related financial stress probability compared to the difference between being in the fourth quintile or the richest.

<sup>3</sup> The binary variable for not being able to pay an electricity, natural gas, or telephone bill on time includes telephone bills, but is primarily an energy variable. The average electricity bill was approximately double the average mobile phone bill in 2015–16 (ABS, 2017).

FIGURE 2

Proportion of Households that Were Unable to Pay Electricity/Natural Gas/Telephone Bills on Time by Tenure Type.



Sources: Based on ABS Basic Confidentialised Unit Record File (CURF) data (2013, 2017).

has grown in relative size in recent years (Kemp, 2015; Hulse *et al.*, 2019).

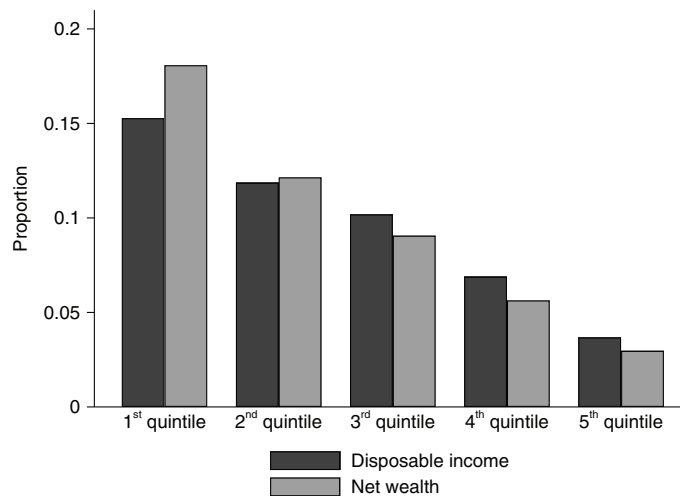
$\mathbf{R}$  in Equation 1 is a vector of financial resource variables for each household. This includes the log of current disposable income, log of net wealth, and the government welfare proportion of income.<sup>4</sup> Figure 3 shows that the proportion of households choosing to restrict heating or cooling is substantially higher for the bottom net-wealth quintile than for the bottom income quintile. While this suggests greater apparent importance of low net wealth, it is only an unconditional association that could be affected by other variables like age. We control for other variables when assessing the effect of net wealth on energy-related financial stress in Section III. The code in the online supplementary materials also includes regressions with binary quintile variables for wealth and income to focus on the effect of being in the bottom quintile. Each of the variables are defined in more detail in Table A.1 in Appendix S1. Table A.2 in Appendix S1 has descriptive statistics.

<sup>4</sup> Disposable income better represents the income available for consumption of energy services than does gross income.

$\mathbf{O}$  is a vector of variables describing occupant characteristics. We use variables for the numbers of people, employed people, and dependent children under 15 years of age, as well as the age of the reference person. As measures of family structure, we include binary variables for single parents with dependent children, couples with dependent children, and couple-only households. We also include a binary variable for households with a resident who uses energy-consuming medical equipment. This incorporates an impact of health on energy-related financial stress, consistent with the complex web of interactions identified by Baker *et al.* (2018). The unconditional effect of this medical binary variable in raising energy-related financial stress is seen in Figure 4.

The  $\mathbf{G}$  vector incorporates a number of geographical factors. We control for the state or territory of residence to account for electricity prices and policies. In addition,  $\mathbf{G}$  includes a binary capital city variable. We also include interaction variables for capital cities and each state/territory. These interactions help to control for population density and electricity price differences between cities and regional areas. Robustness tests in the code in the online supplementary materials include binary variables

FIGURE 3  
*Proportion of Households that Chose to Restrict Heating or Cooling Their Homes Because They Could Not Afford the Extra Costs, Split by Net Wealth and Disposable Income Quintile.*



Source: Based on ABS Basic CURF data (2013).

for 87 Statistical Area Level 4 regions, 4 remoteness codes, and 6 climate zones.

The **E** vector includes variables related to expenditure, as high spending on goods and services could increase energy-related financial stress, all else equal. We include expenditure on electricity and on housing. We only include spending variables in some models, as there is a risk of reverse causation for these variables (as discussed in Section III).

We employ propensity score matching to aid in causal interpretations of the effect of solar panels on energy-related financial stress. In addition, we include results with a linear probability model in the code in the online supplementary materials. A disadvantage of linear probability models is that they sometimes lead to probability predictions outside the unit interval. We use seemingly unrelated bivariate probit regressions to allow statistical testing of effects of wealth on different dependent variables.

As mentioned, we access data from two household surveys conducted by the Australian Bureau of Statistics (2013, 2017). The surveys collected information on household financial resources, energy use, expenditure, and other

characteristics. The first is a Household Energy Consumption (HEC) survey, conducted in 2012, covering 11,978 households. The second is a Household Expenditure Survey (HES) carried out in 2015–16, and covering 10,046 households. The 2015–16 HES is part of a series of surveys conducted at six-year intervals.<sup>5</sup> In contrast, the HEC survey was a one-off. The HEC included many more questions on energy than the HES, which is why we include it in our analysis. Both were in-home, computer-based surveys.

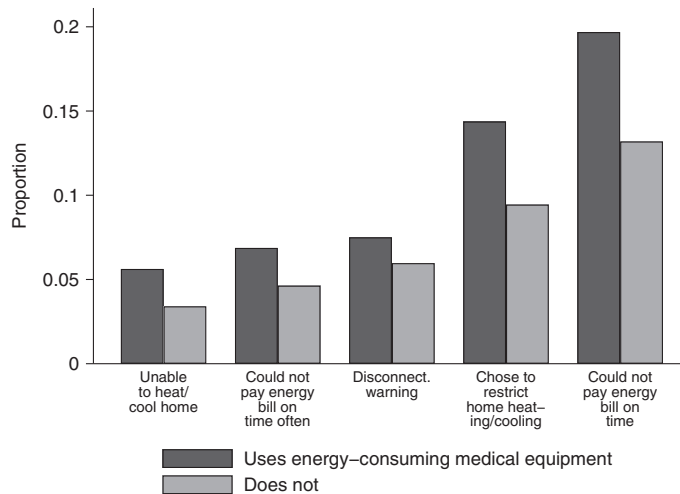
The surveys are intended to be nationally representative, and to provide reliable estimates for each state and capital city. Some variables face measurement challenges. Net wealth, for example, includes the estimated sale price of dwellings, which is subject to measurement error. To address this, we also consider components of net wealth, such as superannuation balances.

The Australian Bureau of Statistics (2013, 2017) surveys include sampling weights, which are the inverse of the probability of a household

<sup>5</sup> Earlier versions of the HES did not include as many questions on energy issues.

FIGURE 4

Proportion of Households that Experienced Each Measure of Energy-Related Financial Stress in the 2012 Household Energy Consumption Survey. Note: Separate bars are shown for households with an occupant who uses energy-consuming medical equipment.



Source: Based on ABS Basic CURF data (2013).

being selected for the survey. Our regressions are unweighted, although results using sampling weights are included in the Stata code in the online supplementary materials, and are similar. Unweighted regression analysis is presented given its efficiency advantage.

### III. Results

Table 1 presents logit results for a range of measures for energy-related financial stress, using data from the 2012 HEC survey. Households that rent are more likely to experience energy-related financial stress than households that own their home without a mortgage. This is consistent with the financial stress documented through in-depth interviews with private Australian renters in the study by Hulse *et al.* (2019). The coefficient for private renters in our results is positive and significant in each column, including coefficients of up to 1.3 as in column (5). This implies that the odds of private renters experiencing energy-related financial stress can be more than triple the odds for the reference group of owners without a mortgage. There are also positive and

significant effects for mortgage holders and public renters.

Table 1 includes some effects of capital additions to the home, which can be regarded as components of wealth. Households without insulation are more likely to feel unable to heat or cool their home, with statistical significance at the 5% level. There are negative and significant effects of having solar panels (that were installed more than 2 years prior) for measures of difficulty paying bills in columns (3)–(5), but not for the quantity restriction measures in columns (1)–(2). The negative effect of solar installations remains, and is statistically stronger, when including all households with solar panels, not just installations more than 2 years prior (see the code in the online supplementary materials).

Table 1 also shows important effects of residential characteristics on energy-related financial stress. There are positive associations between the number of bedrooms and energy-related financial stress, with statistical significance in two columns. More energy is required for temperature control in larger houses. The apartment

TABLE 1  
*Logit Results: Various Measures of Energy-Related Financial Stress, 2012*

	Dependent variables, log odds:				
	(1) Unable to heat or cool home	(2) Chose to restrict heating or cooling	(3) Could not pay electricity, natural gas, or telephone bill on time	(4) Could not pay electricity, natural gas, or telephone bill on time often or always	(5) Received disconnection warning from electricity or natural gas company
Mortgage	0.940*** (0.199)	0.634*** (0.111)	1.282*** (0.126)	1.608*** (0.225)	1.257*** (0.198)
Renter, private	0.530** (0.236)	0.553*** (0.139)	1.209*** (0.145)	1.251*** (0.251)	1.295*** (0.220)
Renter, public	0.398 (0.272)	0.375** (0.175)	1.036*** (0.176)	1.236*** (0.281)	1.407*** (0.252)
Solar panels	0.315 (0.353)	0.106 (0.213)	-0.694*** (0.270)	-0.896* (0.513)	-0.909** (0.461)
Insulation	-0.238** (0.121)	-0.059 (0.078)	-0.011 (0.069)	-0.082 (0.105)	0.013 (0.096)
Bedrooms #	0.052 (0.079)	0.221*** (0.048)	0.119*** (0.044)	0.061 (0.069)	0.006 (0.063)
Apartment	-0.566*** (0.213)	-0.434*** (0.143)	-0.516*** (0.120)	-0.578*** (0.193)	-0.609*** (0.172)
Old house	0.037 (0.121)	0.105 (0.074)	0.148** (0.066)	0.167 (0.105)	0.218** (0.094)
Log wealth	-0.246*** (0.054)	-0.220*** (0.037)	-0.333*** (0.033)	-0.274*** (0.048)	-0.228*** (0.044)
Log income	-0.414*** (0.084)	-0.356*** (0.055)	-0.384*** (0.054)	-0.334*** (0.083)	-0.409*** (0.071)
Government income %	1.256*** (0.198)	0.672*** (0.125)	0.433*** (0.121)	0.981*** (0.179)	0.392** (0.164)
Persons #	0.224*** (0.085)	0.127** (0.054)	0.169*** (0.049)	0.330*** (0.070)	0.243*** (0.066)
Employed #	-0.153 (0.102)	-0.076 (0.060)	0.054 (0.055)	-0.009 (0.082)	0.066 (0.075)
Children #	-0.240** (0.109)	-0.115* (0.069)	0.064 (0.060)	-0.112 (0.087)	-0.009 (0.081)
Couple only	-0.439** (0.171)	-0.303*** (0.097)	-0.468*** (0.096)	-0.570*** (0.164)	-0.362** (0.142)
Couple with dependent child	-0.199 (0.216)	-0.001 (0.130)	-0.134 (0.109)	-0.347** (0.165)	-0.199 (0.150)

TABLE 1  
(continued)

	Dependent variables, log odds:				
	Unable to heat or cool home (1)	Chose to restrict heating or cooling (2)	Could not pay electricity, natural gas, or telephone bill on time (3)	Could not pay electricity, natural gas, or telephone bill on time often or always (4)	Received disconnection warning from electricity or natural gas company (5)
Single parent	0.212 (0.199)	0.422*** (0.129)	0.499*** (0.112)	0.250 (0.162)	0.693*** (0.144)
Medical	0.426 (0.272)	0.501*** (0.173)	0.816*** (0.165)	0.567*** (0.247)	0.608*** (0.236)
Age #	-0.020*** (0.004)	-0.004 (0.003)	-0.018*** (0.003)	-0.022*** (0.004)	-0.024*** (0.004)
Observations	11,661	11,661	11,661	11,661	11,661
Pseudo $R^2$	0.146	0.093	0.182	0.173	0.167

Note: \*\*\*Significant at the 1%, \*\*5%, \*10% level. Standard errors are in parentheses below the coefficients. Coefficients are not shown for constants, state binary variables, capital city binary variable, and state  $\times$  capital city interaction variables. The reference category for tenure type (e.g. mortgage) is owning without a mortgage. A tenure type of other is also a control but is not statistically significant. Logit coefficients are shown. The data are from the 2012 HEC survey. Explanatory variables are binary unless identified by log, percentage (%), or number (#).

binary variable is negative and significant at the 1% level in each column, with logit coefficients between  $-0.4$  and  $-0.6$ , indicating that energy-related financial stress is less likely for apartment dwellers. Exponentiation of the column (5) coefficient of  $-0.6$  gives an odds ratio of  $0.5$ .<sup>6</sup> The apartment effect could perhaps be due to housing structure, as heating and cooling requirements are often smaller for apartments than for stand-alone houses. There is also a positive association between older housing structures and energy-related financial stress, with statistical significance at the 5% level in two columns. Older houses are often less energy efficient.

There are negative associations between financial resources and energy-related financial stress, with each coefficient for log net wealth and log disposable income being significant at the 1% level. In column (1), there is a coefficient for log net wealth of  $-0.2$  in explaining the log odds of being unable to heat or cool a home. This indicates that a 1% increase in net wealth is associated with 0.2% lower odds of being unable to heat or cool a home. This effect is the same when using net wealth excluding the estimated residential dwelling sale price. There is also a significant coefficient of  $-0.2$  for the log superannuation balance if it is used instead of log net wealth (see the code in the online supplementary materials). Energy-related financial stress is also more prevalent among households receiving more of their income from government payments. Further robustness tests in the code in the online supplementary materials confirm the key results. Using a linear probability model, log net wealth continues to have a negative and significant effect on difficulty paying bills.

Wealth has varying effects on different measures of energy-related financial stress. A negative and significant effect of being in the lowest-wealth quintile is larger in magnitude for explaining inability to pay bills compared to feeling unable to heat or cool homes. The null hypothesis of equal effects is rejected at the 1% level using a seemingly unrelated bivariate probit regression. Also, being in the bottom wealth quintile has a larger effect on difficulty paying bills on time than being in the bottom income quintile. The null hypothesis that the coefficients are equal is

<sup>6</sup> This is equivalent to saying that the odds of receiving a disconnection warning for those in an apartment, divided by the odds of receiving a disconnection warning for those not in an apartment, is  $0.5$ .

rejected at the 5% level. These results are available through the code in the online supplementary materials.

There are also some positive and significant effects for the number of people in a household, indicating that larger households are more likely to experience energy-related financial stress, all else equal. The effect of large households on some dimensions of energy-related financial stress has some support in the literature. Azpitarte *et al.* (2015) noted that households that cannot pay bills on time tend to be larger than households experiencing other dimensions of energy-related financial stress. Nelson *et al.* (2019) identified household size as being related to energy-related financial hardship. KPMG (2017) also noted that large low-income families with five or more people would be most affected by rising energy costs. Similarly, robustness tests in the online code suggest that our result of a positive effect of the number of people on energy-related financial stress is primarily driven by the largest households.

Table 1 also has other important results related to occupant characteristics. Single parents with dependent children are more likely to experience energy-related financial stress, while couple-only households are much less likely to experience energy-related financial stress. Households with an occupant who uses energy-consuming medical equipment are more likely to experience energy-related financial stress, all else equal. There is also a negative effect of age on energy-related financial stress, similar to the finding of Marks (2007) for overall financial stress.

Table 2 provides propensity score matching results on the effect of solar panels. We use the same covariates from Table 1 to match each household with the most similar household in all respects other than the binary solar panel variable. We also include a new binary covariate for a lack of energy conservation that is equal to 1 when households reported taking less than five actions to reduce energy use (excluding households who deem their energy use to be low enough already). This variable could be subject to reverse causation from energy-related financial stress if it were included in Table 1.

Table 2 shows that households that have solar panels are less likely to have difficulty paying energy bills. The average treatment effect is approximately 4 percentage points for having solar panels more than 2 years before the survey (first row of column (1)). Slightly larger point

TABLE 2  
Propensity Score Matching Results: Solar Panels Average Treatment Effect, 2012

Details for solar panel average treatment effect	Dependent variables, binary		
	Could not pay electricity, natural gas, or telephone bill on time (1)	Could not pay electricity, natural gas, or telephone bill on time often or always (2)	Received disconnection warning from electricity or natural gas company (3)
Solar panels installed > 2 years ago	-0.040** (0.020)	-0.028*** (0.009)	-0.014 (0.017)
Solar panels installed > 2 years ago, probit	-0.050** (0.025)	-0.023** (0.011)	-0.031* (0.017)
Solar panels installed > 2 years ago and minimum of 2 matches	-0.060*** (0.013)	-0.029*** (0.006)	-0.027*** (0.009)
Solar panels installed any time	-0.042** (0.020)	-0.021 (0.014)	-0.031*** (0.011)

Note: \*\*\*Significant at the 1%, \*\*5%, \*10% level. Average treatment effects are shown. Standard errors are in parentheses below the coefficients. The covariates include all of the explanatory variables from Table 1 plus a binary variable to identify households that are not concerned about energy conservation. The data are from the 2012 HEC survey.

estimates are obtained using a probit model, when requiring that at least two similar households be used in the matching process, and for the treatment of having had solar panels installed at any time in the past. There are slightly smaller absolute effects for the different dependent variables in column (2) and (3). Most coefficients are statistically significant. Results are also similar if households are matched on financial resources only, instead of the full list of covariates (see the online code). This enhances confidence that the solar treatment effect is not just a proxy for wealth.

Table 3 focuses on explaining a composite measure of energy-related financial stress. This binary variable equals 1 if households were unable to pay their bill on time *and* chose to restrict heating or cooling of their home due to a shortage of money. In addition, Table 3 successively adds groups of variables so that we can assess the effect of inclusion of key variables on other explanatory variables. We also add electricity expenditure and electricity consumption as explanatory variables in the final column, as high use and spending would increase difficulty in paying bills, all else equal.

Column (1) of Table 3 suggests a positive effect of not being an owner-occupier on energy-related financial stress. The coefficient for public-housing renters is the largest in magnitude compared to the reference group of owner-occupiers without a mortgage, as expected given that this group likely includes many low-wealth households. The coefficients for public and private renters in column (1) are statistically different at the 1% level. The magnitudes of the renter variables decline when including financial resources such as log net wealth in column (2), but are still positive and significant at the 1% level. This is consistent with the expectation that there are two major constraints for renters on average: a wealth constraint that is more severe for public renters and a property rights constraint that affects both types of renters in a similar way. The results also suggest that part, but not all, of an apparent renter effect on energy-related financial stress is explained by correlation between renter status and net wealth. Selected correlations are shown in a correlation table in Table A.3 in Appendix S1.

Column (3) shows similar effects on the composite measure of energy-related financial stress compared to Table 1 with individual measures. For example, there are negative effects of

apartments, log wealth, log income, couple-only households and age. There are positive effects of government income percentage, suggesting that greater reliance on welfare is associated with additional energy-related financial stress. There are also positive effects of the number of people and for having an occupant using energy-consuming medical equipment. Adding location controls in column (4) has very little effect.

There is a positive coefficient for log electricity consumption, significant at the 10% level, in explaining the composite measure in column (5) of Table 3. This can be regarded as a lower-bound effect, given a potential negative association in the opposite direction of causation, as households having difficulty paying electricity bills may be motivated to lower their electricity consumption and expenditure. The other component of the dependent variable, restricting energy use, would have a negative effect on energy consumption by definition.

Column (5) of Table 3 includes an additional binary explanatory variable, with a value of 1 if households stated that they did not make any investments to save energy in the last 2 years due to high upfront costs. There is a positive and significant effect for this variable, when controlling for other variables such as log net wealth, on energy-related financial stress. This suggests that capital investments can help to ameliorate dimensions of energy-related financial stress. There is also a risk of reverse causation for this variable, as trouble paying bills may influence perceptions of upfront cost. Another potential issue is that both variables could be affected by an omitted variable such as purchasing ability, although we have controlled for log net wealth and log income.

Table 4 adds results for the HES of 2015–16. While the HES has fewer energy-related variables available, such as insulation and solar panels installed 2 years before the survey, the HES has the advantage of being more recent. Also, identifiers are available for welfare recipient groups. Further, we combine indicators of financial stress to assess multi-dimensional poverty measures using the HES. We also produce similar results with additional binary variables for Statistical Area Level 4 and remoteness code regions instead of state and capital city controls (see the code in the online supplementary materials).

Column (1) of Table 4 investigates factors affecting whether households could not pay their energy bills on time. Results are similar to

TABLE 3  
*Logit Results: Composite Energy-Related Financial Stress, 2012*

	Dependent variables: log odds of a composite energy-related financial stress binary variable				
	(1)	(2)	(3)	(4)	(5)
Mortgage	1.597*** (0.182)	1.763*** (0.199)	1.427*** (0.207)	1.418*** (0.207)	1.361*** (0.328)
Renter, private	2.351*** (0.183)	1.656*** (0.226)	1.280*** (0.233)	1.288*** (0.233)	1.718*** (0.366)
Renter, public	2.820*** (0.212)	1.293*** (0.262)	1.015*** (0.267)	1.027*** (0.269)	1.083*** (0.408)
Solar panels	0.036 (0.302)	-0.078 (0.349)	-0.033 (0.352)	-0.034 (0.353)	0.287 (0.485)
Insulation	-0.155 (0.097)	-0.050 (0.103)	0.001 (0.104)	-0.007 (0.106)	0.137 (0.151)
Bedrooms #	0.045 (0.056)	0.274*** (0.061)	0.130* (0.068)	0.134* (0.069)	-0.045 (0.100)
Apartment	-0.717*** (0.178)	-0.793*** (0.194)	-0.750*** (0.196)	-0.721*** (0.199)	-0.823*** (0.279)
Old house	0.278*** (0.097)	0.182* (0.103)	0.175* (0.104)	0.149 (0.105)	0.178 (0.146)
Log wealth		-0.376*** (0.044)	-0.284*** (0.048)	-0.285*** (0.048)	-0.298*** (0.069)
Log income		-0.306*** (0.070)	-0.396*** (0.076)	-0.381*** (0.077)	-0.450*** (0.110)
Government income %		0.685*** (0.141)	0.700*** (0.175)	0.667*** (0.176)	0.926*** (0.250)
Persons #			0.204*** (0.071)	0.215*** (0.072)	0.237** (0.107)
Employed #			-0.068 (0.084)	-0.079 (0.084)	0.071 (0.113)
Children #			-0.126 (0.090)	-0.139 (0.090)	-0.035 (0.127)
Couple only			-0.640*** (0.161)	-0.651*** (0.162)	-0.819*** (0.222)
Couple with dependent child			-0.202 (0.171)	-0.225 (0.171)	-0.509** (0.231)
Single parent			0.307* (0.164)	0.315* (0.165)	-0.012 (0.241)
Medical			0.838*** (0.228)	0.815*** (0.229)	0.525 (0.342)
Age #			-0.017*** (0.004)	-0.018*** (0.004)	-0.018*** (0.006)
Log electricity expenditure					0.160 (0.176)
Log electricity consumption					0.281* (0.164)
Log housing cost					-0.035 (0.106)
Upfront cost too high					0.804*** (0.216)
Location controls	No	No	No	Yes	Yes
Observations	11,978	11,661	11,661	11,660	7,278
Pseudo $R^2$	0.079	0.133	0.151	0.156	0.176

*Note:* \*\*\*Significant at the 1%, \*\*5%, \*10% level. Standard errors are in parentheses below the coefficients. Coefficients are not shown for constants, state binary variables, a capital city binary variable, and state  $\times$  capital city interaction variables. The reference category for tenure type (e.g. mortgage) is owning without a mortgage. A tenure type of other is also a control but is not statistically significant. Logit coefficients are shown. The data are from the 2012 HEC survey. Explanatory variables are binary unless identified by log, percentage (%), or number (#).

TABLE 4  
*Logit Results: Various Measures of Energy-Related Financial Stress, 2015–16*

	Dependent variables, log odds			
	Could not pay pay bill (1)	Unable to heat home (2)	Could not pay bill and unable to heat home (3)	Could not pay bill and unable to heat home and went without meals (4)
Mortgage	1.231*** (0.159)	0.545** (0.244)	1.352*** (0.420)	0.796 (0.651)
Renter, private	1.218*** (0.178)	0.272 (0.276)	1.150*** (0.448)	1.315*** (0.657)
Renter, public	1.105*** (0.211)	0.326 (0.311)	1.039*** (0.486)	1.415*** (0.705)
Bedrooms #	0.025 (0.052)	0.0370 (0.093)	-0.028 (0.126)	-0.114 (0.190)
Apartment	-0.491*** (0.137)	-0.313 (0.225)	-0.370 (0.292)	-0.538 (0.432)
Log wealth	-0.288*** (0.037)	-0.232*** (0.061)	-0.266*** (0.075)	-0.163 (0.112)
Log income	-0.225*** (0.055)	-0.251*** (0.084)	-0.380*** (0.096)	-0.409*** (0.135)
Government income %	0.349** (0.156)	0.568*** (0.267)	0.439 (0.351)	0.030 (0.513)
Persons #	0.147** (0.060)	-0.040 (0.117)	0.0570 (0.146)	0.011 (0.220)
Employed #	0.020 (0.070)	-0.300** (0.148)	-0.156 (0.186)	-0.156 (0.282)
Children #	-0.051 (0.076)	0.170 (0.156)	0.225 (0.182)	0.347 (0.263)
Couple only	-0.325** (0.128)	-0.732*** (0.249)	-0.549 (0.375)	-0.763 (0.632)
Couple with dependent child	-0.170 (0.137)	-0.502 (0.325)	-0.231 (0.379)	-0.194 (0.578)
Single parent	0.423*** (0.140)	0.204 (0.261)	0.544* (0.298)	0.817*** (0.408)
Age pension	-0.442** (0.194)	-0.049 (0.341)	-0.239 (0.501)	-0.136 (0.806)
Disability and carer payments	0.687*** (0.157)	0.883*** (0.296)	1.153*** (0.381)	1.637*** (0.563)
Family support payments	0.687***	0.262	0.092	-0.134

TABLE 4  
(continued)

	Dependent variables, log odds			
	Could not pay bill (1)	Unable to heat home (2)	Could not pay bill and unable to heat home (3)	Could not pay bill and unable to heat home and went without meals (4)
Unemployment, student allowance	(0.139) 0.790*** (0.149)	(0.329) 1.358*** (0.273)	(0.401) 1.419*** (0.353)	(0.608) 1.555*** (0.530)
Other government pensions	-0.050 (0.175)	0.007 (0.375)	-0.051 (0.497)	-0.281 (0.831)
Age #	-0.005 (0.004)	-0.002 (0.007)	-0.002 (0.009)	-0.008 (0.013)
Observations	9,854	9,854	9,854	9,637
Pseudo $R^2$	0.192	0.188	0.219	0.230

Note: \*\*\*Significant at the 1%, \*\*5%, \*10% level. Standard errors are in parentheses below the coefficients. Coefficients are not shown for constants, a capital city binary variable, state binary variables, and state  $\times$  capital city interaction variables. Results are similar if other location variables are included (e.g. Statistical Area Level 4 binary variables or remoteness code binary variables; results are available via the code in the online supplementary materials). The reference category for the main source of social assistance (e.g. age pension) is no social assistance. The reference category for tenure type (e.g. mortgage) is owning without a mortgage. A tenure type of other is also a control. Logit coefficients are shown. The data are from the 2015–16 HES. Explanatory variables are binary unless identified by log, percentage (%), or number (#).

Table 1. There is a negative effect of apartment living on energy-related financial stress, and positive impacts from being a renter and from having a mortgage. There are negative effects of financial resources on the log odds of households having difficulty paying bills on time. A robustness test in the code in the online supplementary materials also finds that the log of equivalised wealth and the log of equivalised disposable income have similar effects when excluding the variable for the number of people. Single parents are more likely to have trouble paying energy bills, while couple-only households are less likely.

There is evidence of greater energy-related financial stress for households for which the main source of social benefits is either disability and carer payments or unemployment and student benefits. There is no evidence that age pension recipients suffer from greater energy-related financial stress on average relative to the reference category of households receiving no cash-based social assistance benefits. Indeed, there is a negative and significant effect of the age pension recipient category on not being able to pay bills in column (1). These results suggest that the recently introduced 2019 Energy Assistance Payment (Australian Government, 2019) may not have been targeted solely at people who are particularly vulnerable to energy-related financial stress, as it included age pension recipients.<sup>7</sup>

The dependent variable in column (2) of Table 4 is the log odds for households being unable to heat their home (rather than heating *or* cooling their home). Many of the results are similar in sign and significance compared to column (1). A key difference is that the renter coefficients are not significant in column (2) in explaining difficulty heating homes. The financial stress from higher bills due to less efficient appliances would likely lead to some renting households changing their heating behaviour, but may not substantially change behaviour for all renting households.

Columns (3) and (4) of Table 4 combine measures of financial stress, revealing some key

groups that are most likely to suffer from multi-dimensional poverty. There are positive and significant coefficients for renting in columns (3) and (4). Based on the multi-dimensional poverty measure in column (4), the odds of energy-related financial stress for renters are more than triple the odds of energy-related financial stress for non-renters, all else equal. Some welfare groups are exposed to much higher likelihood of multi-dimensional poverty indicators. This includes disability and carer payment recipients, and unemployment and student allowance recipients.

#### IV. Conclusion and Policy Implications

Key results in this paper include that renters, along with mortgage holders, are at greater risk of multi-dimensional energy-related financial stress measures. There is a substantial effect of having solar panels in reducing difficulty paying energy bills. Insulation does not have a significant effect on difficulty in paying energy bills, but does reduce the probability that households will be unable to heat or cool their home. We also quantify a negative association between net wealth and indicators of energy-related financial stress, a link not often analysed in prior empirical studies. This reveals that financial resource differences are key to understanding which households are more likely to experience energy-related financial stress, as should be expected. Use of energy-consuming medical equipment makes energy-related financial stress more likely. Some categories of welfare recipients are at particular risk of suffering energy-related financial stress, such as disability and carer payment recipients and those receiving unemployment or student benefits.

Some factors have different effects on different dimensions of energy-related financial stress. Having solar panels helps households to avoid difficulties in paying energy bills, although we find no perceptible effect on being unable to heat or cool homes. Households with an occupant who uses energy-consuming medical equipment are more likely to have difficulty in paying bills, but there are less significant effects on being unable to heat or cool a home. This perhaps reflects the fact that energy use for medical equipment may not be optional.

A key issue is whether policy should be more aggressively targeted at reducing energy-related financial stress. For instance, policy efforts could target low-wealth renters, including via a focus

<sup>7</sup> The 2019 Energy Assistance Payment of \$75 for eligible singles and \$125 for eligible couples was automatically paid to recipients of all social security allowances and some pensions by 30 June 2019. A full list of recipient categories is available at <https://www.humanservices.gov.au/individuals/news/energy-assistance-payments-will-be-paid-june-2019>.

on overcoming principal–agent problems between landlords and renters. Households with occupants using energy-consuming medical equipment could also be targeted for additional support. While there are already federal and state support measures – including the Commonwealth Government Essential Medical Equipment payment of approximately \$150 each year (Australian Government, 2018) – we nevertheless find that households using energy-consuming medical equipment are much more likely to face energy-related financial stress.

Further research could assess the impact of recent schemes that aim to address energy-related financial stress through solar subsidies, including a number of recent schemes using income thresholds. For example, the Solar for Low Income Households Program in the Australian Capital Territory involves subsidies of up to 60% of system costs, targeted at low-income households (ACT Government, 2017). The Victorian Government Solar Panel Rebate excludes households with income above \$180,000 or home values above \$3 million (Victoria State Government, 2018). The ACT scheme has excluded renters, despite their vulnerability to energy-related financial stress, while the Victorian support has been revised to include renters. Supporting solar panel installations on rental properties addresses wealth and property rights constraints and can directly reduce energy-related financial stress among a key group. There are also other more market-focused approaches to addressing these issues, such as developing markets for leasing of solar panels.

#### *Supporting Information*

Additional Supporting Information may be found in the online version of this article:

**Table A1.** Description of variables from the Household Energy Consumption survey.

**Table A2.** Mean values for each survey.

**Table A3.** Correlations of key variables, HES.

**Data S1.** Stata code and data link.

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