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Consumer perception and use intention for household distributed photovoltaic systems

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ABSTRACT

Given the importance of promoting renewable energy, the Chinese government has enacted policies to encourage residents to install and use household distributed photovoltaic (PV) systems. However, only a few studies investigated factors influencing residents' use intention for household PV systems. The present study therefore investigated the influence of Chinese residents' environmental concern and innovativeness on their use intention for household PV system, as well as the mediating effects of perceived benefits and harm of household PV system in this process. Furthermore, the moderating role of residents' monthly electricity consumption in the above-mentioned association was also examined. Questionaire data from 400 Chinese participants in Zhejiang Province were used for analysis. Results from structural equation modeling suggested positive associations between environmental concern and use intention, and between innovativeness and use intention, through the mediating of perceived benefits and harm. Residents' monthly electricity consumption also moderate part of the associations. Based on the results, this paper calls on the government to regulate the safety standard of household PV nationwide to enhance social confidence. Conspicuous consumption, which comes with "traditional customs", should also be reduced.

Introduction

Climate change caused by greenhouse gas emissions has become a global issue of concern. The increasing number of greenhouse emissions accompanied by traditional consumption activities lead to a rise in the global temperature and threatened human health. Under such circumstances, how to reduce energy consumption and pollution emissions has become an urgent policy focus. Several ambitious countries are actively deploying low-carbon energy technologies in pursuit of a more rapid energy transition to achieve the Sustainable Development Goals [1,49]. High expectations have been placed on the deployment of renewable energy technologies [13,48]. IRENA [17] claimed that decarbonization of the electric power sector led by renewable energy was a key to the future of sustainable energy. Recently, solar energy has begun to upend the traditional model of central fossil-fuelled power stations supplying the grid with power [21,35,39,47]. The amount of renewable energy connected to the grid—mostly from large solar and wind farms—has dramatically risen in recent years. EIA [11] reported that solar power generation, including household distributed photovoltaic (PV) systems, increased by 13.7% compared to the first 8 months of 2018, accounting for over 2.7% of total power generation. Small-scale solar power generation increased 19.1% and accounted for nearly a third of the total (32.6%). The distributed PV system is growing faster than any other energy source. Household distributed PV systems, therefore, has become one of the most promising distributed energy systems (DESs).

Socio-technical systems of renewable energy are a frontier topic, whereas there were still concerns about consumers' acceptance of these systems [31,15,35]. It is believed that the challenges to achieving a renewable energy future are not only technical but also social. Therefore, it is necessary to understand factors that might influence customers' use intention for renewable energy systems. Relevant studies are popular in several countries, such as the UK, Germany, Swiss, and Austria. For example, by adopting the Theory of Planned Behaviour (TPB) and hierarchical regression analysis, Ambrosio-Albala et al. [4] studied a sample of 949 citizens in UK. However, most literature are conducted in Western contexts and there are few studies focused on developing countries, especially China.

According to China Photovoltaic Industry Association [9], the

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household PV system has been a bright spot in China in 2019. By the end of 2019, the cumulative installed capacity of household photovoltaic projects exceeded 10 GW, reaching 10.1 GW. In 2019, the total number of installed households in China exceeded 1 million, reaching 1.085 million (Fig. 1.1). However, the existing literature on China mainly focuses on the effect of subsidy policy on the diffusion of household photovoltaic technology [33,18], whereas only a few studies focused on the customers' acceptance of relevant technology. With the introduction of national policies to gradually reduce the power subsidy for household solar power generation, the adoption of household PV systems has become a more challenging task for realizing low-carbon transition. Before 2018, there were three levels of household PV subsidies: national subsidy (0.42 RMB/Kwh) + provincial subsidy + local subsidy. However, subsidies continue to fall after 2018 (Fig. 1.2). The present study therefore investigated Chinese citizen's use intention for PV systems and the two important factors that might influence their use intention: environmental concern and innovativeness. In addition, we examined the mediating effect of citizen's perceived benefits and perceived harm of household PV system in this process.

Theoretical framework

Environmental concern, consumer innovativeness, and use intention

Environmental concern

The Theory of Planned Behaviour (TPB) was proposed by Ajzen [2]. According to this theory, the formation of behavioural intention is influenced by three factors: attitude, subjective norm, and perceived behavioral control. One of the important parts of attitude is environmental concern, which describes individuals' attitude and intention to protect and preserve the environment [29,25,7]. Previous studies found environmental concern significantly influenced consumers' attitude towards green products and then influences consumers' purchase intention [8]. Related literature has also shown that environmental concern is closely related to green technologies' diffusion. Goh and Balaji [13] found environmental concern to affect green buying behaviors. Yadav & Pathak [37] used the TPB to study the purchase intention of Indian young people for green products, and found environmental concern to influence consumers' attitude and purchase intention for green products. However, Sun et al. [32] found that Chinese customers' environmental concerns did not have a significant direct impact on green consumption. Therefore, the relevant studies on environmental concerns

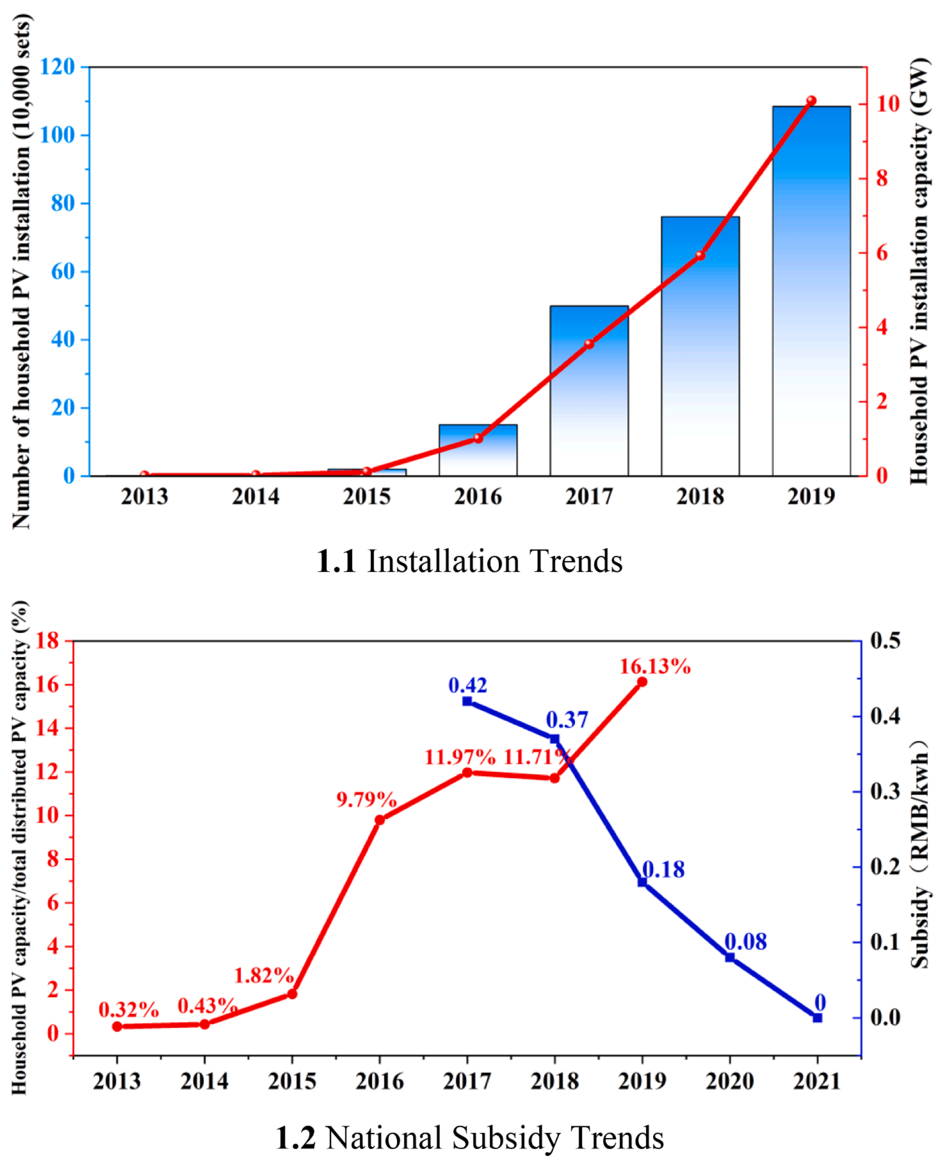

Fig. 1. Installation and Expected Subsidy Trends of Household PV Systems in China.

still need to be further validated.

Innovativeness

Another important factor that might influence customers' use intention is innovativeness (i.e., the degree to which consumers accept innovative things earlier than others; [27]. According to Bernd Schmitt, "novelty seeking" will lead consumers to go beyond the traditional assumption of a "rational consumer". Especially among young consumers, the consumption psychology of "seeking novelty" and "seeking difference" drives them to realize their own value pursuit through various consumption activities. In line with this theory, Mutum et al. [24] analyzed 1186 green consumers using SEM-PLS, and found that consumer innovativeness would affect customers' consumption value and purchase intention. Chen [6] investigated the Solar Power Systems installation intentions of 203 Taiwan students and faculty and found that innovativeness had a significant effect on install intention. However, previous studies about innovativeness did not investigate the mechanism of how innovativeness affected customers' use intention.

Perceived benefits, perceived risks, and use intention

Perceived benefits refer to the perception of the positive consequences, and perceived risks here refer to individuals' subjective perception about the uncertainty of whether the consumption result can meet the expected goal and the possibility of adverse results brought by consumption [20,16,19,22]. They are frequently found to affect use intentions in green diffusion studies. For example, Akroush et al. [3] found perceived benefits had a positive effect on consumer attitudes and purchasing intentions of energy-efficient products. Wilson et al. [34] investigated a sample of 1025 British customers about Smart Home Technologies (eg. smart metering) and found that they refrained from using the technology due to the obvious risk of privacy leakage. However, not much study focused on customers' perceived benefits and harm of PV systems. Although the risk of PV systems has been emphasized in previous reports, there are few relevant studies. According to BJX.com [41], a household photovoltaic knowledge platform in China, the potential technical risks in deploying PV systems are classified as shown in Table 1. Technical risks associated with distributed PV systems are often closely related to practice and will directly affect residents' energy routine. But there is still a lack of specific research on how perception of consequences affects PV adoption. Especially, as more studies focused on centralized solar systems (e.g., [36]), distributed systems even seem to need more stringent risk control than centralized systems. More research for distributed systems is therefore needed.

Moderating effects of energy consumption

Energy consumption also affects people's environmental decision-making. This is explained in the theory of consumption value, which is "an integrated model incorporating components from various consumer value models based on the assumption that consumer choice is a function of multiple consumption values" [40,5]. Even though the daily energy consumption is higher, a rational consumer should want to seek a more energy-saving lifestyle to reduce costs. However, "value-for-money" is only one of the influencing factors, while others, such as social value, play an important role. Through exploring the relationship between climate change and lifestyle, Roy and Pal [28] found that the "social status" symbolized by conspicuous consumption makes less affluent people tend to imitate this lifestyle, thus increasing energy consumption and carbon emission. Mi et al. [23] also analyzed urban residents with High-Carbon Consumption Behaviour (HCCB) in China, and found that "materialistic hedonism, interpersonal mediation and social status demonstration" are the main driving factors of HCCB lifestyle. Although targeted at the energy consumption of different countries, Ehigiamusoe et al. [10] found that energy consumption might moderate the harmful effect of GDP on CO_2. However, existing studies such as Roy and Pal [28] and Mi et al. [23] are only preliminary research on "social value". There is still a lack of relevant research on how customers with different levels of energy consumption would change their use intentions due to various motivations.

Table 1
Potential Technical Risks in Distributed and Centralized PV systems.

	Kinds of risk	Distributed PV systems	Centralized PV systems
Technical Risk	Equipment risk	Important (eg. installation space problem, heat dissipation problem)	Important
	Site environmental risk	Important (eg. dust and pollution problems)	Important
	Building load-bearing risk	Important (eg. load problem, waterproofing problem)	Uninvolved
	Design risk	Important (eg. roof orientation, irradiation and shading problems)	Important
	Construction and installation risks	Important (eg. installation and trial run problems)	Important

The present study

The present study investigated the associations between environmental concern, innovativeness and use intention for household PV systems of Chinese customers in Zhejiang province, as well as the mediating effect of customers' perceived benefits and harm of household PV system. We also further examined customers' monthly consumption of electricity on the above mentioned associations. Based on previous research, we developed the following hypotheses: (1) environmental concern and innovativeness would have positive (negative) associations with perceived benefits (perceived harm) of the household PV system, which in turn would have a positive (negative) association with use intention for the household PV system; (2) customers' monthly consumption of electricity would moderate the study associations, with the positive associations being strong and negative associations being lower for customers with higher monthly consumption.

Method

Case context

Since 2010, Zhejiang's total energy consumption has grown at an average annual rate of 4.8%, higher than the national level in the same period [38]. In 2018, Zhejiang's total primary energy consumption amounted to 217 million tons of standard coal, 1.6 times that of 2006 and 19 times that of 1980. Social electricity consumption is 453.3 billion Kwh, with a growth rate of more than 8% since 2017, ranking first in East China [30]. However, although Zhejiang is a big energy consumption province, it is a province with poor energy resources. Its self-sufficiency rate of primary energy is lower than 5% for a long time. The supply of coal, oil, natural gas, and other energy resources is heavily dependent on external transfer. Guang et al. [14] reported that there were structural risks of energy supply and demand in Zhejiang and short supply in different periods. During the 14th Five-Year Plan period (2021–2025), the province is expected to experience a power shortage of 15 million Kwh [30]. If the shortage is made up entirely by the transfer from outside the province, the proportion of external power will reach more than 50%, and will even be higher in peak periods, and the security risks of the power grid will significantly increase. The shortage of energy and perceived future risks have promoted Zhejiang to put renewable energy at the center of policymaking. The annual average total solar radiation in Zhejiang province is between 4220 and 4950 Mj/m^2, and the average in Zhejiang province is about 4440 Mj/m^2. The solar radiation amount is at the middle level in China, which is a representative region for household PV development. In recent years, the Zhejiang government has issued guidance policies such as the *13th Five-Year Plan for Solar Energy Development in Zhejiang Province*, the *Construction of Millions of Household Rooftop Photovoltaic Projects in Zhejiang Province*, and the *Service Guide for Household Rooftop Distributed Photovoltaic Power Generation Project*, hoping to concentrate on the development of the distributed household PV represented by rooftop PV. Therefore, it is of great significance to explore the use intention of household distributed PV systems in Zhejiang to promote the energy transition in Zhejiang, and it will also help realize the energy transition at the national level.

Participants and procedure

In total, 400 residents (52.8% female) from 11 cities in Zhejiang Province, China participated in the present study by filling in an online questionnaire. The participants had a mean age of 30.36 years (SD = 4.75, ranging from 26 to 61 years). Regarding the education level, most of the participants had at least a college degree (87.1%). Other participants either had a high school degree (11.5%) or a secondary school degree (1.5%). A majority of the participants (75%; $N = 300$) had a low monthly electricity consumption (<RMB 200 per month).

Data were collected in January 2021 through Microsurvey, a data collection platform in China like SurveyMonkey. IP control was posted during the data collection to include only residents in Zhejiang province. The participants gave their consent for participation in the present study by signing an online consent form. The questionnaire included questions about participants' demographic information (e.g., monthly electricity consumption), their Environmental Concern, Innovativeness, Perceived Benefits and Harm of household PV system, and their Use Intention for a household PV system. On average the participants spent around 10 min completing the questionnaire. As the respondents were obligated to finish all the questions, the response rate was 100% and there was no missing value.

Measurements

Environmental Concern. Five items from the Environmental Concern Scale [42] tapping respondents' worries and concerns about the current status of natural environment were used to measure residents' level of environmental concern. An example question is: *When humans interfere with nature it often produces disastrous consequences*. The participants responded to a five-point scale about to what extent they agree with the statement, from 1 (*Totally disagree*) to 5 (*Totally Agree*). To note, constructs and items mentioned below were rated on the same five-point scale (e.g., Innovativeness and perceived benefits of a household PV system). A higher score on this scale reflects a higher level of environmental concern. Previous research provided support for the psychometric properties of the scale (Mostafa, 2006). The items also showed satisfactory reliability (Cronbach's alpha = 0.76) and construct validity (factor loadings range from 0.44 to 0.88) in the present study.

Innovativeness. Residents' level of Innovativeness was assessed with 6 items measuring residents' tendency of approaching and accepting novel ideas and new things, for example, *I am prone to accept new concepts and things.* A high score on this scale represents a higher level of Innovativeness. In the present study, the Innovativeness items showed satisfactory reliability (Cronbach's alpha = 0.76), and sufficient construct validity (factor loadings range from 0.56 to 0.70).

Perceived Benefits of Household PV System. Residents' perceived benefits of a household PV system were measured with five items, tapping their perceptions about environmental, social, and economic benefits of developing and using PV systems. Some example questions include: *I believe household PV system would have benefits to the society*, and *I believe using household PV system at home would help the energy transformation process in China*. Residents with a higher score on this scale gave a higher evaluation of the benefits in using a household PV system. The items showed high reliability (Cronbach's alpha = 0.80) and good construct validity (factor loadings range from 0.47 to 0.82).

Perceived Harm of Household PV System. Residents reported their perceived harm of household PV systems on five items. The items describe respondents' concern and distrust about the security of assembling household PV system, for example, *Mistakes in the design of household PV system would lead to serious incidents,* and *a Household PV system may do harm to the human body*. High scores on this scale indicate more concern about a household PV system in the respondents. In the present study, the items showed high reliability (Cronbach's alpha = 0.82) and sufficient construct validity (factor loadings range from 0.64 to 0.80).

Use Intention for Household PV System. Respondents' intention to use and assemble a household PV system was measured by five items about individuals' plan and willingness to install household PV system at home. Some examples are: *It is a good idea to install a household PV system in my house,* and *I am happy to have a household PV System at home.* A higher score reflects a higher intention to use a household PV system at home. Both the reliability of the items (Cronbach's alpha = 0.84) and construct validity (factor loadings range from 0.69 to 0.75) are supported in the present study.

Analysis

Data were analyzed with Mplus version 7. To test the mediating effect of respondents' perceived benefits and harm of household PV system, we used Structural Equation Modeling (SEM), which produced a more accurate estimation of correlations between latent factors by partitioning measurement errors from the observed scores. We tested a partial mediating model with direct effect from independent variables on dependent variables against a full mediating model without the abovementioned direct effect. We further used the 'Model Indirect' function in Mplus to estimate a potential indirect effect. Based on the final mediating model, we further tested the moderating effect of residents' monthly electricity consumption by employing multiple group modeling. We compared the study associations between residents with a low monthly electricity consumption (<RMB 200/$31.5) and residents with a high monthly electricity consumption (≥RMB 200/$31.5).

In model estimation, Maximum likelihood with robust standard errors and chi-square (MLR) was used. Chi-square tests and fit indices such as Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Standardized Root Mean Square Residual (SRMR) were taken as indicators of the overall goodness-of-fit of the model. A satisfactory model fit is flagged by an insignificant chi-square value, RMSEA values < 0.08 [43], CFI values > 0.90 [44], and SRMR values < 0.08 [43]. Standardized coefficients were reported to indicate whether a significant effect was small ($0.1 < \beta < 0.3$), medium ($0.3 \leq \beta < 0.5$) and large ($0.5 \leq \beta$).

Results

Table 2 presents the descriptive statistics and correlations between the observed scores of the study variables. Environmental Concern was positively associated with Perceived Benefits of a household PV System ($r = 0.26$, $p < .01$) but did not have a significant association with Perceived Harm of household PV System ($r = -0.10$, $p = .214$). Innovativeness was positively associated with Perceived Benefits of a household PV System ($r = 40$, $p < .01$) and negatively associated with Perceived Harm of household PV System ($r = -0.16$, $p < .01$). Perceived Benefits of household PV System was positively associated with Use Intention for household PV System ($r = 0.75$, $p < .01$), and Perceived Harm of household PV System was negatively associated with Use Intention for household PV System ($r = -0.36$, $p < .01$). Both Environmental Concern and Innovativeness were positively associated with Use Intention for a household PV System ($r = 0.39$, $p < .01$).

Table 2
Descriptive Statistics and Correlations between Study Variables.

	Mean	SD	1	2	3	4	5
1. Environmental Concern	3.91	0.63	–				
2. Innovativeness	3.67	0.61	0.26**	–			
3.Perceived benefits of a household PV System	3.90	0.57	0.31**	0.40**	–		
4.Perceived harm of a household PV System	3.13	0.70	-0.10	-0.16**	-0.31**	–	
5. Use Intention for a household PV System	3.81	0.62	0.39**	0.39**	0.75**	-0.36**	–

Note. **: $p < .01$.

A full mediating model versus a partial mediating model

Based on the results from correlations analyses, we tested the fit of a full mediating model against a partial mediating model. Although a partial mediation model had a satisfactory fit (χ^2 (290) = 600.54, $p < .001$, RMSEA = 0.05, CFI = 0.92, SRMR = 0.06), the direct effect of Environmental concern on Use Intention for household PV System (β = 0.07, $p = .141$) and the direct effect of Innovativeness on Use Intention for household PV System (β = 0.04, $p = .475$) were not significant. Therefore, we decided to report results from a full mediating model, which was more parsimonious and also had a good model fit (χ^2 (292) = 600.39, $p < .001$, RMSEA = 0.05, CFI = 0.92, SRMR = 0.06). Regression coefficients are presented in Table 3 and a visualization of this model is provided in Fig. 2. As it can be seen from Table 3, both Environmental Concern (β = 0.32, $p < .001$) and Innovativeness (β = −0.19, $p < .010$) had a positive association with Perceived Benefits of a household PV system, which in turn had positive association with Use Intention for a household PV System (β = 0.84, $p < .001$). Innovativeness had a negative association with Perceived Harm of a household PV System (β = −0.19, $p < .01$), which in turn had a negative association with Use Intention for a household PV System (β = −0.20, $p < .001$). However, Environmental Concern did not have a significant association with Perceived Harm of a household PV System (β = −0.08, $p = .214$). The indirect effect of Environmental concern on Use Intention of a household PV System through Perceived Benefits of a household PV System was positive and significant (β = 0.28, $p < .001$). The indirect effect of Innovativeness on Use Intention for a household PV System through both Perceived Benefits of a household PV System (β = 0.36, $p < .001$) and through Perceived Harm of a household PV System (β = 0.04, $p < .05$) were both significant and positive.

Table 3
Standardized Coefficients of Residents' Environmental concern (EC) and Innovativeness in Predicting the Use Intention (UI) for A Household PV System through Their Perceived Benefits (PB) and Perceived Harm (PH).

	Total Sample		Low Monthly Consumption		High Monthly Consumption	
	β	S.E.	β	S.E.	β	S.E.
Direct Effect						
EC → PB	0.32***	0.05	0.35***	0.06	0.20	0.12
Innovativeness → PB	0.43***	0.05	0.37***	0.06	0.58***	0.10
PB → UI	0.84***	0.03	0.85***	0.03	0.83***	0.10
EC → PH	-0.08	0.06	-0.10	0.07	0.07	0.14
Innovativeness → PH	-0.19**	0.06	-0.19**	0.05	-0.23	0.14
PH → UI	-0.20***	0.04	-0.17**	0.05	-0.21*	0.08
Indirect Effect						
EC → PB → UI	0.28***	0.05	0.27***	0.05	–	–
Innovativeness → PB → UI	0.36***	0.04	0.32***	0.06	0.48***	0.08
Innovativeness → PH → UI	0.04*	0.02	0.03*	0.02	–	–

Note. Standardized coefficients for the total sample, for the sample with a low monthly electricity consumption, and for the sample with a high monthly electricity consumption were provided separately. * $p < .05$, ** $p < .01$, *** $p < .001$.

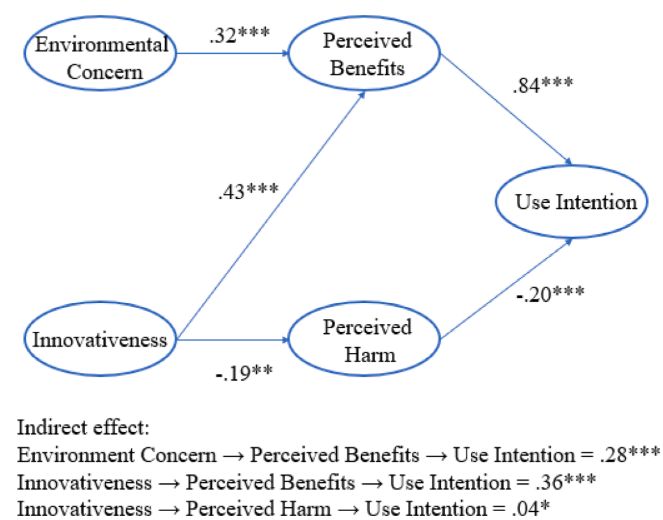

Fig. 2. A visualization of the relationships between Residents' Environmental Concern, Innovativeness, Perceived Benefits, Perceived Harm and Use Intention for Household PV System. *Note.* * $p < .05$, ** $p < .01$, *** $p < .001$.

The moderating effects of monthly electricity consumption

Based on results from the full mediating model, we further conducted multiple group analyses examining the moderating effect of residents' Monthly Electricity Consumption. The regression coefficients are also presented in Table 3 and a visualization of the multiple group model is provided in Fig. 3. The multiple group model had an acceptable fit (χ^2 (626) = 1092.08, $p < .001$, RMSEA = 0.06, CFI = 0.89, SRMR = 0.08). According to Table 3 and Fig. 3, for residents with a low monthly electricity consumption, the study associations showed a similar pattern with the mediating model of the total sample. However, for residents with a high monthly electricity consumption, Environmental Concern did not have a significant association with Perceived Benefits of a household PV System (β = 0.20, $p = .07$). Innovativeness did not have a significant association with Perceived Harm of a household PV System either (β = −0.23, $p = .09$). Moreover, the positive association between Innovativeness and Perceived Benefits of household PV System for residents with a high monthly electricity consumption (β = 0.58) was stronger than the association for residents with a low monthly electricity consumption (β = 0.37). As a result, for residents with a high monthly electricity consumption, Innovativeness only had a positive and indirect effect on Use Intention of household PV System through the mediating of Perceive Benefits of household PV System (β = 0.48, $p < .001$). There is no other significant indirect effect.

Discussion

The present study investigated the factors influencing customers' use intention for a household PV system in Zhejiang, China. Several important findings emerged from the analyses. In line with our hypotheses, customers' innovativeness had positive indirect effects on use intention of a household PV system through the mediating of perceived

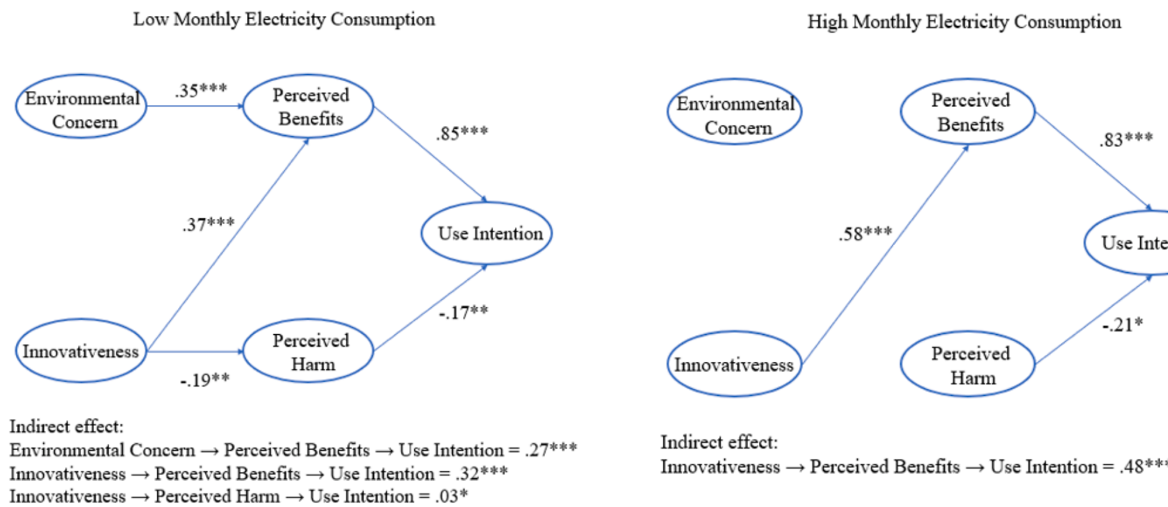

Fig. 3. A visualization of the relationships between Environmental concern, Innovativeness, Perceived Benefits, Perceived Harm and Use Intention for Household PV System of Residents with High Monthly Electricity Consumption and with Low Monthly Electricity Consumption. *Note.* * $p < .05$, ** $p < .01$, *** $p < .001$.

benefits and harm of household PV system. Interestingly, Zhejiang is often closely associated with the word "innovation" in China, and the "Zhejiang Spirit" is also considered as an innovative and enterprising spirit [45,46]. Therefore, our sample may have higher levels of innovativeness and are more willing to use a distributed PV system than Chinese residents in other regions. Future research may include Chinese residents in other regions as well to further explore whether our findings can be generalized to a larger population. In addition, environmental concern also had a positive indirect effect on use intention of household PV system through the mediating of perceived benefits, but the hypothesized association between environmental concern and perceived harm of household PV system was not significant. This indicated that if a household PV system has essential security-related problems that concern the customers, they would not tend to purchase and install a household PV system even if they tend to be environmental-friendly. This finding further stressed the importance of assuring customers about the security and benefits of using household PV system. As an implication, policy-makers and enterprises may put an emphasis on clarifying and mitigating customers' concerns and worries about PV systems. Zhejiang province has made some efforts in ensuring the quality of a household PV system. It is worth noting that Zhejiang is the first province in China to introduce and implement the household PV system standards. In the *Service Guide for Household Rooftop Distributed Photovoltaic Power Generation Project* issued by Zhejiang Provincial Energy Bureau, it is stipulated that PV systems with hidden quality problems should be reviewed, and service enterprises with repeated technical risks should be blacklisted and incorporated into the credit system management. Following these policies, more effort can be put into improving the quality of a household PV system and mitigating customers' worries about the potential risk, so as to enhance their use intention.

As for the moderating effect of customers' monthly electricity consumption, in line with our hypotheses, the positive associations between innovativeness and perceived benefits of household PV system was stronger for customers with a higher monthly consumption. This suggests that, due to a higher energy consumption, these customers would benefit more from using household PV system. Accordingly, policies and enterprises targeting at attracting these customers may stress on the economic and social benefits of installing household PV system. Different from our expectations, after controlling the effect of innovativeness, for customers with a high energy consumption, the association between environmental concern and the mediators was not significant. For these customers, the association between innovativeness and perceived harm of household PV was not significant either. These results indicated that environmental concern may not be an important factor to drive customers with a monthly high energy consumption to install household PV system. A plausible reason might be that their high energy consumption undermines their awareness of the importance of being environmental-friendly. This can also be explained by the "conspicuous consumption motivation" proposed by Mi et al. [23]. The association between conspicuous consumption and energy consumption has recently started to be discussed in developing countries such as India and is considered as an important obstacle to energy transition [26]. Although China has been initiating awareness campaigns in recent years to "change customs" to reduce high-carbon consumption and help citizens forming low-carbon habits, the effectiveness of these campaigns remains unclear. The dominance of conspicuous consumption is evidenced to be obvious in economic developed regions [23]. This indicates that in future policymaking, the government should pay more attention to integrating the concept of low carbon consumption into all sectors of society. Apart from the above discussion, our results indicate that innovativeness seemed irrelevant in mitigating their concerns for the harm of household PV system. These results suggest researchers explore other important factors that might drive this specific group of customers to use household PV system. We expect to explore these questions in our following works.

Conclusion

With the continuous reduction of subsidies in China, the adoption of household PV system in the future will rely more on influencing factors other than subsidies. This paper focus on two variables related to values and personality traits, namely, Environmental Concern and Innovativeness [27], as well as perceived benefits and harms, to discuss the paths that affect use intention of household PV systems. At the same time, the moderating effect of energy consumption on the path were also tested. Through the discussion of the paths, the present study hopes to provide reference for future household PV market promotion and policy.

Through collecting questionnaires from 11 cities in Zhejiang Province, China, the present study investigated Chinese residents' use intention for a household PV system and the factors influencing their use intention. Our findings suggested that customers with higher environmental concern and innovativeness were more likely to use a household PV system, as they tended to perceive a household PV system with more benefits and less harm. For customers with a high monthly electricity consumption, only their levels of innovatiness would affect their use intention for a PV system through improving their perceived benefits of a PV system, whereas their levels of environmental concern did not have a significant association with use intention. Based on these findings, it can be found that the influence mechanism of individual decision in the process of photovoltaic system adoption is complex. For different consumer groups, the influence path of factors is also different. Future policy makers and manufacturers should focus more on consumer concerns about the technical risks of household PV systems. At the same time, limiting the culture of conspicuous consumption would help increase the effectiveness of the other pathways of influence identified in the present study.

Finally, the present study also has several limitations. First, we included cross-sectional data and only focused on a sample of residents in Zhejiang. As such, we cannot examine the causal influence with longitudinal data, and cannot make cross-province comparations to further explore whether our findings generalize to other regions as well. Second, we did not include other behavioural variables, and thus were not sure whether other variables may also affect the pathways for residents with high energy consumption. Therefore, future research is encouraged to include a larger and more comprehensive sample, as well as other contextual variables, to further explore the generalizability and underlying mechanism of our findings.

CRediT authorship contribution statement

Wan-Hao Zhang: Conceptualization, Methodology, Writing – original draft. **Li-Chen Chou:** Funding acquisition, Validation, Supervision. **Mengdi Chen:** Formal analysis, Methodology, Software, Validation.

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.

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