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# Consumer renewable energy technology adoption decision-making; Comparing models on perceived attributes and attitudinal constructs in the case of solar water heaters in Lebanon

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**Abstract**

Climate change and environmental problems are of major concern to governments, organisations, and consumers. This stresses the need for a transition towards clean renewable energy systems. To enable the diffusion of cleaner energy technology it is not enough to just have supportive policies in place. The challenge is to ensure that consumers adopt them. This article integrates insights from different research traditions into a research model to analyse consumers' adoption decision-making behaviour. The innovation-diffusion model by Rogers was used and hypotheses from environmental psychological models were later added. A survey was conducted among householders to assess the adoption of solar heating systems in the Metn neighbourhood in Lebanon (N = 200). The results revealed that adopters and non-adopters differ significantly according to socio-demographic factors, such as income and household size.

The study confirmed the significance of typical variables of the diffusion of innovation model, such as relative advantage, observability, independent judgment-making, and novelty-seeking; even when testing integrative analytical models. Furthermore, the results indicate that, by integrating hypotheses from environmental psychology models to the diffusion of innovation model, a reasonable fit was achieved which is higher than the value of each model tested separately. The results can be of use to policy makers. The article ends with suggestions for future research.

## 1. Introduction

In the light of climate change, the Paris agreement in December 2015 set strict goals and urging all countries to formulate action plans to decrease energy use (Paris, 2015). Green innovations, such as solar panels, have a potential to help reduce carbon emissions, lower fossil fuel dependency and stabilise energy costs (Claudy et al, 2010). However, introducing renewable energy technologies in developing countries requires a lot of financial and educational support (Karp, 2015). Policy interventions are very important to promote the uptake of renewable energy technologies. However, on their own, they are not enough unless consumers take action themselves to adopt these technologies. Therefore, consumers play an important role and it is important to stimulate behavioural change (Bressers and Ligteringen, 2001).

Stern (2000) acknowledged research traditions that study the influence of moral concerns on consumer purchasing decisions, and addressed their importance in understanding environmental consumer behaviour. In doing so, he called for more research on consumers adopting environmental products. In this article, the drivers and barriers to adoption and non-adoption of environmental innovations will be investigated by integrating two research streams rooted in two research traditions: (i) innovation diffusion, and (ii) environmental psychology.

This research deals with householders adopting renewable energy technology in Lebanon. Lebanon is a country that has witnessed various initiatives supported by international funding agencies to develop the renewable energy market; especially solar energy thermal systems. As an example, a Global Environment Facility (GEF) funded initiative aimed to promote solar water heater (SWH) installations in the residential sector to achieve a target of 1.05 $m^2$ by 2020 (LCEC, 2016). This initiative was accompanied by a policy paper which sought to increase renewable and energy efficient technologies penetration by a financing mechanism and thee removal of taxes on imported renewable energy technologies (Bassil, 2010). As a result, the solar market (including suppliers of SWH) grew from 10% to 50% (LCEC, 2016). The residential sector accounts for the highest amount of installed SWHs across sectors (74% of installed systems), showing that the total of installed capacity until 2014 was approximately 550,000 $m^2$. However, the diffusion of renewable energy technologies faced various challenges, namely the absence of clear policies to promote the use of renewable energy sources from the government side, and the overall mentality and culture of the consumers on the other (Kinab and Elkhoury, 2012).

Lebanon has a unique context that influences consumers' adoption decision. For instance, unreliable electricity supply services provided by the national utility provider results in severe daily blackouts across the country (Harajli et. al, 2015) . This has led consumers to rely heavily on expensive substitute sources of electricity supply, such as private backup diesel generators (Dagher and Ruble, 2010). Harajli et al. (2015) found that Lebanese households spend a significant amount of their income to secure the electricity and hot water (given that water is mostly heated through electric boilers) needs. Consumers pay approximately 10.4% of their income on electricity (this includes the utility and the backup generator bill). For this reason, they can arguably be considered 'fuel poor'[1].

In the light of the policies and projects that have been implemented to increase the uptake of such technologies, SWH was chosen as a case for analysis. An important reason for doing so is that this technology has been adopted to a reasonable extent in Lebanon; more than other renewable energy technologies. Instead of analysing the mere intention to adopt (Alam et al., 2014; Ozaki, 2011), actual adoption is addressed. The purpose behind this is to reveal preferences and opinions for the adoption of SWHs from both adopters and non-adopters to understand what makes consumers purchase and use such systems.

Technology diffusion in a community depends on a number of factors, including the type of technology, government policy, and a number of social and culture specific factors (Rogers, 2003). Of these, the social characteristics were assumed to influence diffusion-adoption processes in particular. To address this issue, next to applying the more general innovation-diffusion concepts, this study also pays attention to social norms SWH (non-)adopters have.

The main research question of this article is: To what extent do selected theoretical drivers explain household adoption of SWHs in Lebanon? An integrated research model was used to analyse adoption decision-making using insights from both Rogers' famous 'Diffusion of Innovation' model (Rogers, 2003), together with other relevant models from the domain of

[1] "a fuel poor household is defined as one which needs to spend more than 10% of its income on all fuel use and to heat its home to an adequate standard of warmth" (Energy UK, 2017)

environmental psychology (Jansson et. al, , 2010; Steg, Dreijerink, and Abrahamse, 2005; Steg and Vlek, 2009; Stern et. al, 1999). This integration was made to tackle the gaps of the diffusion of innovation model in addressing values and attitudes on the one hand and to apply factors from the VBN theory on high investment system (rather than on consumption and low investment choices) on the other hand.

To answer the research question, a survey was conducted to test hypotheses from an integrated research model on consumers' choices and preferences regarding adoption of SWHs. Based on the results of the empirical study, implications for policy makers were derived (on how to approach target groups), which will be addressed at the end of this article.

## 2. Consumer decision-making on the adoption of clean energy technology

The focus of this research is on consumers, without ignoring the fact that other actors can also play a crucial role in the process of environmental innovation adoption. In this section relevant theory and results from empirical studies are presented on the adoption of innovation and innovation diffusion in order to identify the factors that influence consumers' adoption decisions and to construct a conceptual framework for this empirical study.

Several studies have addressed the gaps in early research which focused either on non-consumption behaviour (such as energy savings) or on post-purchasing behaviour (such as waste recycling), (Follows and Jobber, 2000; Jansson, 2009; Joshi and Rahman, 2015). These neglected to study the pro-environmental behaviour in high involvement purchases (purchases which require extensive search for information and involve high expenditure (Asamoah, 2012)). This led to calls for more research on high involvement purchases with large environmental impact (Jansson et. al, 2011; Lehman and Geller, 2004). Jansson et al. (2010), for instance, found that the Values-Beliefs-Norms (VBN) theory explained 41% of the variance on adoption of alternative fuel vehicles; leaving a considerable proportion unexplained. In their study, the explanatory power of the model would probably have been higher if contextual factors, such as external drivers and barriers, had been included in the model Stern (2000).

Thus, the "diffusion of innovation theory" (Rogers, 2003), in addition to theoretical literature on pro-environmental behaviour (e.g., Jansson et. al (2009), Jansson (2011), Nordlund and Garvill (2003), were applied to understand consumers' decisions to adopt a technology.

In the next sections (2.1 – 2.4) an overview of the literature on the theory of innovation diffusion regarding adoption of eco-innovations is provided, such as clean energy innovations, and the theory regarding pro-environmental behaviour to provide a rich understanding of 'green' consumer behaviour and, therefore, 'green' innovation adoption decision-making.

### *2.1. Innovation Diffusion*

The diffusion of innovation theory draws upon ideas on organisational life from economics, sociology, and communication theory, and applies these to different types of innovations (Karakaya et. al, 2014). Whereas cognitive behavioural theories focus on intentions as predictors of consumer behaviour, the adoption and diffusion of a technology, as viewed by Rogers (2003), is a social process whereby consumers form a general attitude towards an innovation based on their perception of its characteristics. According to Rogers (2003) several conditions influence individuals and occur before the process of innovation decision-making takes place: e.g. previous practices, existing needs, innovativeness, and norms of the social environment of the consumers. The adoption decision of potential adopters was found by some researchers to be highly influenced by their social environment on the one hand (Jager, 2006; Ozaki, 2011; Sidiras and Koukios, 2004), and interpersonal communication on the other (Mahapatra and Gustavsson, 2008). Therefore, it is assumed that social influence plays a significant role in technology adoption (Rogers, 2003; Young, 2009). Ozaki (2011) confirmed this by showing that consumers engage in activities in which they start to use norms that are considered important in (social) groups to which they belong.

### *2.2. Pro-environmental behaviour*

A consumer's decision to adopt an innovation is related, not only to external influences (e.g. costs and functionality), but also to the way in which it reflects their identity, values, and norms (Ozaki, 2011). Environmental psychological research has focused on the attitudinal factors, due to their success in explaining 'green' consumer behaviour across different aspects (Jansson, 2011). In this field, studies have been conducted to test the relation between certain values and pro-environmental behaviour. As discussed previously, social influence is considered an important factor influencing consumer adoption decision-making. Norms are an important aspect of the social influence. These embrace personal and social norms (Jansson et al, 2017). The unique role of social influence stems from several theories, such as the theory of reasoned action, the theory of planned behaviour, and the norm activation model (Schwartz, 1977).

Stern et al. (1999) developed the norm activation model to a pro-environmental consumer behaviour (the VBN model), which conceptualizes attitudinal factors (values-beliefs-norms). This model has been used to explain a variety of low involvement consumer behaviours, which includes acceptability of energy policies (Steg et al, 2005), energy conservation behaviour (such as power conservation, ecologically aware consumer behaviour, garbage inhibition, and ecological automobile use) (Kaiser et al, 2005), and willingness to reduce car use (Nordlund and Garvill, 2003). According to Jansson et al. (2010) and (Jansson et al., 2017) personal norms had a strong positive influence on green purchasing behaviour of high involvement durables (the case of alternative fuel vehicles).

According to Thøgersen (2006) environmental behaviour not only correlates with personal norms, but also with subjective social norms. The correlations between social norms and behaviour become significantly weaker when personal norms are added to the research models. According to Steg and Vlek (2009), it is very important to consider contextual factors, such as physical infrastructure, product characteristics, and technical facilities, next to intra-personal factors, such as attitudes, norms and habits for engaging people in pro-environmental behaviour.

### *2.3 Innovativeness*

Rogers (2003) defines *innovativeness* as the degree to which an individual has adopted an innovation earlier than others within the social environment of the consumers. However, innovativeness has been operationalized in several ways using different constructs. For instance, Midgley and Dowling (1978) define it as: “the degree to which an individual makes innovation decisions independently of the communicated experience of others”. This construct has been referred to as consumer independent judgment making. This reflects the reliance on others when making decisions. Another concept is consumer novelty seeking: “the desire to seek out the new and different” (Hirschman, 1980). According to Tellis et al, (2009) there has not been a clear census on the measurement of the innovativeness construct. Some researchers found that consumer novelty seeking influenced adoption of new products (Biswas and Roy, 2015; Im et al, 2003; Tanner and Kast, 2003).

*2.4 Perceived Products Characteristics*

Closely related to innovativeness are the product attributes and the ways in which the consumers perceive them. According to Rogers (2003), these attributes influence adoption decision-makings. They concern: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability.

Due to the intrinsic nature of renewable energy technologies, it is important to consider product characteristics when studying consumer behaviour and related adoption decision-making. For instance, several studies (Guagnano et al, 1986; Labay and Kinnear, 1981; Ostlund, 1974) show that perceived attributes are better predictors of consumer adoption than personal characteristics, such as particular socio-demographic factors.

*Relative advantage* refers to: "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 2003). It is considered an important determinant of adoption. Relative advantage can be of any nature, either in economic, social, or personal terms). In several studies, perceived relative advantage was found to have a positive influence on the adoption of several environmental innovations; namely solar energy systems (Guagnano et al., 1986; Labay and Kinnear, 1981), alternative fuel vehicles (Jansson, 2011), and on the intention to adopt electronic indicator providing feedback on in-home energy use (Völlink et al, 2002). In studying the adoption of green power by households, Arkesteijn and Oerlemans (2005) did not find any factor correlating significantly with adoption. On the other hand, Caird et al (2008) and Caird and Roy (2010) found that the main drivers for adopting micro-generation technologies were (perceived) energy savings and lowering of fuel bills. Other studies revealed that investment costs (Mahapatra and Gustavsson, 2008), energy costs, and maintenance costs (Willis et al., 2011) are considered important barriers to adoption of micro-generation technology.

C*ompatibility* is the degree to which an innovation is consistent with existing values, experiences and needs (Rogers, 2003). Some researchers, such as Guagnano et al. (1986) and Völlink et al. (2002), dealt with compatibility in a different way than Rogers did, and explained it as being consistent with values. The more compatible an innovation is, the less change in the behaviour it requires and, thus, the faster it is likely to be adopted (Jansson, 2011; Ozaki and Sevastyanova, 2011).

*Complexity* is defined as the extent to which an innovation is considered difficult to understand and use (Rogers, 2003). Complexity may not be as important as relative advantage or compatibility for some innovations, but for others complexity is an important barrier to adoption. For instance, Mills and Schleich (2009) found that installation piping that is essential for any SWH installation can deter households adopting SWH systems. Labay and Kinnear (1981), compared perception of consumers to solar energy systems and found that adopters consider these innovations as less complex than non-adopters. Hence, perceived complexity was found to negatively influence innovation adoption.

*Trialability* is the degree to which an innovation can be tested on a limited scale (Rogers, 2003). Janssen and Jager (2002), Labay and Kinnear (1981) and Völlink et al. (2002) found that trialability did not relate to adoption of energy conservation intervention technologies, nor to adoption of solar energy systems. In fact, the nature of the technology predetermines its characteristics.

*Observability* is the degree to which the results of an innovation are visible to others (Rogers, 2003). For instance, SWHs by their very nature are installed on rooftops and tend to have a high degree of observability. Several studies revealed that observability has a positive influence on adoption of clean energy technologies (Guagnano et al., 1986; Jager, 2006; Jansson, 2011) However, Labay and Kinnear (1981) argue that, the more familiar a consumer gets with innovations, the less observable they become.

In addition to the five perceived attributes discussed by (Rogers, 2003), several researchers added *perceived risk* or uncertainty on innovations as a factor explaining innovation adoption (Kleijnen et al, 2009; Midgley and Dowling, 1978; Ostlund, 1974). Perceived risk addresses the fact that adopting a new technology bears a certain level of operational or financial risk to potential adopters. To varying degrees it influences adoption decision-making (Labay and Kinnear, 1981) and leads to a negative impact on purchasing green innovations, but also to changing behaviour (Claudy et al, 2011; Jansson, 2009; Ostlund, 1974).

### *2.5 Personal Capabilities: socio-demographic characteristics*

Empirical research reveals that income has a positive influence on installing or adopting solar energy technologies (Jager, 2006; Mahapatra and Gustavsson, 2008; Sidiras and Koukios, 2004;

Wang et al, 2008). Sidiras and Koukios (2004) argue that rent of residential space, and low family income, are major barriers to diffusion of solar hot water collectors among householders. An explanation for this phenomenon would be that households of higher income have a greater financial ability to afford new products. In addition, they usually have a high level of education. Thus, they are more likely to be aware and have a relatively open mind-set to adopt new more expensive products (Wang et al., 2008). Similarly, Claudy et al. (2010) found that the more highly educated people are the more likely they adopt micro-generation technologies, due to their 'high-involvement' with this technology. In a study assessing twenty five issues related to decision-making Kastner and Stern (2015) revealed that education and energy-related investment decisions were found to statistically correlate with household energy investments.

Despite their assumed influence on adoption of clean energy technologies among householders, socio-demographics were found to have relatively little explanatory power (Cottrell, 2003; Ostlund, 1974; Rogers, 2003).

## *2.6 Contextual Forces*

### *2.6.1 Policy and monetary incentives*

According to Rogers (2003) the rate of adoption becomes self-sustaining, once a 'critical mass' point of adopters is obtained. One of the major influences to create 'critical mass' among potential adopters is the use of financial incentives (Mahapatra and Gustavsson, 2008).

Financial incentives are often used in government policies as a means to persuade householders to invest in renewable energy technology. According to Caird et al. (2008), Caird and Roy (2010) and Sidiras and Koukios (2004), governmental grant schemes are important drivers for homeowners to adopt SWHs. Similarly, Zhai and Williams (2012) recognize the importance of the availability of financial programmes for customers purchasing solar energy systems. However, Steg and Vlek (2009) argue that structural strategies that target changing contextual factors are highly important. They are considered more effective in promoting pro-environmental behaviour than informational strategies targeting awareness raising and knowledge provision among target group members.

This research integrates contextual factors from a number of existing perspectives (partly relying on Jansson (2011) and Ozaki (2011). By purposefully integrating factors from diffusion of innovation, and pro-environmental behaviour, the understanding of consumer behaviour will be broadened and the factors that influence adoption of eco-innovation will be further investigated. As such, implications for policy will be drawn, and how renewable energy technologies can be diffused more successfully will be more explored. Due to the nature of SWHs, trialability is removed from the analysis, since it is irrelevant to this technology and might disrupt the analysis.

Theories having a cognitive approach, such as Theory of Planned Behaviour (TPB) and the Theory of Reasoned Action (TRA) focus on intention as a predictor of the actual behaviour. Similarly, the Unified Theory of Acceptance and Use of Technology (UTAUT) developed by Venkatesh and Davis (2000) on the basis of eight theories, explains that one set of factors (performance expectancy, effort expectancy, and social influence) influence behavioural intentions, while these behavioural intentions and facilitating conditions determine the use of technology. Although these models and theories differ in their focus, they overlap in the factors that influence adoption (Ozaki, 2011). Since the focus of this study is on the actual adoption of a technology, the diffusion of innovation theory was applied, given its usefulness as a systemic approach to study adoption and non-adoption (Al-Mamary et. al, 2016). The theories taking a cognitive approach (i.e., TRA, TPB, and UTAUT) were considered in the preparation phase of this study. Due to the focus of the study, the diffusion of innovation theory was mainly used, while constructs from Ozaki’s (2011) adoption study were integrated.

## 3. Research Model

### *3.1 Hypotheses*

The overview of literature in section 2 identified several factors from empirical studies that help explain consumers’ adoption decision. The theory and literature review of empirical studies helped select (independent) variables that covariate with adoption of innovation. The hypotheses that follow from the assumed inferences between the selected independent variables and environmental innovation adoption are clustered by issue: (i) norms and innovativeness; (ii) perceived attributes of the product; and (iii) policy incentives. They derive from both the “diffusion of innovation” research tradition, and from the environmental psychological research tradition. Therefore, combining insights will lead to an integrated research model that has a higher explanatory power when compared to the current mono-disciplinary models.

Norms and innovativeness:

*$H_1$: Pro-environmental personal norms have a significant and positive relationship on householder's decision to adopt a SWH.*

*$H_2$: Social influence and norms have a significant and positive relationship on householder's decision to adopt a SWH.*

*$H_3$: Adopters of SWHs have higher levels of novelty seeking than non-adopters.*

*$H_4$: Adopters of SWHs have higher levels of independent judgment-making than non-adopters.*

Perceived attributes of the product:

*$H_5$: Relative advantage has a significant and positive relationship to a householder's decision to adopt a SWH.*

*$H_6$: Compatibility has a significant and positive relationship to a householder's decision to adopt a SWH.*

*$H_7$: Complexity has a significant and negative relationship to a householder's decision to adopt a SWH.*

*$H_8$: Observability has a significant and positive relationship to a householder's decision to adopt a SWH.*

*$H_9$: Risk has a significant and negative relationship to a householder's decision to adopt a SWH.*

Policy incentives:

$H_{10}$: Financial incentives *have a significant and positive relationship on a householder's decision to adopt a SWH.*

## 4. Research design and methodology

### *4.1. Measures and preparation*

Items in the survey were based both on relevant literature (i.e., Jansson, 2011; Ostlund, 1974; Ozaki, 2011; Steg et al., 2005), and  on the results of a pilot study that preceded the survey. Scale items and reliabilities are presented in Appendix A.

The study conducted a household survey using a questionnaire divided into five sections. The sections covered financial incentives, attitudinal factors and norms, demographic, and household specific details of respondents. A reliability test using Cronbach's alpha was used to measure the reliability of selected constructs (see Table 2).

The survey was conducted in 2015, and was managed in all its stages (pre-test, pilot test, and actual data collection) by the primary researcher (the first author of this article) to ensure the validity of the research design and to evaluate the acceptability and clarity of the questionnaire. The questionnaire design was intended for those who make decisions at the household level .

Several challenges influenced data collection. The first challenge concerned a lack of official statistics and detailed local level information and socio-demographic details about SWH adopters and non-adopters. The second challenge concerned budget constraints and security reasons in a critical period of conflict in Lebanon. These influenced the response of potential respondents when approached by 'strangers', i.e., the researchers contacting them with the aim of having them completing questionnaires.

*4.2 Sampling*

A survey was conducted among a sample of households in the Metn district in Lebanon. The reason behind choosing this region was the high adoption rate that ensured that the data could be collected from both adopters and non-adopters. The adoption rates in each region were acquired by contacting the national energy conservation centre. This helped in locating the regions in which a high concentration of SWHs had been installed. As a second step, major suppliers in the selected region were contacted to identify the areas in which the highest concentration of SWHs had been installed. This helped to locate the survey targets to ensure availability of SWH adopters. The place of residence, type of dwelling, and ownership of SWH were also used to contact potential respondents.

*4.3 Data collection*

A total of 308 households were targeted. The distribution of respondents among socio-demographic statistical indicators is presented in Table 1. The nature of the surveyed region meant the respondents' employment status, education, and income were, to a certain extent, high as when compared to average households in Lebanon.

Data was collected by face-to-face interviews using closed-ended questionnaires. Data collection was conducted between December 2015 and January 2016 by a team of five university students and the study's primary researcher (first author of this article). The average time used for completion of a questionnaire was between 10 and 15 minutes. In the end 213 respondents completed the questionnaires. This yielded valid responses from 200 households. From this sample, responses from 131 adopters and 69 non-adopters (a response rate of 69.2%) were analysed.

*4.4 Data Analysis*

*4.4.1 Descriptive Statistics*

Several analyses were conducted to assess the validity and reliability of the data. First, non-response bias was analysed by comparing early and late respondents, as recommended by Armstrong and Overton (1977), on relevant variables, such as dwelling characteristics, dwelling ownership, employment status, education, and age. No significant differences were found between the two groups, which indicated the absence of non-response bias. Then, the data were tested against common method bias. For this, Harman's single factor test was conducted (Harman, 1967; Kassinis and Soteriou, 2009). The factor analysis, using principal component analysis, revealed seven factors with Eigen values greater than 1.00. In total, they accounted for 61.0% of the total variance. Moreover, the first factor only accounted for 21.0% of the variance (which is less than the official 50% cut-off point). The results show that common method variance can be considered to be of little influence in this study.

To investigate factors driving and hindering adoption, several analyses were conducted. Socio-demographics were operationalized as segmentation variables (Rogers, 2003), both adopters and non-adopters were analysed on differences. The differences between the two groups were tested using a chi-square test for categorical variables and a t-test for continuous variables. Next, the mean, the standard deviation (SD), significance values, and construct validities of the five independent measures were analysed. Further details can be found in Tables 1 and 2.

### *4.4.2 Logistic Regression*

To analyse the influence of selected items of perceived attributes, and attitudinal and innovativeness factors on SWH adoption, a binary logistic regression with the backward stepwise likelihood ratio was used. All variables were entered in the first step, and in every step after that the variable with the smallest correlation with adoption was removed; Exp β coefficient being the odds ratio of the probability that an event will occur against that it will not occur (Arkesteijn and Oerlemans, 2005). To assess the model fit, model chi-square was used. A p-value less than 0.05 shows that the model with its variables fits the data better than when those variables are excluded. The second test was a Hosmer and Lemeshow goodness-of-fit. This test tests the statistical significant differences between the observed and the predicted probabilities in the model. One can deduce that the model fits the data when the value of this test is small and p-value is greater than 0.05. Nagelkerke R square was used to check the predictive values of the independent variables, in which 0 means no predictive value and 1 presenting a perfect prediction.

In order to test the hypotheses (formulated in Section 3), logistic regression was used to identify those predictors most strongly associated with adoption. Since the nature of the dependent variable is binary (adoption/non-adoption), binary logistic regression was performed. This was preferred to alternatives, such as structural equation modelling. The main reason is that the main interest in this study is testing theoretically predicted statistical relationships between multiple independent variables and one dependent variable (instead of between variables without a sound theoretical basis). Moreover, by selecting binary logistic regression, the authors adhere to methods commonly used by researchers studying household adoption of green energy innovations (e.g., Arkesteijn and Oerlemans, 2005; Claudy et al., 2010; Jansson et al., 2011, 2017; Walekhwa et. al, 2009).

## *5* Results

To examine factors influencing the adoption of SWH systems, an analysis was carried out on different categories of variables: (1) to test the influence of perceived attributes, attitudinal and innovativeness factors, and other influencers in explaining adoption; and (2) to test the differences on socio-demographic characteristics between adopters and non-adopters.

### *5.1 Socio-demographics*

Among 200 surveyed households 65.50% were adopters of SWHs. The statistical mean of time since adoption was 3.92 years, the SD being 3.378 years. The statistical mean of age and household size was respectively 42.23 years, and 4.30 household members with standard deviations of 12.230 years and 1.311 household members respectively. 53.5% reported a monthly income between 900 and 1,799 US dollars. 42.5% of respondents lived in urban areas, 35.5% in suburban areas, and 22.0% in rural areas. 32.0% of the respondents live in an apartment in a building with more than 5 floors, 44.0% live in an apartment of less than 5 floors, and 24.0% live in a detached house.

### *5.2 Financing incentive and customer satisfaction*

To gain a better insight about adopters and non-adopters and their responses regarding various factors, further details about the adopters and their time of adoption and satisfaction level are provided. Furthermore, the importance of financing incentives from the point of view of both groups are discussed.

Among the surveyed adopters 64.20% stated that they had purchased a SWH in the past 2 to 6 years. A possible (context-related) explanation for this could be that, in 2011, the Lebanese government introduced a subsidy scheme to promote the use of renewable energy (Abou Jaoudeh, 2015). To analyse the significance of this subsidy in households' decision to purchase a SWH, respondents were asked to indicate the importance they give to each item of the subsidy programme. The results show that the importance of subsidized loans had a mean of 3.81. This is slightly less than the mean of the importance given to cash grants (4.01). Mostly non-adopters agreed that financing incentives were important when purchasing SWHs. When testing for differences between adopters and non-adopters on financing incentive construct, no significant differences were found ($p=0.321$). Furthermore, the construct did not show significant correlation with adoption of SWH. Therefore, $H_{10}$ can be rejected. It is important to note that, after the first year of implementing the incentive programme, conditions of applying for these subsidies became more difficult as stricter qualification rules were imposed on the installing companies to ensure high quality installations. In this case, households faced the dilemma of a complex or time-consuming application process for grants. The chances were high that consumers become demotivated to apply, and could have either postponed their adoption decision or sought other financing options.

*5.3 Differences between adopters and non-adopters*

Table 1 shows no statistical differences were found between adopters and non-adopters on most of the socio-demographic data. Two significant statistical differences ($p<0.05$) appeared between the two groups, (1) household size, and (2) income. Results show that adopters had a greater number of persons living in the house (Mean is 4.57), and that there was a higher number of adopters with higher incomes ($p<0.05$). Although education and employment status did not have any statistical significance, they reflected important characteristics of the households. More than half of the householders (adopters 52.70% and non-adopters 65.20%) were employed and earning wages. Moreover, the majority of the householders had at least a university degree.

Table 2 presents the mean, standard deviation (SD), significance values and the construct validities of the five independent measures (relative advantage, observability, personal norms, social norms, and consumer novelty seeking) assessed by Cronbach's alpha values (ranging from 0.629 to .845).

**Table 1**
Differences between adopters and non-adopters.

| Socio demographic variables | Adopters (%) | Non-Adopters (%) | Chi-square | p | T value |
|---|---|---|---|---|---|
| ***Gender*** | | | 0.990 | 0.320 | |
| Male | 56.50 | 63.80 | | | |
| Female | 43.50 | 36.20 | | | |
| ***Employment status*** | | | 7.263 | 0.123 | |
| employed for wage | 52.70 | 65.20 | | | |

| | | | | | |
|---|---|---|---|---|---|
| | self employed | 32.10 | 15.90 | | | |
| | Unemployed | 3.10 | 1.40 | | | |
| | Housemaker | 9.20 | 11.60 | | | |
| | Retired | 3.10 | 5.80 | | | |
| ***Income*** | | | | 17.567 | 0.007 | |
| | <$500 | 0.00 | 3.00 | | | |
| | $500-$899 | 16.90 | 26.90 | | | |
| | $900-$1,199 | 22.30 | 34.30 | | | |
| | $1,200-$1,499 | 16.90 | 16.40 | | | |
| | $1,500-$1,799 | 13.80 | 6.00 | | | |
| | $1,800-$2,099 | 8.50 | 7.50 | | | |
| | >$2,100 | 21.50 | 6.00 (contributing most) | | | |
| ***Education*** | | | | 6.951 | 0.073 | |
| | Primary or less | 5.30 | 16.20 | | | |
| | High School | 21.40 | 19.10 | | | |
| | University | 45.00 | 44.10 | | | |
| | Graduate Studies | 28.20 | 20.60 | | | |
| ***Dwelling characteristics*** | | | | 0.511 | 0.775 | |
| | Apartment in building less than 5 floors | 43.50 | 44.90 | | | |
| | Apartment in building more than 5 floors | 33.60 | 29.00 | | | |
| | Detached house | 22.90 | 26.10 | | | |
| ***Region*** | | | | 2.751 | 0.253 | |
| | Urban | 42.00 | 43.50 | | | |
| | Rural | 19.10 | 27.50 | | | |
| | Suburban | 38.90 | 29.00 | | | |
| ***Dwelling ownership*** | | | | 2.796 | 0.094 | |
| | Owned | 93.90 | 87.00 | | | |
| | Rented | 6.10 | 13.00 | | | |
| ***Age*** | | | | | 0.461 | -0.826 |
| | Mean (SD) | 41.710 (10.466) | 43.220 (15.059) | | | |
| ***Household size*** | | | | | 0.000 | 4.218 |
| | Mean (SD) | 4.570 (1.228) | 3.780 (1.316) | | | |

Regarding product perceived attributes, the results show that adopters perceive SWHs to be more advantageous, compatible with their values, and observable by others. The results show that adopters exhibit significantly higher levels of relative advantage, compatibility with values, and observability. This supports the hypotheses $H_5$ and $H_6$ and $H_8$. Moreover, SWHs were seen by adopters to be less complex to install and use properly; meaning that $H_7$ is supported. Functional risk was not statistically significant ($p>0.05$) different between the two groups, which means $H_9$ are rejected. Thus, functional risk did not have an impact on purchasing decisions. Turning to attitudinal factors, adopters had significantly higher levels of social norms, independent judgment making, and novelty seeking, which supports $H_2$, $H_3$, and $H_4$. Conversely, environmental personal norms did not show any significant difference between adopters and non-adopters, which means that $H_1$ can be rejected.

**Table 2**

Independent constructs and differences between adopters and non-adopters using t-tests.

| **Independent variables** | | **Adopters** | | **Non-adopters** | | ***p*** |
|---|---|---|---|---|---|---|
| | Scale (# of items) | Mean | SD | Mean | SD | |
| ***Perceived attributes*** | | | | | | |
| RA | 0.657 (4) | 4.130 | 0.580 | 3.890 | 0.666 | **0.014*** |
| *COM_value* | | 4.090 | 0.808 | 3.710 | 0.941 | **0.005*** |
| COMX_inst | | 2.310 | 1.068 | 2.670 | 0.934 | **0.021*** |
| OBV | 0.670 (2) | 4.090 | 0.725 | 3.690 | 0.858 | **0.001*** |
| RSK | | 3.090 | 1.048 | 2.970 | 0.874 | 0.389 |
| ***Attitudinal factors*** | | | | | | |
| PN | 0.796 (2) | 3.900 | 0.835 | 3.930 | 0.653 | 0.778 |
| SN | 0.644 (2) | 3.940 | 0.757 | 3.540 | 0.721 | **0.000**** |
| IJM | | 2.080 | 0.982 | 1.700 | 0.880 | **0.008*** |
| CNS | 0.629 (2) | 3.890 | 0.761 | 3.510 | 0.817 | **0.001*** |

values in bold show statistical significance, **$p<0.01$, *$p<0.05$

5.4 *Bivariate correlations*

The analysis bivariate correlations show that some variables were measured with a combination of several items. Each item represented a specific concept (such as saving, investment cost, and convenience which fall under relative advantage). These items are listed in Table 3. The following analysis is on the level of these items. An analysis using Spearman nonparametric correlation was performed (see Table 3) between items of previously tested variables and adoption of SWH systems to provide primary clues for the next analysis step to support or reject hypotheses. Although the determination coefficient (R-square) had relatively low statistical power, the results reveal that the most significant positive impact on adoption was the perceived advantageous convenience of the SWH ($p<0.001$, $r=0.266$), followed by social norms as approved by peers ($r=0.262$), and by people who consider, “I should change to environmental boiler” ($r=0.220$).

Respondents seemed unsure of SWHs’ reliability in the long run (with a mean of 3.05). Although this item was not significant, it does reveal that consumers might not be fully informed about the functionality and nature of the system they are purchasing. Thus, providing information for consumers about the pros and cons of the system can increase trust in the system’s functionality. In fact, this factor might influence adopters’ trust and motivation to buy other renewable energy technologies.

For the next analysis, items were selected based on higher significant values, correlation, and on the higher prediction ability that would be used in the next test (logistic regression goodness of fit).

**Table 3**
Correlation coefficient and means of items.

| **Item** | **R** | **Mean (SD)** |
|---|---|---|
| ***Relative advantage*** | | |
| RA_saving | 0.085 (0.136) | 4.1925 (0.7241) |
| RA_cost | 0.114 (0.108) | 3.640 (0.993) |
| RA_conv | **0.266** (0.000)** | 4.160 (0.853) |
| *COM_value* | **0.212** (0.003)** | 3.960 (0.873) |
| *COMX_inst* | **-0.187** (0.008)** | 2.440 (1.035) |
| ***Observability*** | | |
| OBV_care | **0.222** (0.002)** | 3.860 (1.003) |
| OBV_notice | **0.215** (0.002)** | 4.050 (0.822) |

| | | |
|---|---|---|
| ***RSK*** | 0.073 (0.302) | 3.050 (0.991) |
| ***Personal green norms*** | | |
| PN_obl | -0.084 (0.235) | 3.800 (0.891) |
| PN_help | 0.099 (0.161) | 4.030 (0.808)) |
| **Social influence/social norms** | | |
| SN_repl | **0.220** (0.002)** | 3.700 (0.94) |
| SN_encr | **0.262** (0.000)** | 3.910 (0.842) |
| **IJM** | **0.208** (0.003)** | 1.950 (0.963) |
| **Consumer novelty seeking** | | |
| CNS_inform | **0.148* (0.037)** | 3.790 (0.878) |
| CNS_search | **0.248** (0.000)** | 3.730 (0.992) |

values in bold show statistical significance, $**p<0.01$, $*p<0.05$

*5.5 Backward stepwise logistic regression analysis*

In this analysis, three models were constructed. In the first model, the influence of perceived attributes was tested; in the second model, the influence of attitudinal factors and innovativeness; in the third model, the influence of both factors combined was tested. All models regressed separately on the likelihood of adoption. As a result, the predictive power of each set of variables was analysed. The third model combined perceived attributes to attitudinal factors and innovativeness. The three regression models are presented in Table 4. The aim of this combination of models was to explore the predictive ability of different sets of variables to adoption.

The three models had a relatively sufficient degree of model fit; referring to model Chi-aquare and Hosmer and Lemeshow test. Model 3, which incorporated product perceived attributes with attitudinal factors and innovativeness, had a reasonable fit of Nagelkerke $R^2$ of 0.233, which is higher than that of each partial model.

The accuracy of each model in explaining correctly predicted cases varied between 69.50% of the model containing perceived attributes and attitudinal factors each separately and 72.50% of the model including all variables. This revealed a sound fit of the models.

Each model had a different set of predictive variables. Model 1 tested the influence of product perceived attributes on adoption/non-adoption. Significantly higher levels of convenience in relative advantage of SWHs, and higher levels of environmental observability are found to increase the likelihood of SWHs adoption.

In model 2, attitudinal factors and innovativeness were included in the logistic regression model. The model shows that social norms, independent judgment making *(friend's opinion)*, and novelty seeking *(searching for new)* are highly significant and positively influenced adoption. However, social norms were excluded from the model (referring to model 3) when perceived attributes were combined with attitudinal factors. It seems that consumer decisions to adopt or not to adopt sustainable technologies mainly relies on technology-related attributes and personal characteristics, such as independent judgment making and novelty seeking.

Model 3 combined perceived attributes, attitudinal factors and innovativeness. It achieved a reasonable fit of Nagelkerke $R^2$ of (0.233), which is higher than the value of the models 1 and 2. Four out of ten variables were statistically significant. Higher levels of observability, convenience, novelty seeking, and independent judgment-making all increased the likelihood of adoption. A possible explanation for that could be the innovativeness of consumers in making decisions on the one hand and the advantages one perceives of having convenience and high observability to neighbours on the other hand.

**Table 4**
Logistic regression model with adoption being the dependent variable.

| **Independent variables** | **Model 1** | **Model 2** | **Model 3** |
|---|---|---|---|
| ***Perceived attributes*** | | | |
| RA_conv | **1.708* (0.005)** | | **1.574* (0.026)** |
| COM_value | 1.340 (0.119) | | 1.306 (0.186) |
| COMX_inst | 0.782 (0.125) | | 0.802 (0.193) |
| OBV_care | **1.413* (0.031)** | | **1.473* (0.028)** |
| RSK | 1.224 (0.232) | | 1.215 (0.309) |
| ***Attitudinal Factors & innovativeness*** | | | |
| PN_obl | | 1.070 (0.741) | 1.017 (0.945) |
| SN_repl | | **1.532* (0.023)** | 1.267 (0.261) |
| IJM | | **1.964* (0.001)** | **2.070* (0.001)** |
| CNS_search | | **1.698* (0.003)** | **1.669* (0.006)** |

| | | | |
|---|---|---|---|
| Constant | 0.057 (0.010) | 0.016 (0.000) | 0.003 (0.000) |
| Model -2LL | 239.621 | 228.112 | 220.757 |
| Model chi-square | 18.097 (0.000) | 29.607 (0.000) | 39.961(0.000) |
| Hosmer & Lemeshow test | 7.773 (0.255) | 7.637 (0.470) | 10.268 (0.247) |
| Nagelkerke R square | 0.119 | 0.190 | 0.233 |
| % Correct Overall | 66.00% | 69.50% | 72.50% |
| % Correct Adoption (accuracy rate of predicting) | 89.30% | 87.00% | 89.30% |
| % Correct Non-Adoption | 21.7% | 36.2% | 40.6% |

values in bold show statistical significance, *$p<0.05$

## *6* Discussion and conclusion

The main research question in this study was: To what extent do selected theoretical drivers explain household adoption of SWHs in Lebanon? An integrated research model was used to analyse this using insights from both Rogers' 'Diffusion of Innovation' model and related models from the domain of environmental psychology. A key strength was the use and integration of combined models. The integrated model was found to be more powerful than each of the models alone. It shows the importance of combining theoretical notions from different academic traditions. Another strength of the study was that actual adoption was analysed, instead of mere intention to adopt (Alam et al., 2014; Ozaki, 2011).

An important goal of this study was to analyse which factors best-explained consumers' decision to adopt SWHs. The major contribution of this study is that the research results support most of the hypotheses formulated and support the higher explanatory power of the more comprehensive model in this "high involvement" context. How adopters perceive certain characteristics of innovations was found to correlate significantly with adoption decision-making. This is in line with the diffusion of innovation model (Rogers, 2003).

The results show that, not only does novelty seeking and independent judgment making influence adoption decision-making, but also that strong social norms have significance when people are able to show their social inclusiveness by engaging in activities that are regarded by the social group they belong to, as a social norm. As SWHs are often visible from the street, their adoption cannot only be viewed as an activity of high involvement, but can also be characterised by their high observability. It is important to understand consumers' views to be able to choose the right technique which can increase their knowledge about certain technologies.

Policy incentives were also found to correlate positively with adoption decision-making. The availability of funding programs (Zhai and Williams, 2012) and government support and policies (Luthra et al, 2016) were important in tackling barriers and driving adoption of technologies. The results of this study show that the grant incentive programme implemented in Lebanon to increase the uptake of SWHs did have a positive impact on adoption decision-making. This policy approach can therefore be seen as successful in the Lebanese market, yet it might likely fall far short of what is truly achievable if it continues to neglect insights on the social and the behavioural characteristics of consumers and their energy use.

The results demonstrate that relative advantage, environmental observability, consumer novelty seeking, and independent judgement making were significant in all three models. However, social norms were not significant when model 2 was combined with model 1. This result contradicts the results of Thøgersen's study (2006), since social norms had higher explanatory power when combined with pro-environmental personal norms. As socio-demographic indicators were used as control variables in this analysis, the results reveal that more than half of the surveyed households had higher education (Claudy et al, 2010; Kastner and Stern, 2015) and that most of the householders were employed (earning wages). This says much about the particular (high-end) social environment in which adopters of SWH systems live.

The results also revealed that, among perceived attributes, there were significant differences between adopters and non-adopters in relative advantage, compatibility, complexity, and observability. This would imply that adoption might be related to particular social norms, independent judgment making, and consumer novelty seeking which are prevalent in a (given) social community to which a certain consumer is a member.

The study also revealed that relative advantage, compatibility, and observability increase the likelihood of adoption, whilst complexity was found to lower the likelihood of adoption. When SWHs are viewed as advantageous, more compatible, and less complex, it is more likely that they will be adopted. The results of this study are in line with Arkesteijn and Oerlemans (2005) in that consumers do not adopt an innovation if they do not see the differences in the advantages when compared to conventional purchases.

The results of this analysis also show that adopters have a relatively high novelty seeking motivation. This indicates that there is a certain market segment that exhibits innovative traits. Although advertisements in the mass media are useful to create knowledge and influence earlier adopters, interpersonal sources were found to be more effective in influencing individuals' attitudes. This, in turn, was useful in the process of persuading householders to adopt SWHs.

In summary, this research provides evidence in support of claims for the influence of social norms on adoption decision-making (Jager, 2006; Mahapatra and Gustavsson, 2008; Sidiras and Koukios, 2004). However, they seem to contradict the claim by Thøgersen (2006) that personal norms are more important than social norms when it comes to adoption decision-making.

## 7 Limitations and further research

The study presented in this article had several limitations that should be addressed. For instance, the surveyed respondents who had adopted SWHs could have formed their attitudes after adopting the innovation and not before. To avoid this from happening in future studies, longitudinal studies that analyse specifically how attitudes change before and after adoption could be conducted. Further studies also could test a wider set of factors from the pro-environment behaviour literature, such as consumption attitude. Another limitation was that only one type of renewable energy technology was tested to generalise findings to other higher involvement products, e.g. solar panels and other technologies available in the market. The low statistical power of R square and Nagelkerke R square, which leaves 76.7% of the variance unexplained, concerns another limitation. Finally, this research focused on only one type of renewable energy technology. This made it difficult to generalise the findings of this study to other high involvement products and renewable energy and other technologies more generally available in the market.

Looking to future research opportunities, giving more attention to the consumers' role in the diffusion process will provide more clarity of users' perspectives as a starting point for technical developments. It would also be of great importance to study the awareness of consumers of policy incentives, and to analyse to what extent householders accept, use, and benefit from those policy incentives. This could give clarity from a consumer's perspective on how they would benefit most from programmes and initiatives that primarily target engagement of consumers in sustainable energy markets and contribute to better living conditions.

Another issue concerns socio-cultural and aesthetic aspects. Although they were not examined in detail because of the specific focus of this study, it can be suggested that they should receive more attention in future research. Going forward, it is also important to research community-based approaches in fostering innovation and adoption of renewable energy technology. Achieving remarkable diffusion rates will likely require the integration of various technological, economic, social and cultural aspects, as well as policy and environmental perspectives.

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**Appendix A**

*Survey items, constructs, and Cronbach's alpha coefficients*

Cronbach's alpha of 0.5 and above where selected (Neuendorf, 2003)

***GRNT:*** Financial Incentives (α=0.845)

*GRNT_ln: The importance of interest free loans in the decision to buy SWHs*

*GRNT_sub: The importance of the financial subsidies in the decision to buy SWHs*

***RA:*** Relative Advantage (α=0.657)

*RA_dep: To use a SWH means that I depend less on electricity from private generators*

*RA_saving: To use a solar water heater would reduce my heating bill*

*RA_cost: To purchase a SWH is a low cost investment*

*RA_conv: To use a solar water heater means increase in the hot water comfort at home.*

***COM:*** Compatibility

*COM_value: When I use SWH in my house, I reduce national dependency on foreign energy sources.*

***COMX*:** Complexity

*COMX_inst: Installing a SWH would lead to high annoyance (because of piping).*

***OBV:*** Observability (α=0.670)

*OBV_care: By buying a SWH I show people living nearby that I care about the environment.*

*OBV_notice: By buying a SWH it would be noticed by people close to me.*

***RSK:*** Functional Risk

*SWHs are risky since they often break (stop heating properly)*

***PN:*** Personal Norms (α=0.796)

*PN_obl: I feel a personal obligation to prevent climate change, no matter what other people do*

*PN_help: People like me should do everything they can to reduce their emissions and help prevent climate change*

***SN:*** Social Norms (α=0.644)

*SN_repl: People close to me think I should replace my water heater with an environmentally friendly water heater.*

*SN_encr: The people in your life whose opinion you value most would encourage you to install SWH on your house*

***IJM:*** Total Independent Judgment Making (α=0.537)

*When I am interested in buying a new product/service I usually trust/rely on opinions of friends or close acquaintances who have used this product/service (reverse coding)*

***CNS:*** Consumer Novelty Seeking (α=0.629)

*CNS_inform: I like newspapers and magazines that inform about new brands*

*CNS_search: I continuously look for new products and new brands*