Modelling household energy consumption to understand sustainable energy behaviour

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4. Relationships between socio-demographic variables, psychological factors and the likelihood of installing PV

Climate change is one of the most urgent issues we are facing today, largely caused by emissions of CO_2. Households can reduce their carbon emissions by reducing their fossil fuel consumption and generating their own renewable electricity, for example by installing photovoltaic systems (PV) (IPCC, 2018). To mitigate climate change, and to promote the adoption of PV, it is important to understand which factors affect the likelihood that household's install PV, as this reveals which factors can best be targeted by policy to promote the installation of PV.

Some studies examined what drives household's intention to install PV. Yet, these studies focused on a limited set of factors, so a comprehensive view of the main antecedents of PV adoption is lacking. For example, some studies examined to what extent socio-demographic variables are related to PV adoption (Robinson et al., 2016; Vicente-Molina et al., 2018). These studies have found that older people, households with a higher education level and households with a higher income are more likely to install PV (Davidson, Drury, Lopez, Elmore, & Margolis, 2014; Islam, 2014; Kwan, 2012; Peters, van der Werff, & Steg, 2019; Robinson, Murphy, & Laczniak, 2016; Sigrin, Pless, & Drury, 2015; Vicente-Molina, Fernández-Sainz, & Izagirre-Olaizola, 2018). Yet, other studies suggest that younger people are more likely to install PV than older people, as they are more open to accepting new technologies than older people, and thus, more likely to install PV (Drury et al., 2012). Therefore, the question remains of how age is related to the likelihood that households install PV. Moreover, females are generally more aware of environmental problems than males, and as a consequence, they are more likely to accept renewable energy technologies (Bashiri & Alizadeh, 2018; Laroche, Bergeron, & Barbaro-Forleo, 2001). This may imply that females are more likely to install PV than men. Furthermore, it has been found that larger households are more likely to install PV than smaller households (Dong et al., 2017). In addition, a higher educational level is generally related to a higher adoption of green electricity (F.-Y. Chen, Hsu, & Lin, 2011; Sánchez, López-Mosquera, & Lera-López, 2015; Tilikidou, 2007). This implies that education level may also increase the likelihood that people own PV. Moreover, a higher income is associated with more pro-environmental behaviour, including installing PV (Devine-Wright, 2007; Jager, 2006; Keirstead, 2007). Therefore, we expect that people with a higher income are more likely to install PV.

As yet, little is known about how psychological factors affect the likelihood that households install PV. Yet, it has been found that stronger altruistic values (i.e., reflecting concern for other human beings), stronger biospheric values (i.e., focusing on valuing the environment), and a stronger personal norm (e.g., feelings of moral obligation) to engage in sustainable energy behaviour are associated with an increased interest in adopting PV (Wolske, 2020; Wolske, Stern, & Dietz, 2017), probably because the adoption of PV has benefits for others and the environment, and because people are motivated to act in line with their personal norms as this makes them feel good. Likewise, studies have found that households who installed PV reported that helping the environment and feeling responsible for future generations were key reasons for them to install PV, again indicating that stronger biospheric and altruistic values affect the adoption of PV (Haas, Ornetzeder, Hametner, Wroblewski, & Hübner, 1999; Jager, 2006).

Yet, many other psychological factors may be related to the likelihood that households install PV. Notably, PV adoption may be affected by similar factors as other types of sustainable energy behaviour. First, stronger hedonic values (i.e., focusing on pleasure and comfort) and egoistic values (i.e., focusing on increasing one's personal resources) generally appear to reduce the likelihood that people engage in sustainable energy behaviour (Şener & Hazer, 2008; Steg & Groot, 2012; Stern & Dietz, 1994), and may thus also inhibit the installation of PV, as doing so is rather costly and effortful. Second, people may be more likely to install PV if they have a stronger goal to engage in sustainable energy behaviour, as people are motivated to act in line with their goals (Sloot et al., 2018). Third, a stronger environmental self-identity (i.e., the extent to which people see themselves as a pro-environmental person) is likely to encourage the likelihood that households install PV, in a similar way as other types of sustainable energy behaviour, as people are motivated to act in line with how they see themselves in order to (appear to) be consistent (REF; Ruepert, Keizer, Steg, et al., 2016). Furthermore, people are more likely to engage in sustainable energy behaviour when they think such behaviours would help reduce environmental problems, as reflected in a higher outcome efficacy (Stern, 2000). Therefore, we expect that people are more likely to install PV when they more strongly believe that doing so would help reduce energy problems.

Extending previous research, this paper aims to examine the extent to which a wide range of socio-demographics and psychological factors are uniquely related to the likelihood that households install PV. Notably, extending previous studies, we examine the unique contribution of socio-demographic variables (i.e., age, gender, household size, educational level and income) and psychological factors (i.e., altruistic values, biospheric values, hedonic values, egoistic values, sustainable energy use goals, environmental self-identity, personal norm to reduce energy use, and outcome efficacy). For this purpose, we use Multinomial Logistic Regression (MLR: cf. Schwab, 2002) to test to what extent these types of factors are uniquely related to the intention to install PV, as well as actual PV ownership.

4.1 Method

A questionnaire study was conducted in neighbourhoods where a Buurkracht initiative was established, a network of energy initiatives that aims to promote sustainable energy use in different communities in the Netherlands (Buurkracht, 2018)[11]. We invited members and non-members of Buurkracht to participate in the study. For each household one person (usually the 'head of the household') filled in the questionnaire. Among others, the questionnaire included questions on socio-demographic variables, psychological factors, intention to install PV and PV ownership. In this paper, we analyse data of 166 households that completed the full questionnaire. The sample size of 166 households is large enough according to the sample size guidelines for MLR advise a minimum of 10 cases per independent variable, and we included 13 independent variables (Hosmer, Lemeshow, & Sturdivant, 2013; Schwab, 2002).

Questionnaire

Socio-demographic variables

Table 4.1 shows the descriptives of socio-demographic variables included in this study. In total 111 males and 55 females filled in the questionnaire. Age ranged from 32 to 86 (M = 58.95, SD = 11.67). Most households are comprised of two-persons (53.6%). Almost 39% of the participants had higher education/ vocational

11 The data contains Buurkracht members and non-members.

education, which is the largest proportion, whereas less than 5% of households had lower vocational education. As such, our sample is not fully representative of the Dutch population.

Table 4.1. Descriptive for socio-demographic variables (%; bold: the reference categories: gender: female; household size: 1; education: lower vocational education; income: 1,000-2,000 euro per month)

Variable	Response categories (percentage)
Respondent age	M = 58.95, SD = 11.67, Min = 32, Max = 86
Respondent gender	**Female (33.1%)**, Male (66.9%)
Household size (person per household)	**1 (10.2%),** 2 (53.6%), 3(12.1%), 4 (16.3%), 5 or more (7.8%)
Educational level	**Lower vocational education (4.2%)**, Secondary education/ vocational education (27.1%), Higher education/ vocational education (42.2%), Academic education (26.5%)
Income (net per month)	**1,000-2,000 euro (9.6%)**, 2,000-3,000 euro (39.2%), 3,000-4,000 euro (27.1%), 4,000-5,000 euro (15.7%), More than 5,000 euro (8.4%)

Psychological factors

Values. Respondents filled in a value questionnaire with 16 items to measure their altruistic, biospheric, hedonic, and egoistic values (see Steg et al., 2014). A short explanation was given of the relevant values. The scale included four altruistic values (Equality: equal opportunities for everyone; A peaceful world: free from war and conflict; Social justice: restoring injustice, taking care of the weak; Helpful: working for the good of others), four biospheric values (Respect for the earth: living in harmony with other species; Unity with nature: feeling connected to nature; Environmental protection: preservation of environmental equality and nature; Environmental pollution avoid: protect natural resources), three hedonic values (Fun: pleasure, fulfilment of desires; Enjoy life: from food, sex, relaxation; Enjoy yourself: doing pleasant things), and five egoistic values (Social power: control over other people, dominance; Wealth: material possessions, money; Authority: the right to lead or command; Influential: affect people and events; Ambitious: hardworking, aspiring). Respondents were requested to indicate to what extent these values were important to them as a guiding principle of their life, on a 9-point scale (−1 opposed to my values to 0 not important to 7 extremely important). Following Schwartz

(Schwartz, 1992, 1996), respondents were advised to distinguish as much as possible between the importance of the values by selecting different numbers, and to rate no more than two values as extremely important, to ensure that participants distinguished between the importance of the different values. The items of altruistic values, biospheric values, hedonic values, and egoistic values formed reliable scales; Table 4.2 provides an overview of the reliability, means, and standard deviations of the scales. The mean scores indicate that people generally rather strongly endorse biospheric, altruistic and hedonic values, while egoistic values were relatively less important to people on average.

Sustainable energy use goal. Sustainable energy use goal was measured with three items: I find it important to be conscious about my energy behaviour; I find it important to save energy; I find it important to use more sustainable energy. Respondents indicated to what extent they agree with the items on a 7-point scale ranging from 1 (completely disagree) to 7 (completely agree). The items formed again a reliable scale; the mean score indicates that respondents find it generally important to use energy in a sustainable way (see Table 4.2).

Environmental self-identity. A validated scale was used to measure environmental self-identity, comprising three items: Being environmentally friendly is an important part of who I am; I am the type of person who acts environmentally friendly; I see myself as an environmentally friendly person (Van der Werff, Steg, & Keizer, 2013a, 2013b). Respondents rated each item on a 7-point scale, ranging from 1 'completely disagree' to 7 'completely agree'. The items formed a reliable scale. The mean score indicates that respondents generally see themselves as a person who acts pro-environmentally (see Table 4.2).

Personal norm. Personal norm to save energy was measured with two items: I have the moral ideal to reduce my energy consumption; I feel morally obliged to reduce my energy consumption (adapted from Zeiske, Venhoeven, Steg, & van der Werff, 2020). Respondents rated each item on a 7-point scale, ranging from 1 'completely disagree' to 7 'completely agree'. The two items formed a reliable scale. Respondents generally experience a strong personal norm to reduce their energy use (see Table 4.2).

Outcome efficacy. Outcome efficacy was measured with one item: I can make an important contribution to reducing energy problems by reducing my energy consumption. Respondents indicated to what extent they agree with the item on a 7-point scale ranging from 1 (completely disagree) to 7 (completely agree). Respondents generally think they can to some extent contribute to reducing energy problems by reducing their energy.

Table 4.2. Descriptive statistics for the psychological factors

Variable	*Cronbach's alpha*	*M (SD)*	*Min*	*Max*
Altruistic values	.84	5.46 (0.91)	3.00	7.00
Biospheric values	.82	5.23 (1.09)	0.00	7.00
Hedonic values	.83	4.77 (1.33)	1.33	7.00
Egoistic values	.85	2.37 (1.24)	-0.60	5.20
Sustainable energy use goal	.83	5.46 (0.92)	2.33	7.00
Environmental self-identity	.82	4.77 (1.01)	2.00	7.00
Personal norm	*r* =.77[12]	5.10 (1.06)	2.00	7.00
Outcome efficacy	-[13]	4.60 (1.57)	1.00	7.00

Dependent variable: likelihood to install PV

Respondents indicated to what extent they are likely to install PV or have installed PV, on a 3-point scale: 1 = no intention to install PV, 2 = intend to install PV, and 3 = have already installed PV. Table 4.3 shows the frequencies and percentages of respondents for these three categories of the likelihood that households install PV.

Table 4.3. Descriptive statistics for the likelihood that households install PV across households (n = 166; bold = reference level: No intention to install PV)

PV ownership	Frequency	Percentage
No intention to install PV	60	36.1%
Intend to install PV	39	23.6%
Already installed PV	67	40.3%

Statistical analysis: Multinomial Logistic Regression (MLR)

We use Multinomial Logistic Regression (MLR: cf. Schwab, 2002) to test to what extent the socio-demographic variables and psychological factors are related to the likelihood that households install PV. MLR is considered as a simple extension of the binomial logistic regression that allows for more than two categories of the dependent variable, in this case PV ownership versus intention to install PV versus none of these. Like binary logistic regression, MLR uses maximum likelihood estimation to evaluate the probability of categorical membership on the dependent

12 Personal norm was measured with two items, and therefore, the reliability of two-item measures is assessed by computing a Pearson correlation coefficient.

13 Outcome efficacy was measured with one item, and therefore, we were not able to assess a reliability coefficient.

variable (Kwak & Clayton-Matthews, 2002). One of the main advantages of MLR is easy to implement and interpret. Most importantly, MLR gives more accurate estimates than multiple linear regressions, especially when data are sparse.

We fitted three MLR models to the data of our study. We started with an empty model with only the intercept. In the second model, we included socio-demographic variables. In the third model, we added psychological factors along with socio-demographic variables. The purpose of fitting these three MLR models was to test the effect size of the different types of predictors on the likelihood of installing PV.

We use the "multinom" function from the "nnet" package in R programming (Computing, 2020) to estimate an MLR model, where the *p*-values are computed using Wald tests. To evaluate the goodness of fit of the MLR, we calculated Pearson's Chi-squared test. Furthermore, Nagelkerke's R squared using the "DescTools" package is used to estimate the effect size. To ease interpretation of the MLR model, we converted coefficients into odds ratio (OR) (i.e., inverse log of the estimated coefficients)[14].

4.2 Results and Discussion

The model in which we included all socio-demographic variables explained 40% of the variance in the likelihood of installing PV (Nagelkerke's R squared) ($X^2_{(4)} = 47.18$, $p < .001$), indicating that the model with socio-demographic predictors provided a better fit than the null model. The third model explained 58% of the variance in the likelihood of installing PV (Nagelkerke's R squared), and the Pearson's Chi-squared test, $X^2_{(4)} = 97.82$, $p < .001$, indicating that the model including the psychological factors improved the explanation of likelihood of installing PV.

Table 4.4 displays the results of the third MLR model to explain the likelihood that households install PV. We first discuss which factors increase the likelihood that people intend versus not intend to install PV. Second, we discuss which factors increase the likelihood that people have installed versus not intend to install PV.

14 In the context of logistic regression, each exp(β) is the ratio of the odds for successive values of the associated covariate when all else is held equal. The OR is the multiplier that shows how the odds change for a one-unit increase in the value of the covariate. When the OR is greater than 1, it describes a positive relationship, and an OR less than 1 implies a negative relationship.

Table 4.4. Results for the Multinomial Logistic Regression (MLR) model for the likelihood that households install PV including socio-demographic variables and psychological factors as predictor variables. Unstandardized Beta coefficients (B) and Odd Ratios (OR) shown. "*" p < .05; "**" p < .01; "***" p < .001. The reference categories are: gender: female; household size: 1; education level: lower vocational education; income: 1,000-2,000 euro per month

	Intention to install PV vs. No intention to install PV				**Already installed PV vs. No intention to install PV**			
Variable	***B***	**SE**	**OR (95% CI)**	***p*-value**	***B***	**SE**	**OR (95% CI)**	**p-value**
Age	-.097	.040	.915 (.847; .989)	.015*	-.032	.032	.975 (.912; 1.036)	.313
Gender: male	-.365	.731	.694 (.176; 2.915)	.617	.134	.572	1.142 (.374; 3.512)	.813
Household size								
2	2.030	.945	7.614 (3.916; 9.218)	<.001***	.495	.952	1.643 (.253; 4.063)	.602
3	1.660	.997	5.259 (1.389; 4.192)	<.001***	-1.033	1.160	.368 (.402; 3.461)	.373
4	1.629	.930	5.098 (1.926; 8.378)	<.001***	-.258	1.131	.772 (.805; 4.709)	.818
5 or more	2.235	1.145	9.346 (5.604; 11.650)	<.001***	.625	1.640	1.875 (.865; 5.952)	.702
Education level								
Secondary education	-.853	.739	.435 (.105; 1.815)	.248	.464	.665	1.592 (.435; 5.879)	.485
Higher education	.502	1.145	.963 (.163; 5.684)	.730	.318		1.758 (.408; 7.778)	.858
Academic education	-.044	.908	1.658 (.165; 8.715)	.961	.560	.759	1.733 (.046; 4.586)	.460

Income (net per month)								
2000-3000 euro	3.018	1.365	20.450 (14.11; 29.10)	.027*	3.079	1.268	21.842 (18.102; 26.100)	.015*
3000-4000 euro	2.352	1.360	10.541 (4.125; 17.274)	.083	4.013	1.308	55.398 (42.652; 71.920)	.002**
4000-5000 euro	1.366	1.560	3.925 (.187; 8.359)	.380	4.318	1.496	75.146 (39.94; 141.20)	.003**
More than 5000 euro	2.355	1.657	10.265 (4.158; 27.243)	.155	3.948	1.585	51.987 (23.243; 159.12)	.012*
Altruistic values	-1.270	.509	.286 (.102; .769)	.012*	-.262	.388	.778 (.361; 1.653)	.499
Biospheric values	.666	.499	1.952 (.732; 5.189)	.181	-.052	.390	.951 (.441; 2.048)	.893
Hedonic values	.023	.299	1.023 (.571; 1.847)	.937	-.276	.254	.765 (.465; 1.252)	.278
Egoistic values	-.037	.281	.962 (.554; 1.679)	.892	.131	.245	1.149 (.702; 1.852)	.591
Sustainable energy use goal	1.489	.591	4.441 (1.396; 14.158)	.011*	1.041	.547	2.835 (.975; 8.281)	.057
Environmental self-identity	-.810	.483	.446 (.175; 1.152)	.093	-.351	.400	.702 (.326; 1.544)	.380
Personal norm	.739	.466	2.103 (.847; 5.236)	.112	1.178	.424	3.256 (1.416; 7.479)	.005**
Outcome efficacy	-.249	.265	.78 (.468; 1.314)	.346	-.32	.246	.728 (.452; 1.175)	.189

Extending previous research on PV adoption (Robinson et al., 2016; Vicente-Molina et al., 2018), we found that both socio-demographic and psychological factors are both important and reliable unique predictors of the likelihood that households intend to install PV (vs. not intent to do so). In line with some previous studies (Drury et al., 2012), we found that younger households were more likely to intend to install PV than older households (OR = exp (-.09) = .915 p <.05). Yet, this contrasts with other studies that suggest that older households were more likely to install PV (Davidson, Drury, Lopez, Elmore, & Margolis, 2014; Islam, 2014; Kwan, 2012; Peters, van der Werff, & Steg, 2019; Robinson, Murphy, & Laczniak, 2016; Sigrin, Pless, & Drury, 2015; Vicente-Molina, Fernández-Sainz, & Izagirre-Olaizola, 2018). These findings support the reasoning that younger people are more open to new technologies than older people, and thus, more likely to install PV. Furthermore, replicating earlier findings (Dong et al., 2017), we found that larger households had a stronger intention to install PV than single households. Specifically, households with one member in the household were 7.61 less likely than households with two members to intend to install PV compared to not doing so (OR = 7.61, p <.001). One explanation could be that larger households consume more energy than smaller households, making PV a more attractive option to reduce energy costs. Moreover, in line with our expectations and earlier research (Devine-Wright, 2007; Jager, 2006; James Keirstead, 2007), a higher household income increased the likelihood that households intend to install PV. Specifically, households with income less than 2,000 euro per month were 20.45 less likely than households with income between 2,000 and 3,000 euro per month to intend to install PV compared to not doing so (OR = 20.45, p <.05). These findings suggest that a higher income is associated with a higher likelihood of installing PV, probably as higher income groups can more easily afford to install PV than lower income households.

Results further showed that psychological factors play an important role in explaining the intention to own PV. Specifically, as expected, a stronger sustainable energy use goal increased the likelihood that people intend to install PV compared to not doing so (OR = 4.44, p < .05). These findings support our reasoning that people are more likely to install PV as they are motivated to act in line with their sustainable goals. Yet, in contrast to what we expected, stronger altruistic values reduced the likelihood that people intend to install PV compared to not to do so (OR = .28, p < .05). This finding contrasts with previous studies that generally show that stronger altruistic values promote sustainable energy behaviour. Future research is needed to test why this is the case. In contrast to previous research that found that stronger biospheric values are likely to increase the intention to install PV (Wolske, 2020; Wolske et al., 2017), we found no significant association between biospheric values and the intention to install PV. Furthermore, hedonic values, egoistic values, environmental self-identity, personal norm to reduce energy use, and outcome efficacy did not affect the intention to own PV when the other variables were controlled for.

Next, we examined which factors increase the likelihood that households actually have installed PV. In line with our reasoning, households with a higher income were more likely to actually have installed PV. Specifically, households with income less than 2,000 euro per month were 21.84 less likely than households with income between 2,000 and 3,000 euro per month to already have installed PV compared to not intend to install PV (OR = 21.84, p <.05). This may again be because households with higher income can more easily afford to install PV and are more likely to own their dwelling and thus able to install their own PV. Furthermore, a stronger personal norm to reduce energy use increased the likelihood that people have installed PV compared to not intend to install PV (OR = 3.25, p < .01). This is in line with our reasoning and previous research showing that households are more likely to engage in sustainable energy behaviour, such as installing PV, when they feel a stronger sense of moral obligation to do so (Ajibade & Boateng, 2021; Ateş, 2020; Geiger, Steg, van der Werff, & Ünal, 2019; Namazkhan et al., 2020; van der Werff, Taufik, & Venhoeven, 2019; van der Werff & Steg, 2016).

In contrast with previous studies (Bashiri & Alizadeh, 2018; Laroche et al., 2001) that reported that females are more likely to install PV, we found no relationship between gender and PV ownership. Furthermore, in contrast to previous studies that found that a higher educational level increased the adoption of PV (F.-Y. Chen, Hsu, & Lin, 2011; Sánchez, López-Mosquera, & Lera-López, 2015; Tilikidou, 2007), we found that educational level was not related to the likelihood that households actually have installed PV. Moreover, altruistic values, biospheric values, hedonic values, egoistic values, sustainable energy use goals, environmental self-identity, and outcome efficacy did not affect the likelihood that people have actually installed PV, when the other variables were controlled for. Overall, our result showed that the sociodemographic and psychological variables explained intentions to install PV better than actual ownership of PV; future research is needed to explore this further.

This study has important practical implications. Policies would be more effective when they address key antecedents of the likelihood that people install PV. Our findings suggest that policies could particularly consider age, household size, income, altruistic values, sustainable energy use goals, and personal norms to reduce energy use, as these were most strongly related to the likelihood to install PV. Socio-demographic can be considered by targeting populations that are less likely to install PV yet, such as, older people, smaller households, and lower income households.

Moreover, lower income households can be encouraged to install PV by providing subsidies that make it more affordable to install PV. Furthermore, our findings suggest that policies could target different psychological factors, such as sustainable energy use goals and personal norm to reduce energy use, as both increase the likelihood that people install PV. For example, policy could strengthen the sustainable energy goal by indicating why it is important to install PV, and how this would help mitigate climate change. Furthermore, personal norm can be strengthened by increasing individuals' awareness of the positive environmental consequences of installing PV. Future research is needed to examine which interventions would be most effective to motivate and empower households to install PV.

4.3 Conclusion

This paper aimed to assess the importance of socio-demographic variables and psychological factors in explaining the likelihood that households install PV. Our result showed that variables explained intentions to install PV better than actual PV ownership. Extending previous research, we found that both socio-demographics and psychological factors explained unique variance in the likelihood that households install PV. More specifically, younger people, larger households, higher income groups, people with a stronger sustainable energy use goal, and people with weaker altruistic values were more likely to intend to install PV. Moreover, people with a higher income and stronger personal norm to reduce energy use were more likely to actually have installed PV.