Energy Research & Social Science 111 (2024) 103481

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

Pro-environmental, prosocial, pro-self, or does it depend? A more nuanced understanding of the motivations underlying residential solar panel adoption

Lisa Legault [a,*], Stephen Bird [b], Martin D. Heintzelman [c]

[a] Department of Psychology, Clarkson University, United States of America
[b] Institute for a Sustainable Environment, Clarkson University, United States of America
[c] Department of Applied Economics and Statistics, University of Delaware, United States of America

A R T I C L E I N F O

Original content: Solar Data 2023 (Original data)

Keywords:
Solar panel adoption
Environmental motivation
Values
Demographics

A B S T R A C T

Although a small body of research has examined the motivational foundations of homeowners' decisions to adopt rooftop solar panels, in this research we compared adoptive and non-adoptive homeowners in the United States ($N = 824$) across a spectrum of values and motives to identify the most salient predictors of solar adoption within various demographic and political strata. Results of hierarchical logistic regressions revealed that autonomous (i.e., internal) pro-environmental motivation linked to solar adoption regardless of age, income, and education. In contrast, the effects of altruism and controlled (i.e., image and status based) environmental motivation depended on demographic characteristics. That is, altruism was positively associated with adoption for older homeowners, but negatively linked to adoption for younger homeowners. Additionally, controlled motivation predicted solar adoption for both younger and higher income homeowners, but it was not a predictor for older and lower income homeowners. We highlight the importance of assessing interactions between demographics, on one hand, and motives and values, on the other, in order to reveal nuances in the motivations of different types of adopters. These findings underscore the need for more targeted solar policy, marketing, and public messaging.

1. Introduction

Integration of rooftop solar in the residential sphere has great potential to diminish greenhouse gas emissions and aid the energy transition [1,2]. However, in order to design initiatives that will promote widespread solar adoption among homeowners, it is necessary to understand the motivational foundations of personal solar adoption decisions. For instance, are homeowners who adopt solar more environmentally concerned than those who choose not to adopt? Are they driven more by benevolent concerns? Status concerns? Going a step further, are there different types of solar adopters – who perhaps hold different motivations underlying adoption? Although past studies have investigated some of the personal characteristics associated with solar panel decision-making, most have examined adopters or non-adopters separately rather than simultaneously, and none have examined values and motivations comprehensively.

In this research, we offer a novel predictive analysis of the likelihood of adopting a home solar system (or not), based on individual demographics, ideology, core values, and motivations. Using theoretically connected frameworks of values and motives, we offer an original and comprehensive assessment of the social and motivational differences between solar adoption and non-adoption, as well as an examination of how the role of motivation in predicting adoption changes depending on key demographic attributes.

1.1. Who adopts solar panels?

1.1.1. Sociodemographic characteristics

Most research examining the determinants of renewable resource adoption in the residential sector has focused on demographic and socioeconomic predictors. According to the Lawrence Berkeley National Lab, one of the most important factors associated with household solar panel adoption in the United States is income – solar adopters generally have higher incomes and tend to live in more urban centers [3]. In line with this, a recent review of the predictors of household solar adoption and adoption intentions in the U.S confirmed that income, education,

* Corresponding author.
E-mail address: llegault@clarkson.edu (L. Legault).

https://doi.org/10.1016/j.erss.2024.103481
Received 31 July 2023; Received in revised form 9 February 2024; Accepted 14 February 2024
Available online 22 February 2024

and age are the most important social determinants of adoption-related behavior across >300 studies, with adopters having more income and more education than the average citizen [4]. Past research has shown that marital status and gender do not link to solar adoption among Americans [5].

With respect to age, solar adopters are older than the average American, but younger than the average homeowner [4]. This is a key distinction; when trying to understand the average American adopter of renewable residential energy, it is less useful to compare them to the average citizen than it is to compare them with the average homeowner with comparable solar adoption potential. When solar adoption studies use the 'average citizen' as a comparison group [e.g., [3]], they include in this baseline many irrelevant comparison subpopulations who are unable to choose to install solar systems, either because they live in apartments or non-detached dwellings, or are otherwise unable or unwilling to own a home. This precludes a true understanding of the psychological factors that distinguish adopting from non-adopting homeowners. Unlike many previous studies, our analysis intentionally samples American homeowners who have adopted solar and those who are able to, but have not.

1.1.2. *Beyond demographic predictors*

When researchers look beyond the demographic predictors of solar adoption, they typically focus on economic drivers besides income [6–8]. Financial return is the single most important predictor of solar adoption in the commercial sphere [9], and financial incentives and financial knowledge are well-established predictors of adoption intentions among individual homeowners [4,5]. Although these economic factors are important, Wolske and colleagues [8] note that the strong research and policy focus on economic factors neglects the role of psychological indicators of solar adoption. Indeed, financial policies and incentives alone do not account for the variability in decisions to install solar systems and despite generous financial incentives, research suggests adoption rates are still low [10]. Although we recognize the urgent need to create policy that supports widespread ease of access to solar energy in order to allow for extensive adoption, the likelihood of such structural change is unknown. Moreover, the low adoption rate in the United States is unlikely to be reversed through policy and incentives alone. For these reasons, it is essential to understand the non-financial factors underlying solar adoption.

1.1.2.1. The role of human values. A small body of recent work suggests that, in addition to economic variables, social and psychological factors are important in shaping consumer interest in renewable energy technologies – and that these factors should be considered if policymakers want to widen opportunities for solar access and acceptance [6]. In particular, human values play an important role in homeowners' decisions to adopt solar [8]. Values are expansive "trans-situational *goals* … which serve as guiding principles" [11,p. 21]. Although Schwartz [11,12] describes 10 basic and universal human values, the fundamental duality between self-transcendent values of universalism and benevolence (i.e., concern for the welfare of others) and the self-enhancement values of hedonism, achievement, and power has received the most attention in environmental psychology [13].

Values are important for understanding environmental decision-making because they shed light on what people prioritize [14–16]. *Altruistic values* predispose people to focus on ways to benefit others; *biospheric values* attune people to the needs of nature and the environment, and *egoistic values* drive the pursuit for personal gain (i.e., wealth and status). Wolske and colleagues [8] sampled 904 non-adoptive homeowners to ascertain the role of values in influencing interest in contacting a solar installer. They found that altruism predicted interest in adoption, but self-interest (egoism) did not. However, this study combined proenvironmental concern and social altruism into a single altruism score. Moreover, the relative importance of environmental or biospheric values in solar adoption is not clear – as other work has suggested that environmental values alone are not enough, and are not always necessary, to motivate adoption [17]. Thus, a comprehensive assessment of the *relative* importance of biospheric, egoistic, and altruistic values underlying adoption is needed.

Beyond solar adoption, research suggests that altruistic and biospheric values positively predict pro-environmental behavior (PEB) more broadly [15,18–20], although biospheric values more strongly so [[21], or see [15] for a review]. In contrast, egoistic (i.e., self-interest) and hedonic (i.e., pleasure and comfort) values are, in general, negatively associated with PEB, probably because PEBs are often personally costly or arduous [e.g., [22,23]]. Despite this general pattern, many positive or helpful environmental behaviors arise from non-biospheric concerns. Howell [24] found that the most commonly reported reasons for engaging in environmentally friendly lifestyles involved prosocial goals—including social justice and community contribution. On the flipside of the same coin, many studies have found positive associations between self-interest/egoism and proenvironmental decisions [e.g., [25]]. In particular, status-motivated individuals are likely to adopt sustainable innovations that are expensive and publicly conspicuous [26,27] – for instance, when purchasing an electric vehicle [28]. All told, it appears that the role of human values in predicting environmentally impactful behaviors depends on the type of behavior in question, as different environmental actions invoke different types of personal values and goals [29,30]. In this work, we aim to clarify the relative importance of altruistic, egoistic, and biospheric values in predicting solar adoption, alongside the predictive value of more domain-specific *proenvironmental motivation*.

1.1.2.2. The role of motivation. Values often give rise to motivation. Although research on motivation and solar adoption is nascent, the role of motivation in understanding other environmental behavior is well established. In particular, research using *self-determination theory* (SDT) [31] consistently shows that those with more *autonomous motivation* toward proenvironmental behavior engage in more frequent, more difficult, and longer lasting proenvironmental behavior compared to those whose motivation is *controlled*. That is, those for whom proenvironmental deeds are driven by personal concern for helping the environment are more successful than those who are driven by social expectations or need for approval [15,32–34]. Research on energy saving behavior suggests that autonomous motivation toward the environment is a more important predictor of energy conservation than other psychological factors, including behavioral intentions, subjective norms, perceived behavioral efficacy, and past behavior [35]. In the current study, we provide first insight into the roles of autonomous and controlled motives in the decision to install solar panels.

When it comes to the motivational predictors of solar adoption specifically, findings are disparate and mixed. Wolske and colleagues [8] offered a broad survey of non-adopters' beliefs, attitudes, motivations, and intentions and found that intentions to contact an installer were predicted by proenvironmental concerns, attitudes toward innovation, beliefs about the financial benefits of solar, beliefs that significant others would support the decision to go solar, and concerns for costs, risks, and practicality. However, because these many divergent theories were tested separately rather than comparatively, the analyses did not unveil the relative importance of each predictor. Moreover, because they only surveyed non-adopters, the motivations of actual adopters remained unclear. Indeed, recent notable research indicates that those *considering* adoption have stronger proenvironmental motivation/concern and higher levels of novelty seeking compared to those who have already adopted solar [36]. This suggests that while solar adopters may care more about the environment than does the average citizen [e.g., [3,37]] they do not necessarily care more than prospective adopters.

While proenvironmental motivation is sometimes cited as a reason for intentions to adopt solar, some research has suggested that status and self-image-based intentions may drive actual adoption [38]. In their model of motivations to adopt sustainable innovations, Noppers and colleagues [27] highlight the importance of *symbolic attributes* in the adoption of highly visible smart energy systems like solar panels and sustainable innovations like electric vehicles. Symbolic attributes refer to the positive characteristics that innovative adoptions signal about the self (e.g., that one is eco-conscious; that one can afford novel technology). Thus, in addition to proenvironmental and prosocial motives [8], solar adoption can also stem from controlled motivation (i.e., to gain social approval).

Given the various competing motives for solar adoption, there is a need for research to illuminate when (and for whom) different motivations matter most. Two recent studies indicate that different people adopt solar for different reasons. First, Palm [39] proposed that early adopters are primarily driven by environmental concern, whereas later adopters are not. Extending this idea, Wolske [7] notes that low income adopters demonstrate more environmental concern and more interest in green technology innovations than high-income solar adopters. It appears, therefore, that the role of different motives and values in predicting adoption may depend on noteworthy sociodemographic factors. *The current study identifies not only the motivational correlates of adoption vs. non-adoption, but also assesses whether key factors, like income, moderate or change the nature of the relationship between motivations and adoption*. These moderating effects, we argue, are essential to clarifying the disparate predictors of solar adoption.

2. The current research

We extend past work in various ways in order to achieve a balanced understanding of the motivational underpinnings of solar panel adoption in the residential sphere. First, most research examines factors predicting people's willingness or intentions to use renewable resources in their homes rather than assessing actual adoption behavior [e.g., [4,5,8]]. This is problematic as ecological consciousness and interest in sustainable consumption regularly fail to translate into real behavior (such as purchasing; [40]) – a problem which has been characterized as an 'intention-behavior' gap within green and renewable energy behavior [41]. This suggests that the focus on adoption intentions may be of little use in understanding actual solar adoption [42].

A few studies have considered actual adoption behavior. However, these have been descriptive rather than predictive; they describe the traits and beliefs of solar adopters without using a comparison group [e.g., [17,37]]. Alternatively, past studies have almost exclusively used non-equivalent comparison groups – that is, they have compared the characteristics of solar panel adopters to those of the general national population [e.g., [3]]. These approaches do not offer a clear understanding of what predicts the decision to adopt or not. In the current study, we contrast solar adopters with comparable non-adopters. In addition, unlike past research, we aim to examine important interactions in the prediction of solar adoption. That is, we will ascertain whether adopters from different demographic groups have different underlying motivations.

2.1. Goals and hypotheses

We sought to understand differences between homeowners who have installed rooftop solar panels versus a comparison group of homeowners who have not installed solar panels. We were interested in three key categories of predictors, from relatively distal to relatively more proximal to the adoption behavior in question: 1) established demographic correlates of adoption, including income, age, and education; 2) basic human values, including altruistic, egoistic, and biospheric values; and 3) motivation toward environmental behavior, including autonomous motivation (e.g., wanting to help the environment because it is personally important), controlled motivation (e.g., to follow the trend, to keep up an image), and amotivation (i.e., no interest in positive environmental behavior). In addition, we examined the covariates of both political orientation and interest in innovation.

We sought to assess the unique role of each value and each motive in predicting solar adoption, in order to address current debates about the relative importance of values versus motives in proenvironmental behavior [see [15,30]]. We expected that environmental motivations would be more important predictors of solar adoption than broader values, because of their motivational proximity to the behavior in question [29].

However, we expected the effects of motivations on solar adoption would be qualified by interactions with key demographics. We reasoned that because solar adoption is a complex environmental behavior imbued with multiple competing goals and incentives [e.g., [27,38]], it is unlikely to be explained by a single set of core motivational factors, and that there are indeed different types of solar panel buyers. Thus, we sought to test the moderating effects of age, education, and income on links between motivation and adoption. However, we specified confirmatory hypotheses only for income – given new research suggesting that low income adopters may care more about the environment than high income adopters [7]. We expected those with larger incomes might adopt solar for more external reasons, for instance to be recognized by others or to signal status and wealth, compared to those lower in income. Similarly, because solar panels are expensive, those with financial means may be most likely to invest in order to save more money long-term, and thus their primary motivation is likely to be more financial than pro-environmental in nature. In contrast, those lower in income might invest in solar for more diverse reasons, including long term savings, but also autonomous proenvironmental motivation [8,39]. Indeed, when people lack disposable income to afford solar panels, the decision to adopt might be driven more strongly by genuine care and concern for the environment. Said differently, because investing in solar is more financially costly for these individuals, proenvironmental concern is likely to be a stronger predictor of solar adoption.

3. Method

3.1. Design and procedure

We administered a one-time cross-sectional survey to single-dwelling homeowners residing mostly in the state of New York, including those who had adopted rooftop solar and those who owned single-dwelling homes but had not installed solar panels. We asked that the household member filling out the survey be the person who paid for, or was most familiar with, the electricity bill. The survey was administered throughout 2017 and assessed demographic characteristics, political affiliation, preference for innovation, basic values, and motivations toward the environment. Solar adopters were targeted through email, using adoption records from New York's regional community solar adoption program known as Solarize.[1] The Solarize organizers also disseminated our survey to solar adopters outside of NY State. Adopters were compensated with a $25 Amazon gift card. Non-adopters were screened for home ownership and state of residence through Prolific Academic and Qualtrics platforms. Non-adopters were paid $5.00 USD for their participation.

3.2. Sampling, data screening, and participants

A power analysis for logistic regression [43] revealed that 258 participants were required to generate very high power (0.95) to detect a small effect (i.e., odds ratio of 1.68; [44]) with an error likelihood of $\alpha =$

[1] At the time of the survey, over 43 New York municipalities had participated in the Solarize program, which encourages community jurisdictions to adopt solar in a focused timeframe, to reduce installation costs through economies of scale with government approved installers.

0.05. We originally sought to use caution by oversampling 1000 homeowners in New York State (500 with solar panels and 500 without them). In total, 1021 surveys were returned (623 nonadopters and 368 adopters).

We used multiple attention checks to verify data reliability and attentive responding. Among the nonadopters, we removed 13 participants who failed attention checks via three required long answer questions. The remaining 610 nonadopters provided meaningful responses to the long answer attention checks and were retained in the final sample. This nonadopter subsample was also used in a separate study examining nonadopters' willingness to pay for solar [73].

In our sample of solar adopters, we again used required long answer questions to detect attentional engagement. Unfortunately, we detected a large number of fraudulent surveys ($n = 154$) in this subsample.[2] After removing these fraudulent responses, our sample consisted of 214 solar adopting homeowners across the United States – 87 of whom resided in New York State. Because a snowball convenience sampling method was used, many out of state solar adopters completed the study. As these data were valid, we retained them in the final sample (we include the same analyses using only New York State data to ensure generalizability across the New York and non-New York samples). All data, measures, and analyses are openly available at https://osf.io/h5msc/?view_only=ab3c832475ed4f13a1e44401e3cf86ec. The final sample consisted of 824 owners (i.e., 610 non-adopters and 214 adopters) of single dwelling homes with independent rooftops within the United States (i.e., not condominiums or apartments). Participants were 45 % male (54 % female). Most were white (68 %) while 9.3 % were Black and 15 % were Latine. Note that neither gender ($r = 0.05$, $p = .13$), nor race ($r = -0.04$, $p = .22$) was correlated with adoption. The age breakdown was as follows: 16.3 % were between 18 and 30 years old; 32.1 % were between the ages of 31 and 40 years; 17.8 % were between 41 and 50; 17.3 % were between 51 and 60; 12.1 % were between 61 and 70; 3.8 % were between 71 and 80; and 0.5 % were over 81 years old. The most frequent education level was a Bachelor's degree (36.5 %); whereas 24 % had received graduate degrees and 25 % had received less than a Bachelor's degree (14.7 % had obtained "some college" and for 9.6 %, a high school diploma was their highest education level). Descriptive statistics for demographic variables of interest (i.e., income, age, and education) are shown in Table 1 for adopters and non-adopters separately.

3.3. Measures

3.3.1. Key demographics and party identification

We were interested in evaluating the roles of income, age, and education in predicting solar adoption. As shown in Table 1, these key demographics were assessed as discreet categories rather than as continuous raw data. We created each scale to include all the levels needed to fully describe the natural range for each demographic variable. Thus, we measured income on a scale from 1 (0–10K per year) to 9 (>200K per year) using 10K–25K increments. Age was assessed on a scale from 1 (18–30 years) to 7 (71 or more years) using approximately 10-year increments. Education was gauged on a scale from 1 (no high school) to 8 (completion of doctorate) to encapsulate all possible education levels.

Using a single item, we also asked participants to indicate their party identification using party lean ("even if you don't identify with one party or the other, which one do you lean to?"), which is often used as a proxy for ideology. Ideology links to both environmental values and support for various kinds of environmental technology [45,46]. This measure was dichotomous, with 0 = "lean Republican" and 1 = "lean Democrat," and has demonstrated validity as an indicator of party representation. "Party lean" accommodates considerations for third parties, variation in political belief, and aligns with considerations for institutional two party dominance in the American system [e.g., [47,48]].

3.3.2. Preference for innovation

Past research suggests that solar adoption and adoption curiosity are linked with interest in innovation and new technology – including enjoyment of the technical aspects of energy systems [8,17,49]. This interest in technological innovation may be particularly salient among the earliest and least financially motivated adopters of solar energy [50], according to the diffusion of innovations perspective, which states that interest in new technology disperses throughout society as different types of people begin to consider adoption for different reasons [51]. Thus, we assessed preference for innovation using the Innovativeness Scale [52] in order to ascertain the unique effects of values and motives beyond this key predictor. The measure asks participants to report how they feel about new ideas and novel experiences (e.g., "I must see other people using new innovations before I will consider them" (reverse-scored)). Responses to each of the four items were recorded on a Likert scale from 1 (not at all like me) to 7 (completely like me).

3.3.3. Altruistic, egoistic, and biospheric values

Because of their well-established and unique roles in environmental decision-making and behavior, we assessed altruistic (self-transcending), egoistic (self-enhancing), and biospheric (proenvironmental) values [13]. We implemented Lindeman and Verkasalo's [53] short values survey, which has shown to correlate highly with Schwartz's original Value Survey [SVS; [11,12]], and where each value type is defined for participants. *Benevolence* is referred to as helpfulness, honesty, forgiveness, loyalty, and responsibility; *universalism* is denoted as broad-mindedness, beauty of nature and arts, social justice, a world at peace, equality, and wisdom. *Power* is defined as social power, authority, and wealth. *Achievement* is characterized as success, capability, ambition, and influence on people and events. Finally, *hedonism* is referred to as gratification of desires, enjoyment in life, and self-indulgence. Respondents indicated the importance of each of these five value categories as a guiding principle in their daily lives (where 0 = the value is opposed to your principles, 1 = the value is not important for you, 4 = the value is important, and 8 = the value is of supreme importance). In line with Schwartz's [11] conceptualization of the relations between values, we measured self-transcending (altruistic) values using benevolence and universalism (Cronbach's $\alpha = 0.71$), and self-enhancing (egoistic) values using power, achievement, and hedonism (Cronbach's $\alpha = 0.70$).

In line with previous research that recommends integrating biospheric valuing into individuals' core value system [20,54,55], we included an adapted measure of biospheric values [56]. Two items targeted 'respect for the earth' (i.e., "Plants and animals have as much right to exist as humans") and 'desire to protect the environment' (i.e., "I'm very concerned about protecting nature"; split half reliability = 0.70). Participants indicated the extent to which they endorsed each item on a scale from 1 (not at all) to 7 (completely).

3.3.4. Motivation toward the environment

We assessed the source and quality of individuals' motivation to help/conserve the environment using 20 items from the Motivation toward the Environment Scale [MTES; [34]]. According to research on

[2] Fraudulent/algorithmic responses were detected using a long answer question required near the beginning of the survey. We ascertained that many fraudulent answers to this question appeared to be systematically generated by computer programs that copy text from later in the survey and paste it into earlier spaces in the survey (which is chronologically impossible if answering the survey honestly), yielding generic and copied responses to the open-ended question. To confirm this problem, we checked all additional long-answer attention check questions in the survey, and each of these yielded impossible responses from these 154 cases. Upon inspecting the time stamps and durations of these surveys, we concluded that the same individual or program was responsible for all 154 invalid cases (i.e., nonsensical long answers).

Table 1
Descriptive statistics for variables in the current study (adopters and nonadopters).

Variable	Mean		SD		Skewness		Kurtosis	
	NonAdopt	Adopter	NonAdopt	Adopter	NonAdopt	Adopter	NonAdopt	Adopter
Demographics, party, & innovativeness								
House income (scaled 1–10)	4.85	7.00	2.20	1.93	0.89	−0.53	0.34	−0.58
Age (scaled 1–7)	3.03	2.53	1.48	1.20	0.34	0.99	−0.78	0.23
Education (scaled 1–8)	5.35	5.95	1.54	0.89	−0.27	−0.20	−0.84	0.63
Party identification	0.62 (62 % Democrat)	0.65 (65 % Democrat)	0.49	0.48	−0.50	−0.62	−1.76	−1.63
Innovation (scaled 1–7)	3.43	3.52	0.51	0.50	0.01	0.03	1.21	0.06
Core values								
Altruistic (scaled 0–8)	6.85	6.30	1.68	1.46	−0.58	−0.06	−0.19	−0.48
Egoistic (scaled 0–8)	4.38	5.28	1.79	1.71	0.38	−0.34	−0.28	−0.68
Biospheric (scaled 1–7)	4.55	4.87	1.44	0.93	−0.50	−0.05	−0.15	−0.07
Motivations								
Autonomous (scaled 1–7)	4.43	5.28	1.47	0.94	−0.44	−0.70	−0.18	1.29
Controlled (scaled 1–7)	1.96	3.87	1.16	1.96	1.32	−0.44	1.58	−1.43
Amotivated (scaled 1–7)	2.29	3.83	1.40	1.92	1.03	−0.46	0.47	−1.35

Note. We used categories to measure income (1 thru 10), age (1 thru 7), education (1 thru 8), and party identification (0 = Republican; 1 = Democrat). For income, 4 = 50K–75K/year; 5 = 75K–100K/year; and 7 = 125K–150K/year. For age, 2 = 31–40 years and 3 = 41–50 years. For education, 5 = associate degree and 6 = college degree.

proenvironmental motivation, individuals vary in terms of the degree to which their reasons for engaging in proenvironmental behavior are self-determined (i.e., stemming from personal endorsement of the behavior). Participants were asked to rate their motivations for engaging in environmental behaviors on a scale from 1 (does not correspond at all) to 7 (corresponds exactly). As in previous research [34,57], we computed *autonomous* (i.e., internal) motivation to help the environment using a composite of *intrinsic* (e.g., "Because I like the feeling I have when I do things for environment"; 4 items), *integrated* (e.g., "Because being environmentally conscious has become a fundamental part of who I am"; 4 items), and *identified* ("Because I think it's a good idea to do something about the environment"; 4 items) motivations (Cronbach's α = 0.91). *Controlled* or external motivation toward the environment reflected the desire to do things for the environment because for the external reward or consequence (i.e., bolstered image, praise). Example items included "For the recognition I get from others" and "To avoid being criticized"; 4 items; Cronbach's α = 0.90. Finally, *amotivation* reflected perceived futility in helping the environment (e.g., "I don't know; I can't see how my efforts to be environmentally-conscious are helping the environmental situation"; 4 items; Cronbach's α = 0.89).

Although values and motivations undoubtedly share variance in predicting environmental behavior [21,30], Steg [15] notes that values underlie motivations, and that individuals are more likely to act on their broader biospheric values when they are autonomously motivated toward the environmental decision in question. In this way, values are broader principles, and may give rise to more specific motives – which may then predict environmental behaviors more closely [30].

3.4. Analytic strategy

We sought two overarching goals: 1) to assess the relative importance of income, age, and education, as well as each value type (altruistic, egoistic, biospheric) and each motivation type (autonomous, controlled, amotivated) in linking to solar adoption, and; 2) to determine whether the effect of motivations would change as a function of demographics – i.e., age, income, and education.

We pursued these objectives using two approaches. We first assessed the relative strength of each predictor in determining solar adoption using hierarchical logistic regression. We used logistic regression because our outcome variable was binary (adopt vs. non-adopt), and we selected the hierarchical approach because of the grouped structure of our predictors, where demographics were assumed to comprise values, and values were assumed to comprise motives. In this way, we were able to observe the relative contribution of each group of predictors. We entered demographic variables (age, education, and income), party identification, and the innovativeness covariate in the first block, value orientations (altruistic, egocentric, and biospheric) in the second block, and environmental motivations (autonomous, controlled, and amotivation) in the final block. This hierarchical approach allowed us to investigate the ordered effect of each theorized set of predictors.

Then, to evaluate the interaction effects between demographic variables and motivational factors, we used a combination of confirmatory and exploratory methods. Our general approach was to evaluate the moderating effect of age, income, and education on links between motivations on one hand, and adoption behavior on the other – because we expected motivations to be more important predictors than values. As mentioned, we expected income to moderate the effects of autonomous and controlled motivations. The same moderation model was explored for age and education; however, we did not have any clear expectations for these proposed moderators. Our strategy was to evaluate each motivational effect at high, average, and low levels of age, education, and income. By focusing on the most salient predictors, we aimed to constrain the number of interaction tests performed.

4. Results

4.1. Preliminary analyses

Descriptive statistics for each variable under study are presented in Table 1. Nearly two thirds of the sample leaned Democrat, and solar adopters comprised 26 % of the total sample. Most of the psychological variables of interest were moderately endorsed and all univariate data were normally distributed such that histograms roughly followed the normal curve and skewness and kurtosis values all fell close to the acceptable range of −1 to +1.

Table 2 displays the bivariate correlations. As per Cohen [58], a correlation of 0.1 is weak; 0.3 is moderate, and 0.5 is strong. All measured variables except party identification significantly correlated with adoption. Income and controlled motivation were the strongest correlates. Preference for innovation was modestly associated with adoption. As in past research, solar adoption was inversely related to age and positively related to education. Correlations among motivational variables and adoption were moderate to moderately strong. Environmental amotivation (i.e., not caring about helping the environment) linked to solar adoption. This may be explained by two forces: a) the connection between environmental amotivation and controlled environmental motivation, and b) the notion that, although pro-environmental concern is related to adoption, there are nonetheless important non-environmental predictors. For instance, many adopters prioritize financial incentives when deciding to implement solar [51].

Table 2
Correlations among measured variables.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Demographics and covariates											
1. Income											
2. Age	0.02										
3. Education	0.37***	0.04									
4. Democrat	−0.08*	0.04	0.11**								
5. Innovation	−0.10**	−0.02	0.02	−0.12**							
Core values											
6. Altruistic	−0.13***	0.02	0.13***	0.28***	0.06						
7. Egoistic	0.19***	−0.35***	0.05	−0.07	0.26***	0.06					
8. Biospheric	−0.02	−0.07	0.11**	0.22***	0.18***	0.39***	0.09**				
Motivations											
9. Autonom.	0.14***	−0.11**	0.14***	0.20***	0.14***	0.41***	0.15***	0.63***			
10. Controlled	0.35***	−0.26***	0.05	−0.14***	0.28***	−0.19***	0.44***	0.11**	0.25***		
11. Amotivat.	0.26***	−0.18***	0.00	−0.22***	0.22***	−0.30**	0.35***	−0.12**	−0.07*	0.73***	
12. Adoption	0.40***	−0.15**	0.19***	0.02	0.07*	−0.15***	0.22***	0.10*	0.27***	0.51***	0.40***

* $p < .05$.
** $p < .01$.
*** $p < .001$.

These same individuals tend to also be less interested in novel green technology or with helping the environment [50].

4.2. Main analyses

4.2.1. Hierarchical logistic regression: main effects and interactions

We performed a hierarchical logistic regression analysis to understand the ordered structure of values and motivations in linking to solar adoption (see Table 3a). Demographic variables, political party identification, and the covariate of innovation preference were entered as predictors first. Because core human values are theorized to be broad and organizing life goals, whereas motivations toward the environment are more specific to environmentally-relevant behavior, we entered values in the second block and motivations in a third block. In the fourth and final block, we entered the key interaction terms. In addition to testing the interactions between motivations and demographics, our general approach was to explore demographic moderation of predictors that remained significant in Block 3, to test their boundary conditions. All variables comprising interaction terms were mean-centered prior to multiplication and analysis in Block 4. In addition to performing this analysis on the full sample (Table 3a), we also supplemented this by running the same analysis using only New York state homeowners (Table 3b).

4.2.1.1. Effects of demographics, ideology, innovativeness, and values. In *Block 1*, for the full sample, all key demographic variables predicted that homeowners adopted solar panels. Specifically, solar adopters were significantly younger, wealthier, and more educated than nonadopters. Leaning democratic was not a significant predictor in Block 1 (although it was in the New York only subsample), nor was preference for innovation. As shown by the Hosmer and Lemeshow Test in Tables 3a and 3b, *Block 1* was an acceptable fit to the data. Fit improved when adding core values as predictors in *Block 2*, as shown by the increase in the Nagelkerke R^2 – which reflects a pseudo R^2 where directly comparisons can be made across models of varying complexity [60]. Demographic predictors remained significant and leaning democratic also predicted adoption at this stage.[3] In addition, all values predicted adoption, with adoption significantly less likely among those with higher altruistic values and significantly more likely among those with higher egoistic and biospheric values. This pattern was similar for the New York sample, with the exception of egoistic values, which was not a significant predictor.

4.2.1.2. Effects of motivation. In Block 3, all motivation variables predicted solar adoption – which rendered the contribution of egoistic and biospheric predictors negligible. Thus, as predicted, when entering both values and motives into the model, motivational factors were generally stronger and more reliable predictors of adoption – for both the full sample and the New York only subsample. Relative to nonadopters, solar adopters were significantly more likely to demonstrate both autonomous and controlled motives for environmental behavior, suggesting both a desire to help the environment and a desire to follow environmental trends and norms for image-bolstering and social approval. Amotivation toward the environment was also a positive predictor of solar adoption for the full sample data, which indicates some solar behavior likely stems from non-environmental reasons.

Next, we investigate the interactive effects to further elucidate the roles of these motivational predictors. In particular, as shown in both Tables 3a and 3b, the link between controlled environmental motivation and solar adoption and the link between amotivation and solar adoption were qualified by key demographic moderators.

4.2.1.3. Probing the interactions. Although our threshold for statistical significance is 5 %, we flagged interactions in Table 3a that were significant at $p < .10$, in order to then tease them apart. For these interactions, we tested simple effects using PROCESS model 1 for binary logistic regression (see Figs. 1 through 6). Note that all predictors that make up the probed interactions are mean-centered. The interactions depicted in the figures report solar adoption probability at low (16th percentile), medium (50th percentile), and high (84th percentile) values of *each predictor, after mean-centering.*

Although PROCESS can also test the main effects reported in Tables 3a and 3b (in addition to the interactions), it does not as easily demonstrate the hierarchical structure of values and motives in uniquely predicting solar adoption. Thus, we deemed it important to examine the ordered structure of main effects and interactions using hierarchical regression, and use PROCESS to better probe the interactions. We used the pick-a-point approach [59], where we examined the link between motivation type (autonomous, controlled, or amotivation) and solar adoption at low (i.e., 16th percentile), moderate (i.e., 50th percentile), and high (i.e., 84th percentile) levels of income, age, and education. Note that for the PROCESS analyses, we use only the full sample, as it

[3] Note that Democratic Party leaning became a significant predictor only when introducing broader values into the model. This suggests that party identification alone is not a good linear predictor of adoption, but that when we control for broader values, it indeed becomes a predictor of adoption. In line with research on Simpson's Paradox [61], this occurs when a variable is a poor linear predictor of an outcome, but then becomes more important once important confounds have been considered.

Table 3a
Hierarchical logistic regression of the predictors of rooftop solar adoption (main effects and interactions; full sample).

	Block 1			Block 2			Block 3			Block 4		
	B	OR	95 % CI	*B*	OR	95 % CI	*B*	OR	95 % CI	*B*	OR	95 % CI
Demographics, party, innov.												
Income	**0.40*****	1.50	1.37, 1.63	**0.36*****	1.44	1.32, 1.58	**0.24*****	1.27	1.15, 1.40	**0.27*****	1.31	1.12, 1.52
Age	**−0.41*****	0.66	0.57, 0.77	**−0.28*****	0.75	0.64, 0.88	−0.15	0.86	0.72, 1.03	**−0.39***	0.68	0.52, 0.88
Education	**0.22***	1.25	1.06, 1.48	**0.26***	1.29	1.08, 1.54	**0.39*****	1.47	1.20, 1.80	**0.30***	1.35	1.01, 1.81
Democratic	0.38	1.46	0.99, 2.17	**0.51***	1.67	1.09, 2.55	**0.62***	1.86	1.12, 3.09	0.68	2.08	0.80, 4.88
Pref. for innovativeness	0.23	1.26	0.87, 1.81	−0.04	0.96	0.64, 1.43	**−0.58***	0.56	0.35,0.89	−0.29	0.74	0.41, 1.34
Core values												
Altruistic				**−0.33*****	0.72	0.63, 0.82	**−0.31*****	0.73	0.62,0.87	**−0.28***	0.76	0.60, 0.96
Egoistic				**0.20*****	1.22	1.08, 1.38	−0.03	0.97	0.84, 1.13	−0.05	0.95	0.78, 1.16
Biospheric				**0.36*****	1.44	1.20, 1.72	−0.03	0.97	0.77, 1.24	0.00	1.00	0.75, 1.33
Motivations												
Autonomous							**0.70*****	2.00	1.53, 2.63	**0.71*****	2.03	1.41, 2.91
Controlled							**0.45*****	1.57	1.25, 1.96	**0.38***	1.46	1.05, 1.99
Amotivation							**0.27***	1.31	1.06, 1.62	0.22	1.25	0.91, 1.67
Interactions												
Income × democrat										−0.03	0.98	0.82, 1.16
Income × altruistic										**0.08**	1.08	0.99, 1.17
Income × autonomous										−0.01	0.99	0.87, 1.14
Income × controlled										**0.16***	1.18	1.01, 1.37
Income × amotivation										0.08	1.09	0.94, 1.26
Age × democrat										−0.07	0.93	0.69, 1.25
Age × altruistic										**0.14**^{t}	1.15	0.99, 1.35
Age × autonomous										0.00	0.97	0.81, 1.25
Age × controlled										**−0.21**^{t}	0.81	0.65, 1.01
Age × amotivation										**−0.32***	0.72	0.58, 0.90
Education × democrat										**0.35***	1.42	1.02, 1.98
Education × altruistic										−0.18	0.84	0.70, 0.99
Education × autonom.										−0.08	0.92	0.70, 1.23
Education × controlled										**−0.27***	0.77	0.60, 0.99
Education × amotivation										−0.19	0.83	0.65, 1.07
Democrat × autonom.										**0.30***	1.35	1.00, 1.83
Democrat × controlled										−0.17	0.85	0.61, 1.17
Democrat × amotivation										−0.15	0.86	0.63, 1.15
Hosmer and Lemeshow test			8.80ns			5.82ns			9.75ns			6.84ns
Nagelkerke R^2			0.28			0.34			0.51			0.67

B = value for the equation in predicting the outcome, expressed in log-odds units. OR = odds ratio (the predicted change in odds for a unit increase in the predictors). 95 % CI = 95 % confidence interval around the odds ratio. Significant predictors in the final block are in **bold**.
[t] p < .10 (we flag the marginal interactions only).
[*] *p* < .05.
[***] *p* < .001.

offers more statistical power.

4.2.1.3.1. Motivation × income. As shown in Fig. 1, our hypothesis that controlled motivation would predict adoption for higher income homeowners but not lower income homeowners was supported, B = 0.22, SE = 0.04, 95 % CI [0.14, 0.29], z = 4.32, p < .0001. That is, at the high income bracket (i.e., 84th percentile or 150–200k/household/year), controlled motivation for environmental behavior was strongly and positively connected to solar adoption, B = 1.10, SE = 0.12, 95 % CI [0.88, 1.33], z = 9.56, *p* < .0001. This effect size was somewhat smaller but still significant at the mid-income level (50th percentile or 75–100k/year), B = 0.46 SE = 0.09, 95 % CI [0.29, 0.63], z = 5.29, *p* < .0001. However, when income was lower (16th percentile or 25–50k/year), the link between controlled motivation and adoption was not significant (and more than four times smaller than those with higher incomes), B = 0.03, SE = 0.14, 95 % CI [−0.24, 0.29], z < 1 (see Fig. 1). This interaction was observed for both the full sample and the New York only subsample (although only the full sample is reported here). Notably, contrary to our expectation, the effect of autonomous motivation was *not* moderated by income, suggesting *autonomous motivation was a reliable predictor across all income levels*. These findings partially supported our hypotheses regarding motivation and income.

4.2.1.3.2. Motivation × age. As shown in Fig. 2, age also moderated the effect of controlled motivation on solar adoption, B = −0.41, SE = 0.06, 95 % CI [−0.53, −0.30], z = −7.26, *p* < .0001. More precisely, controlled motivation (image bolstering/social approval) strongly predicted adoption for younger homeowners (i.e., 18 to 30 year-olds), B = 1.41, SE = 0.12, 95 % CI [1.18, 1.65], z = 11.82, *p* < .0001; and moderately predicted adoption for mid-aged homeowners (i.e., 41 to 50 year-olds), B = 0.59, SE = 0.07, 95 % CI [0.44, 0.73], z = 8.00, *p* < .0001. However, controlled motivation was not linked to adoption for older homeowners (i.e., 61 to 70 year-olds), B = −0.24, SE = 0.15, 95 % CI [−0.53, 0.05], z = −1.61, *p* = .11. Said differently, older homeowners were less likely to adopt solar as they became more controlled in their environmental motivation, whereas the opposite was true for younger homeowners; they were very likely to adopt solar when controlled motivation was high. As with income, the effect of autonomous motivation was not moderated by age – suggesting autonomous motivation was important across age groups. This interaction was observed across both the whole sample (reported here) and the New York only sample.

As shown in Fig. 3, age interacted with environmental *amotivation* in the same way as it did with controlled motivation, B = −0.44, SE = 0.05, 95 % CI [−0.54, −0.34], z = −8.403, *p* < .0001. That is, when older homeowners were amotivated, they were less likely to adopt, B = −0.52, SE = 0.14, 95 % CI [−0.79, −0.25], z = −3.73, *p* = .0002. In contrast, increased amotivation positively predicted solar adoption for mid-aged (B = 0.37, SE = 0.07, 95 % CI [0.24, 0.50], z = 5.53, *p* < .0001) and younger homeowners (B = 1.26, SE = 0.11, 95 % CI [1.04, 1.47], z = 11.55, *p* < .0001). These results show that younger homeowners in particular are strongly likely (80 % probability) to adopt solar panels for non-environmental reasons, even if they do not care about the environment (whereas older homeowners are <10 % likely under these circumstances). This interaction was observed across both the whole

Table 3b
Hierarchical logistic regression of the predictors of rooftop solar adoption (main effects and interactions; NY only sub-sample).

	Block 1			Block 2			Block 3			Block 4		
	B	OR	95 % CI	*B*	OR	95 % CI	*B*	OR	95 % CI	*B*	OR	95 % CI
Demographics, party, innov.												
Income	**0.26*****	1.30	1.17, 1.44	**0.25*****	1.28	1.15, 1.42	**0.16***	1.17	1.04, 1.32	**0.39***	1.47	1.18, 1.84
Age	−0.13	0.88	0.74, 1.04	−0.11	0.90	0.75, 1.07	−0.03	0.97	0.80, 1.18	−0.37	0.69	0.46, 1.03
Education	**0.39*****	1.25	1.19, 1.18	**0.42***	1.53	1.22, 1.90	**0.58*****	1.78	1.38, 2.30	0.38	1.46	0.92, 2.32
Democratic	**0.92*****	2.52	1.42, 4.47	**0.96***	1.67	1.42, 4.79	**0.94***	2.57	1.31, 5.03	**–**	–	–
Pref. for innovativeness	−0.40	0.67	0.41, 1.09	**−0.45**	0.64	0.38, 1.06	**−0.84***	0.43	0.24, 0.76	−0.66	0.52	0.24, 1.12
Core values												
Altruistic				**−0.24***	0.79	0.67, 0.94	**−0.33***	0.72	0.58, 0.90	−0.25	0.78	0.58, 1.05
Egoistic				0.02	1.02	0.88, 1.18	−0.14	0.87	0.73, 1.04	−0.19	0.83	0.66, 1.05
Biospheric				**0.24*****	1.28	1.03, 1.57	−0.26	0.77	0.59, 1.02	−0.14	0.87	0.62, 1.22
Motivations												
Autonomous							**0.87*****	2.40	1.72, 2.63	**0.93*****	2.54	1.56, 4.12
Controlled							**0.57*****	1.77	1.33, 2.35	0.22	1.24	0.78, 1.98
Amotivation							−0.06	0.94	0.71, 1.25	−0.41	0.67	0.40, 1.11
Interactions												
Income × democrat										0.004	1.00	0.80, 1.26
Income × altruistic										**0.10***	1.10	1.00, 1.22
Income × autonomous										−0.05	0.95	0.81, 1.12
Income × controlled										**0.20***	1.22	1.00, 1.50
Income × amotivation										0.15	1.16	0.95, 1.42
Age × democrat										−0.10	0.91	0.65, 1.26
Age × altruistic										**0.20***	1.22	1.01, 1.47
Age × autonomous										−0.05	0.95	0.74, 1.22
Age × controlled										**−0.22**^{t}	0.80	0.61, 1.06
Age × amotivation										**−0.31***	0.73	0.55, 0.99
Education × democrat										**0.35**^{t}	1.42	0.94, 2.15
Education × altruistic										−0.16	0.86	0.69, 1.06
Education × autonom.										−0.01	0.99	0.69, 1.42
Education × controlled										**−0.34***	0.71	0.50, 1.00
Education × amotivation										−0.02	0.98	0.66, 1.46
Democrat × autonom.										0.12	1.13	0.76, 1.67
Democrat × controlled										0.14	1.16	0.70, 1.92
Democrat × amotivation										−0.30	0.74	0.46, 1.20
Hosmer and Lemeshow χ^2 test			13.60ns			8.75ns			12.53ns			15.35ns
Nagelkerke R^2			0.19			0.21			0.37			0.52

B = value in log-odds units. OR = odds ratio (the predicted change in odds for a unit increase in the predictors). 95 % CI = 95 % confidence interval around the odds ratio. Significant predictors in the final block are in **bold**. Party lean removed due to multicollinearity.
[t] p < .10 (we flag the marginal interactions only).
[*] p < .05.
[***] p < .001.

sample (reported here) and the New York only sample.

4.2.1.3.3. Motivation × education. Education also interacted with controlled motivation, B = −0.26, SE = 0.06, 95 % CI [−0.37, −0.13], z = −4.17, *p* < .0001. More precisely, controlled motivation was a very strong predictor of adoption among those with *less* education (i.e., "some college"; B = 1.26 SE = 0.15, 95 % CI [0.98, 1.55], z = 8.70, *p* < .0001. Controlled motivation was less strongly (though still positive) connected to adoption for those at the mid-point in education (i.e., "finished college"; B = 0.75, SE = 0.06, 95 % CI [0.63, 0.88], z = 12.09, *p* < .0001), and for those at the highest education level (i.e., "finished Master's degree"; B = 0.50, SE = 0.08, 95 % CI [0.34, 0.66], z = 6.24, *p* < .0001) – although this latter link was notably weaker. Assessment of the Johnson-Neyman significance region suggested that controlled motivation ceased to be a significant predictor of solar adoption at the 96th percentile of education (B = 0.25, SE = 0.13, 95 % CI [−0.004, 0.50], z = 1.93, *p* = .06). In other words, only for the top 4 % most educated homeowners did controlled motivation *not* predict adoption. This interaction was observed across both the whole sample (reported here) and the New York only sample. No additional interactions between motives or values and education were observed.

4.2.1.4. Other exploratory interactions[4]

4.2.1.4.1. Altruism and demographic moderators. Surprisingly, altruistic values were negatively linked to solar adoption, even after controlling for the effects of motivations. That is, those high in altruism were less likely to adopt than those lower in altruism. However, the significant interaction between altruism and age helped to elucidate this seemingly paradoxical finding, B = 0.20, SE = 0.04, 95 % CI [0.12, 0.28], z = 4.87, *p* < .0001. That is, although altruism was negatively linked to solar adoption for young (B = −0.54, SE = 0.09, 95 % CI [−0.71, −0.37], z = −6.17, *p* < .0001) and middle-aged participants (B = −0.14, SE = 0.05, 95 % CI [−0.25, −0.04], z = −2.63, *p* = .01), this relationship *reversed and became positive* for older participants (B = 0.25, SE = 0.11, 95 % CI [0.04, 0.46], z = 2.35, *p* = .02). That is, older homeowners were more likely to adopt when altruism was high (see Fig. 4). This interaction was observed across both the whole sample (reported here) and the New York only sample. The negative link between adoption and altruism for younger homeowners makes sense given that younger homeowners are also very motivated by self-interest and image – which are incompatible with altruism.

4.2.1.4.2. Interactions with party identification. We verified whether political party affiliation interacted with any other predictors. Interestingly, political affiliation interacted with two variables – education (B = 0.56, SE = 0.19, 95 % CI [0.18, 0.94], z = 2.91, *p* = .004), and autonomous motivation, (B = 0.53, SE = 0.26, 95 % CI [0.02, 1.04], z = 2.03, *p* = .04). As shown in Fig. 5, increasing education was positively linked to adoption among Democrats, B = 0.67, SE = 0.12, 95 % CI [0.44, 0.91], z = 5.58, *p* < .0001, but not Republicans, B = 0.12 SE = 0.15, 95 % CI [−0.18, 0.40], z < 1. Stated differently, democrats were more

[4] There were no significant 3-way interactions.

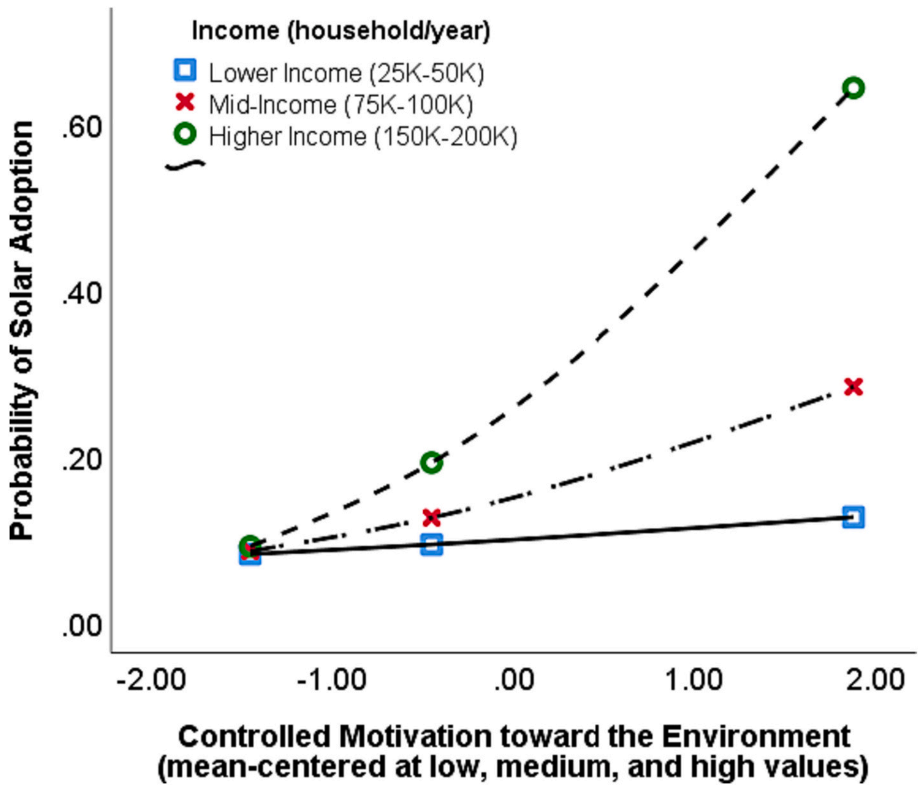

Fig. 1. Moderating effect of income on the link between controlled motivation and solar adoption.

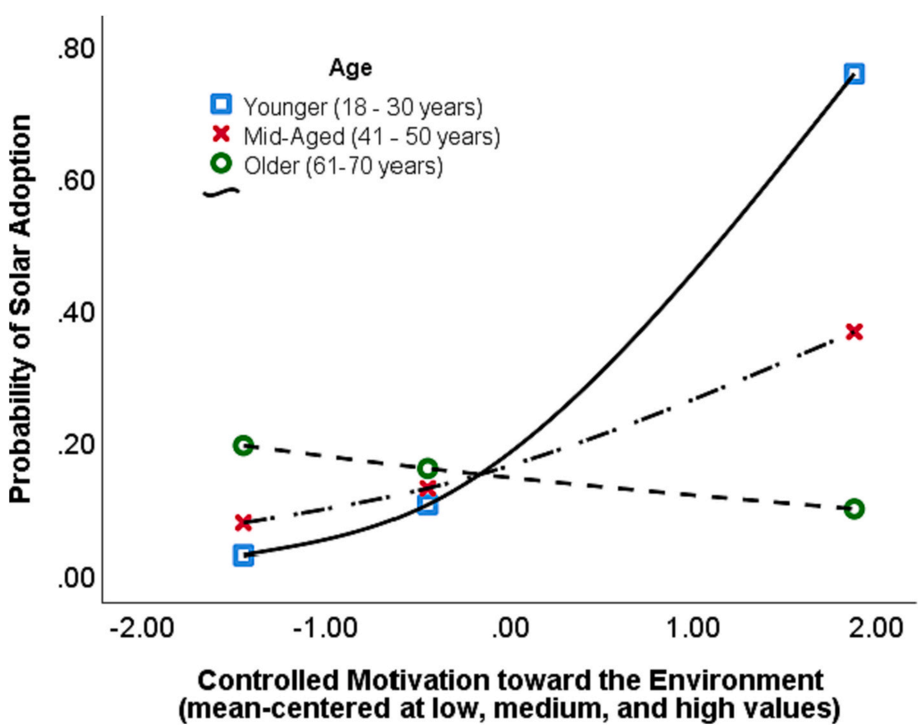

Fig. 2. Moderating effect of age on the link between controlled motivation and solar adoption.

likely to adopt as they became more educated whereas adoption probability remained unchanged for Republicans across all education levels (from 'no high school' to 'completion of graduate school'). This interaction was observed across both the whole sample (reported here) and the New York only sample.

As shown in Fig. 6, autonomous motivation significantly predicted solar adoption probability for those leaning Democrat, B = 0.91, SE = 0.16, 95 % CI [0.59, 1.24], z = 5.56, $p < .0001$, but not for those leaning Republican, B = 0.38, SE = 0.23, 95 % CI [−0.07, 0.84], z = 1.64, $p =$ .10 – suggesting that only Democrats are likely to adopt solar out of

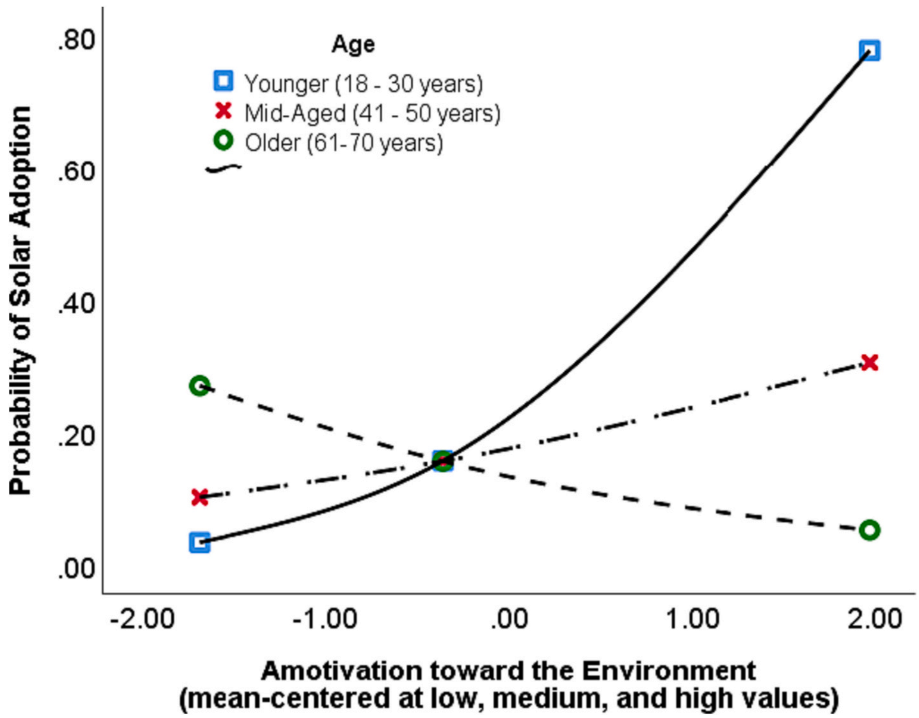

Fig. 3. Moderating effect of age on the link between amotivation and solar adoption.

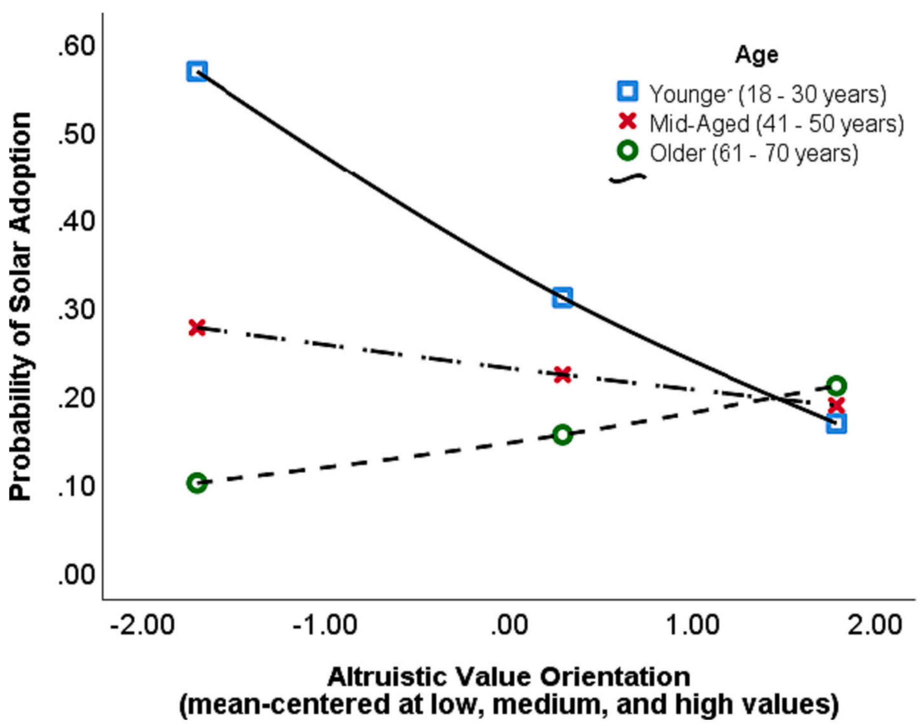

Fig. 4. Moderating effect of age on the link between altruism and solar adoption.

proenvironmental concerns.

5. Discussion

We show that when examining the motivational correlates of solar panel adoption, it is important to consider interactions with key demographic variables. That is, motivation changes as a function of age, education, and income. Although neither egoism nor biospheric concern were unique predictors of adoption, we found that altruistic values of benevolence and universalism were negatively linked to solar adoption when adopters were young and middle-aged. However, the role of altruism in predicting adoption reversed *and became positive* for older homeowners – suggesting that older adopters tend to be altruistic but younger adopters do not. Age was the only demographic to moderate the effect of altruism on adoption.

We found support for our hypothesis that higher income adopters

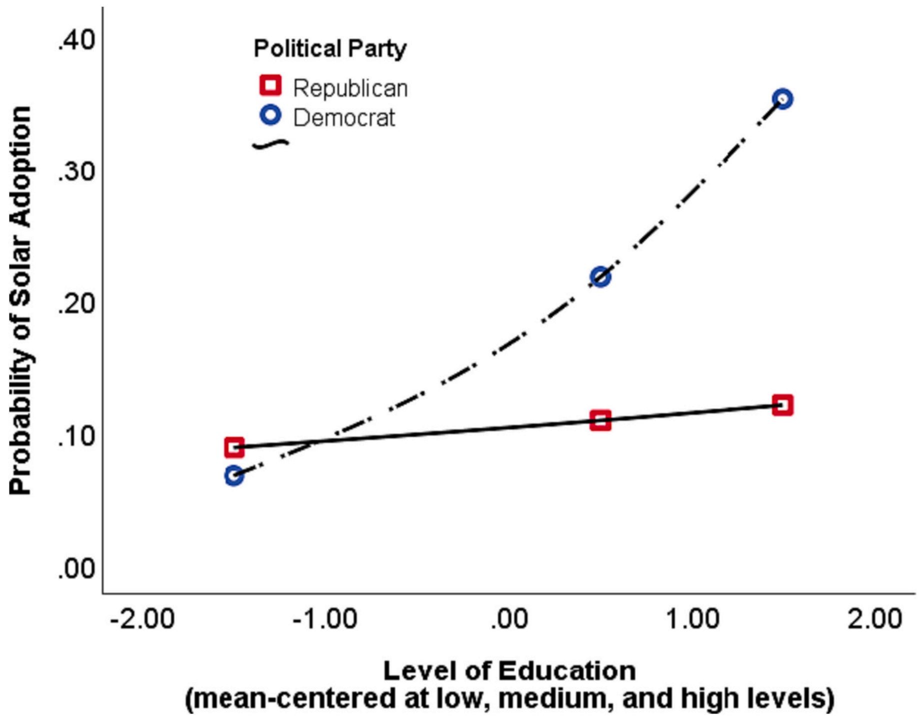

Fig. 5. Education predicts solar adoption for Democrats but not Republicans.

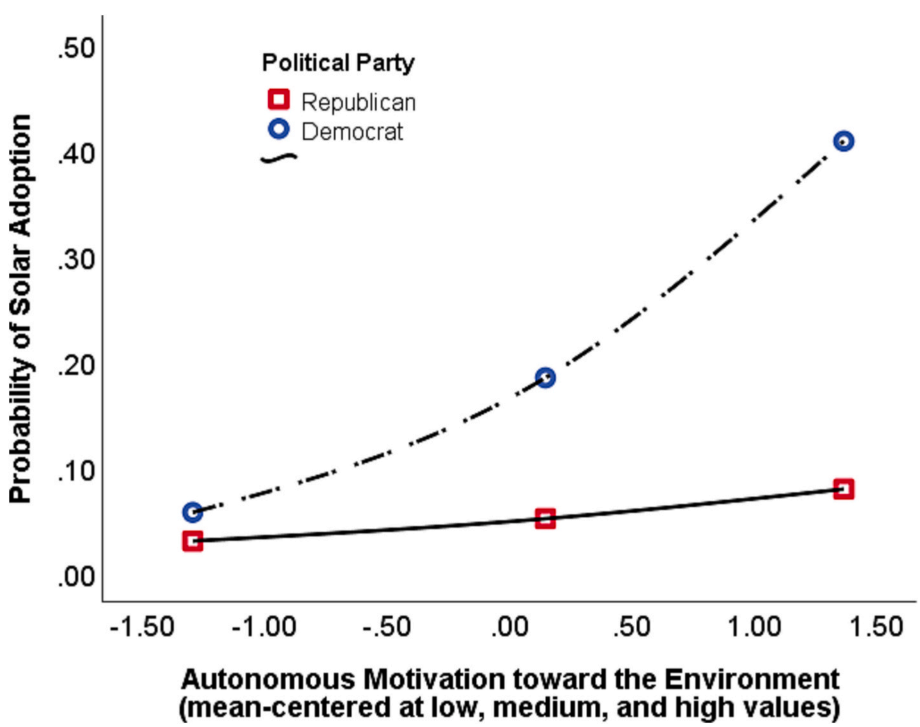

Fig. 6. Autonomous motivation predicts solar adoption for Democrats but not Republicans.

would hold more controlled motivation toward the environment. High-income adopters were strongly motivated for controlled reasons (e.g., to signal status or to show they have as many resources as their neighbors). However, this association vanished for low-income adopters. Additionally, both age and education moderated the effect of controlled motivation on adoption, where controlled motivation was a significant predictor for young and middle-aged homeowners, but not for older homeowners, and although controlled motivation predicted adoption across most education levels, it ceased to be a predictor for the most highly educated (i.e., top 4 % of education). Echoing the results for controlled motivation, we found that younger homeowners who do not care at all about the environment are very likely to adopt solar (with 80 % probability). This might seem counterintuitive at first but makes sense considering many states subsidize solar substantially, which reduces electricity costs over the long-term. Thus, motivation for solar may be purely economic for young homeowners thinking about long-term investments. Other practical and protective motivations may be at play; residential solar panels allow for electric service reliability in the face of storms and extreme weather events, and promote energy sustainability in the face of potential shortages and variation in costs, which provide homeowners with a greater sense of their own energy and financial independence.

Unlike controlled motivation and amotivation, autonomous (i.e., personal or internal) proenvironmental motivation was a robust unique predictor of adoption across the demographic board, and this was not significantly moderated by income, age, or education. Notably, autonomous motivation predicted adoption over and above the effects of values, demographics, preference for innovation, and political affiliation. This suggests that autonomous motivation plays a central role in solar adoption decisions – with one stipulation: although it is a significant predictor for Democrats, this is not the case for Republicans. Thus, while most homeowners become more likely to adopt solar panels as their personal concern for and motivation toward the environment increases, Republicans are unmotivated by environmental concern. Following a similar pattern, increasing education is not a predictor for Republicans, whereas the reverse is true for Democrats, who are more likely to adopt solar as education level rises.

Taken together, our findings indicate that explanations of solar adoption are not straightforward, and any analysis that neglects to consider interactive effects will fall short. There are different types of solar adopters – some who care about the collective and the environment and some who are less motivated by these munificent factors and more motivated by external norms and image concerns. In general, ascertaining whether solar adopters care about the environment itself or make environmental choices as a by-product of less altruistic and more external concerns depends mainly on income and age. Younger and wealthier homeowners are more likely to adopt solar when they are externally motivated and older and lower income homeowners are more likely to adopt solar when they genuinely care about protecting the natural environment and the welfare of others.

We highlight the boundary conditions of past work that draws straight lines between values/motivation and solar adoption. For instance, previous research showed that prospective adopters higher in altruism were more likely to contact a solar installer [8]. However, the current study reveals that *actual* adoption is connected to altruism only when homeowners are older in age. Younger and higher income adopters are more concerned with external, symbolic [see [27,38]], and normative pressures around sustainable actions. Similarly, whereas past research has suggested that many sustainable adoptions are driven by egoistic motives, [e.g., [25,28]], we find here that this is not the case among older and lower income adopters. Other research has noted that *both* environmental concern and the symbolic attributes of ecological innovations (which serve to signal positive attributes of the self to others) are simultaneously predictive of the adoption of sustainable technological advances – including renewable energy systems [27]. However, our results suggests that these two categories of motivations might not be held by the same adopters simultaneously – and that age, income, and education predict when one type of motivation may be prioritized over the other. Indeed, the current findings help to clarify the conditions under which these seemingly disparate predictors become salient.

Importantly, the current findings validate and extend recent evidence that low-income solar adopters demonstrate somewhat more environmental concern than high-income solar adopters [7]. In contrast to this previous study, however, we use a non-adopter comparison group. Additionally, whereas Wolske [7] noted that the difference in environmental concern between high- and low-income adopters was small, we find here that both income and age are rather robust determinants of the role of altruistic vs. symbolic/external motives in predicting adoption.

5.1. Broader implications: solar policy, marketing, and messaging

Our finding that different demographic groups exhibit different motivations underlying solar adoption is important for future solar policy and communication. A great deal of solar marketing and resultant adoption has emphasized economic advantages [62] and has been targeted mostly to those with high incomes [63,64]. Meanwhile, lower income homeowners are underrepresented in solar adoption [65], creating renewable-energy injustice [64,66]. Given the current findings that low- versus high-income adopters (as well as younger versus older adopters) differ in the type of motivation underlying adoption, it follows that, in order to attract and include older and lower income homeowners in the solar marketplace, messaging and policy should emphasize proenvironmental and altruistic rationales for adoption, rather than the typical economic, peer-focused, or status symbol-driven messaging. Similarly, our results suggest that, because different factors guide their decision-making, policy and messaging should target Democrats and Republicans in different ways. Indeed, within the domain of sustainable behavior, recent attention has been paid to the benefits of matching political and educational messages to the motivational characteristics of the message recipient – in order to reach a wider audience in a more impactful way [29,67,68]. In the context of environmental justice and low-income adopters, policies that focus more on environmental and prosocial rationales (in addition to the necessary lessening of up-front costs and bureaucratic requirements) are likely needed.

5.2. Limitations and future directions

We provide evidence for a more nuanced portrayal of solar adoption. Nonetheless, our cross sectional approach serves to distinguish between adoption and non-adoption rather than to predict adoption over time. We show that adoption is linked to different combinations of indicators rather than assume a causal or temporal sequence. Future research using longitudinal methods is needed to establish whether motivations, age, and income interact to predict prospective adoption.

There are a variety of policy considerations that we are not able to fully address in this research. Financial incentives in particular are known to influence adoption in different ways [e.g., [69,70]]. While some work suggests incentives promote adoption [50], other studies suggest the role of incentives may be relatively small [71]. Because our sample crosses multiple state lines, we cannot control for the varying effects of differing policies, incentives, or transaction costs associated with different utilities or states. Nonetheless, for our New York sample, state net metering credits during the survey time period allowed for selling back energy but only at wholesale costs, which suggests the return incentive was relatively low. We address the impact of financial incentives in part by controlling for innovation preference. Research has shown that those interested in innovative green technology are less affected by policy incentives and financial motives [50]. Because we controlled for innovation preference (as well as age, education, income, political orientation and additional motives related to self-interest and external influence), it is likely that effects we observed are robust regardless of financial incentive policies.

There may still be unaccounted for variables that help to explain differences between adopters and nonadopters. For instance, because residential solar is still relatively difficult to adopt in the US compared to other countries (e.g., the residential adoption rate in the US is 3.4 % compared to 12 % in Germany, 21.5 % in Japan, 24 % in the Netherlands, and 37.7 % in Australia; [72]); it is possible that those with resources to overcome these obstacles are more likely to adopt. Thus the effort required to adopt solar (vs. the convenience of non-adoption) may be an important factor to consider in future research.

Marketing strategies could also affect adoption. In the case of New York, the solarize campaigns were intensive approaches that coordinated local communities, the state government agency NYSERDA, and approved solar developers. Addressing the type of marketing approach, particularly given our multi-state sample, is outside the scope of this research. Similarly, whether adopters own or lease their systems (and those associated costs and benefits) is not addressed by this research.

5.3. Conclusion

With this study, we offer an account of the non-economic factors predicting the adoption vs. non-adoption of residential solar panels. Wolske [7] and Wolske and colleagues [8] have noted that the overemphasis of economic factors in predicting residential solar decisions neglects the important role of psychological indicators of solar adoption – particularly motivational indicators. Indeed, since economic concerns and interests fail to correspond to high rates of adoption [10], our examination of various non-financial motivations is important.

Because we compare adopters to non-adopters, we advance understanding of what predicts solar adoption relative to non-adoption. We also help to resolve debate in the literature regarding which types of motives are most important in predicting adoption [e.g., [29,30,8]]. That is, by testing multiple groups of correlates simultaneously, we extend past research by showing that autonomous and controlled motivations, as well as altruistic values, are among the strongest overall indicators of adoption – but that their associative strength changes according to income, age, education, and political identification.

These results have potential to inform solar messaging and policy. We show that interactions between demographic and motivational variables complicate solar adoption. As such, policies to increase solar adoption will need to consider not just the basic challenges of initial investment, bureaucratic hurdles, and structural logistics, but also residents' unique social and psychological characteristics. By targeting communication and strategy to prospective adopters' differing values and motives, widespread adoption is possible.

CRediT authorship contribution statement

Lisa Legault: Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Stephen Bird:** Software, Resources, Project administration, Methodology, Data curation, Conceptualization. **Martin Heintzelman:** Software, Resources, Project administration, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

I have shared the link to my data in the attach data step Solar Data 2023 (Original data) (Mendeley Data)

References

[1] D. Ivanova, J. Barrett, D. Wiedenhofer, B. Macura, M. Callaghan, F. Creutzig, Quantifying the potential for climate change mitigation of consumption options, Environ. Res. Lett. 15 (9) (2020) 093001.

[2] P. Zhai, P. Larsen, D. Millstein, S. Menon, E. Masanet, The potential for avoided emissions from photovoltaic electricity in the United States, Energy 47 (1) (2012) 443–450, https://doi.org/10.1016/j.energy.2012.08.025.

[3] G.L. Barbose, S. Forrester, E. O'Shaughnessy, N.R. Darghouth, Residential Solar-Adopter Income and Demographic Trends: 2021 Update, United States, 2021, https://doi.org/10.2172/1775422.

[4] M. Alipour, H. Salim, R.A. Stewart, O. Sahin, Predictors, taxonomy of predictors, and correlations of predictors with the decision behaviour of residential solar photovoltaics adoption: a review, Renew. Sustain. Energy Rev. 123 (2020) 109749.

[5] E. Sardianou, P. Genoudi, Which factors affect the willingness of consumers to adopt renewable energies? Renew. Energy 57 (2013) 1–4, https://doi.org/10.1016/j.renene.2013.01.031.

[6] B. Lin, S. Kaewkhunok, The role of socio-culture in the solar power adoption: the inability to reach government policies of marginalized groups, Renew. Sustain. Energy Rev. 144 (2021) 111035.

[7] K.S. Wolske, More alike than different: profiles of high-income and low-income rooftop solar adopters in the United States, Energy Res. Soc. Sci. 63 (2020) 101399.

[8] K.S. Wolske, P.C. Stern, T. Dietz, Explaining interest in adopting residential solar photovoltaic systems in the United States: toward an integration of behavioral theories, Energy Res. Soc. Sci. 25 (2017) 134–151.

[9] C.L. Crago, E. Koegler, Drivers of growth in commercial-scale solar PV capacity, Energy Policy 120 (2018) 481–491, https://doi.org/10.1016/j.enpol.2018.05.047.

[10] C. Bauner, C.L. Crago, Adoption of residential solar power under uncertainty: implications for renewable energy incentives, Energy Policy 86 (2015) 27–35, https://doi.org/10.1016/j.enpol.2015.06.009. Nov. 2015.

[11] S.H. Schwartz, Universals in the content and structure of values: theoretical advances and empirical tests in 20 countries, in: M. Zanna (Ed.), Advances in Experimental Social Psychology, Academic Press, Orlando, FL, 1992.

[12] S.H. Schwartz, Are there universal aspects in the structure and contents of human values? J. Soc. Issues 50 (1994) 19–45.

[13] J.I. De Groot, L. Steg, Value orientations to explain beliefs related to environmental significant behavior: how to measure egoistic, altruistic, and biospheric value orientations, Environ. Behav. 40 (3) (2008) 330–354.

[14] T. Dietz, Environmental value, in: Oxford Handbook of Values, 2015, pp. 329–349.

[15] L. Steg, Values, norms, and intrinsic motivation to act proenvironmentally, Annu. Rev. Env. Resour. 41 (2016) 277–292.

[16] P.C. Stern, T. Dietz, T. Abel, G.A. Guagnano, L. Kalof, A value-belief-norm theory of support for social movements: the case of environmentalism, Hum. Ecol. Rev. (1999) 81–97.

[17] C. Schelly, Residential solar electricity adoption: what motivates, and what matters? A case study of early adopters, Energy Res. Soc. Sci. 2 (2014) 183–191, https://doi.org/10.1016/j.erss.2014.01.001.

[18] T. Gärling, S. Fujii, A. Gärling, C. Jakobsson, Moderating effects of social value orientation on determinants of proenvironmental behavior intention, J. Environ. Psychol. 23 (1) (2003) 1–9.

[19] P.W. Schultz, L. Zelezny, Values as predictors of environmental attitudes: evidence for consistency across 14 countries, J. Environ. Psychol. 19 (3) (1999) 255–265.

[20] P.C. Stern, T. Dietz, The value basis of environmental concern, J. Soc. Issues 50 (1994) 65–84.

[21] J.I. De Groot, L. Steg, Relationships between value orientations, self-determined motivational types and pro-environmental behavioural intentions, J. Environ. Psychol. 30 (4) (2010) 368–378.

[22] A.M. Nordlund, J. Garvill, Value structures behind proenvironmental behavior, Environ. Behav. 34 (6) (2002) 740–756.

[23] L. Steg, G. Perlaviciute, E. Van der Werff, J. Lurvink, The significance of hedonic values for environmentally relevant attitudes, preferences, and actions, Environ. Behav. 46 (2) (2014) 163–192.

[24] R.A. Howell, It's not (just) "the environment, stupid!" Values, motivations, and routes to engagement of people adopting lower-carbon lifestyles, Glob. Environ. Chang. 23 (1) (2013) 281–290.

[25] C. Koo, N. Chung, Examining the eco-technological knowledge of Smart Green IT adoption behavior: a self-determination perspective, Technol. Forecast. Soc. Chang. 88 (2014) 140–155.

[26] V. Griskevicius, J.M. Tybur, B. Van den Bergh, Going green to be seen: status, reputation, and conspicuous conservation, J. Pers. Soc. Psychol. 98 (3) (2010) 392.

[27] E.H. Noppers, K. Keizer, J.W. Bolderdijk, L. Steg, The adoption of sustainable innovations: driven by symbolic and environmental motives, Glob. Environ. Chang. 25 (2014) 52–62.

[28] G. Schuitema, J. Anable, S. Skippon, N. Kinnear, The role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles, Transp. Res. A Policy Pract. 48 (2013) 39–49.

[29] L. Legault, The "what" and the "why" of proenvironmental deeds: How values and self-determined motivation interact to predict environmentally protective behavior, in: R.M. Ryan (Ed.), The Oxford Handbook of Self-Determination Theory, London, Oxford, 2023, pp. 1130–1148.

[30] T. Masson, S. Otto, Explaining the difference between the predictive power of value orientations and self-determined motivation for proenvironmental behavior, J. Environ. Psychol. 73 (2021) 101555.

[31] R.M. Ryan, E.L. Deci, Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being, Am. Psychol. 55 (1) (2000) 68–78, https://doi.org/10.1037/0003-066X.55.1.68.

[32] H. Joachain, F. Klopfert, Smarter than metering? Coupling smart meters and complementary currencies to reinforce the motivation of households for energy savings, Ecol. Econ. 105 (2014) 89–96.

[33] L. Legault, S. Bird, S.E. Powers, A. Sherman, A. Schay, D. Hou, K. Janoyan, Impact of a motivational intervention and interactive feedback on electricity and water consumption: a smart housing field experiment, Environ. Behav. 52 (6) (2020) 666–692.

[34] L.G. Pelletier, K.M. Tuson, I. Green-Demers, K. Noels, A.M. Beaton, Why are you doing things for the environment? The motivation toward the environment scale (mtes), J. Appl. Soc. Psychol. 28 (5) (1998) 437–468.

[35] D. Webb, G.N. Soutar, T. Mazzarol, P. Saldaris, Self-determination theory and consumer behavioural change: evidence from a household energy-saving behaviour study, J. Environ. Psychol. 35 (2013) 59–66.

[36] M.G. Fikru, Residential photovoltaics adopters versus considerers in the United States, Energy Res. Lett. 2 (4) (2021) 28129.
[37] C. Schelly, J.C. Letzelter, Examining the key drivers of residential solar adoption in upstate New York, Sustainability 12 (6) (2020) 2552.
[38] E.H. Noppers, K. Keizer, M. Milovanovic, L. Steg, The importance of instrumental, symbolic, and environmental attributes for the adoption of smart energy systems, Energy Policy 98 (2016) 12–18.
[39] A. Palm, Early adopters and their motives: differences between earlier and later adopters of residential solar photovoltaics, Renew. Sustain. Energy Rev. 133 (2020) 110142.
[40] M.C. Claudy, M. Peterson, A. O'Driscoll, "I like it, but I won't buy it": exploring the attitude-behaviour gap for renewable energy adoption, in: 37th Macromarketing Conference vol. 324, 2012, June.
[41] M.A. Hai, M.M.E. Moula, U. Seppälä, Results of intention-behaviour gap for solar energy in regular residential buildings in Finland, Int. J. Sustain. Built Environ. 6 (2) (2017) 317–329.
[42] L.M. Hassan, E. Shiu, D. Shaw, Who says there is an intention–behaviour gap? Assessing the empirical evidence of an intention–behaviour gap in ethical consumption, J. Bus. Ethics 136 (2016) 219–236.
[43] F. Faul, E. Erdfelder, A. Buchner, A.-G. Lang, Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses, Behav. Res. Methods 41 (2009) 1149–1160, https://doi.org/10.3758/BRM.41.4.1149.
[44] H. Chen, P. Cohen, S. Chen, How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiological studies, Commun. Stat. Simul. Comput.® 39 (4) (2010) 860–864.
[45] E.D. Groh, C.V. Möllendorff, What shapes the support of renewable energy expansion? Public attitudes between policy goals and risk, time, and social preferences, Energy Policy 137 (2020) 111171, https://doi.org/10.1016/j.enpol.2019.111171.
[46] E. Lachapelle, C.P. Borick, B.G. Rabe, Public opinion on climate change and support for various policy instruments in Canada and the US: findings from a comparative 2013 poll, in: Issues in Energy and Environmental Policy 11, 2014.
[47] D.P. Green, E. Schickler, Multiple-measure assessment of party identification, Public Opin. Q. 57 (1993) 503–535.
[48] H.F. Weisberg, A multidimensional conceptualization of party identification, Polit. Behav. 2 (1980) 33–60.
[49] D.G. Labay, T.C. Kinnear, Exploring the consumer decision process in the adoption of solar energy systems, J. Consum. Res. 8 (1981) 271–278.
[50] G. Simpson, J. Clifton, Testing diffusion of innovations theory with data: financial incentives, early adopters, and distributed solar energy in Australia, Energy Res. Soc. Sci. 29 (2017) 12–22.
[51] E.M. Rogers, Diffusion of Innovations, 5th ed., Free Press, New York, 2003.
[52] R.E. Goldsmith, The validity of a scale to measure global innovativeness, J. Appl. Bus. Res. (2011) 89–97.
[53] M. Lindeman, M. Verkasalo, Measuring values with the short Schwartz's value survey, J. Pers. Assess. 85 (2) (2005) 170–178.
[54] P.C. Stern, Toward a coherent theory of environmentally significant behavior, J. Soc. Issues 56 (2000) 407–424.
[55] J.I. De Groot, L. Steg, Value orientations and environmental beliefs in five countries: validity of an instrument to measure egoistic, altruistic and biospheric value orientations, J. Cross Cult. Psychol. 38 (3) (2007) 318–332.
[56] E. Van der Werff, L. Steg, K. Keizer, I am what I am, by looking past the present: the influence of biospheric values and past behavior on environmental self-identity, Environ. Behav. 46 (5) (2014) 626–657.
[57] A.K. Sherman, A.J. Rowe, S. Bird, S. Powers, L. Legault, Motivational orientation explains the link between political ideology and proenvironmental behavior, Ecopsychology 8 (4) (2016) 239–249.
[58] J. Cohen, Statistical Power Analysis for the Behavioral Sciences, 2nd ed., Erlbaum, Hillsdale, NJ, 1988.
[59] A.F. Hayes, J. Matthes, Computational procedures for probing interactions in OLS and logistic regression: SPSS and SAS implementations, Behav. Res. Methods 41 (3) (2009) 924–936.
[60] N.J.D. Nagelkerke, A note on a general definition of the coefficient of determination, Biometrika 78 (1991) 691–692.
[61] S. Berman, L. DalleMule, M. Greene, J. Lucker, Simpson's paradox: a cautionary tale in advanced analytics, Significance (2012).
[62] T. Holowkal, Top Four Benefits of Installing Solar Panels on Your Home April, U.S. Green Building Council, 2017. https://www.usgbc.org/articles/top-four-benefits-installing-solar-panels-your-home.
[63] G.L. Barbose, N.R. Darghouth, B. Hoen, R.H. Wiser, Income Trends of Residential PV Adopters: An Analysis of Household-level Income Estimates, Lawrence Berkeley National Laboratory, 2018.
[64] S. Borenstein, Private net benefits of residential solar PV: the role of electricity tariffs, tax incentives, and rebates, J. Assoc. Environ. Resour. Econ. 4 (S1) (2017) S85–S122.
[65] B.O. Sigrin, M.E. Mooney, Rooftop Solar Technical Potential for Low-to-moderate Income Households in the United States (No. NREL/TP-6A20-70901), National Renewable Energy Lab.(NREL), Golden, CO (United States), 2018.
[66] S. Borenstein, L.W. Davis, The distributional effects of US clean energy tax credits, Tax Policy Econ. 30 (1) (2016) 191–234.
[67] L.G. Pelletier, E. Sharp, Persuasive communication and proenvironmental behaviours: how message tailoring and message framing can improve the integration of behaviours through self-determined motivation, Can. Psychol. 49 (3) (2008) 210–217.
[68] S. Tagkaloglou, T. Kasser, Increasing collaborative, pro-environmental activism: the roles of motivational interviewing, self-determined motivation, and self-efficacy, J. Environ. Psychol. 58 (2018) 86–92.
[69] D. Kocakusak, J. Senick, C.J. Andrews, Implementing the energy transition: lessons from New Jersey's residential solar industry, Clim. Pol. (2023) 1–14.
[70] D.C. Reeves, V. Rai, Strike while the rebate is hot: savvy consumers and strategic technology adoption timing, Energy Policy 121 (2018) 325–335.
[71] K.K. Zander, G. Simpson, S. Mathew, R. Nepal, S.T. Garnett, Preferences for and potential impacts of financial incentives to install residential rooftop solar photovoltaic systems in Australia, J. Clean. Prod. 230 (2019) 328–338.
[72] Ember, European Electricity Review 2022, Energy Institute Statistical Review of World Energy, 2023. https://ember-climate.org/insights/research/european-electricity-review-2022.
[73] Badole, S., Bird, S., Heintzelman, M., & *Legault, L. (under review). Willingness to pay for solar adoption: Economic, ideological, motivational, and demographic factors.