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Sustainable Consumption from the Consumer's Perspective: Antecedents of Solar Innovation Adoption

Kawaljeet Kaur Kapoor
Aston Business School
Aston University, UK
E-mail: kawalkap@gmail.com

Yogesh K. Dwivedi
Emerging Markets Research Centre (EMaRC)
School of Management, Swansea University
Swansea, SA1 8EN, Wales, UK
Email: y.k.dwivedi@swansea.ac.uk

Abstract

Rising focus on solar power and better world environment have set ambitious plans in motion on the amount of solar power generation, worldwide, for the coming years. In the interest of socially responsible use of energy, both developed and developing countries are exploring their potential of going green. However, low solar adoption rates are a cause of pressing concern for some of these countries. This study investigates consumer intentions to adopt solar innovations, with particular empirical interest in the adoption of solar equipment by Indian households. We use a cross-sectional field survey approach to gather relevant data from four most populous cities in India. Structural equation modelling and logistic regression are employed to deduce results by analyzing data from 320 respondents. Building on characteristics from diffusion of innovation theory, this study finds that relative advantage and compatibility strongly influence consumer intentions, and such behavioral intentions have a positive and significant effect on the adoption of solar equipment.

Keywords Adoption, Behavioral Intention, Diffusion of Innovations, Green, Innovation, Solar

1. Introduction

Adverse effects of industrialization are becoming obvious in its negative impact on the environment, given the associated unsustainable production and consumption arrangements (Tseng et al., 2018). The world is battling fast depletion of fossil fuels while having to cater for growing energy demands. Excessive exploitation of natural resources leading to environmental degradation has resulted in increased environmental awareness (Alhaj et al., 2016) and promotion of sustainable consumption (Kitikorn et al., 2016).

Many countries are focusing on protecting the environment by promoting sustainable development (Song et al., 2015a). In the interest of tapping usable energy from lasting sources, and ensuring a better world environment, countries are turning towards renewable forms of energy, such as solar (Gençer and Agrawal, 2018; Islam, 2014; Klepacka et al., 2018; Schmidt-Cost et al., 2019) and other green technologies (Li et al., 2018; Winslow et al., 2018; Xia et al., 2019). Countries are being encouraged to reduce their overall carbon footprint, directed at global welfare. Governments are offering subsidies at residential, organizational, and industrial levels to promote the adoption of different solar innovations (Olson, 2014). Bauner and Crago (2013) claim that despite such generous monetary incentives, the adoption rates of such solar innovations have remained low.

We evaluate the factors affecting the adoption and use of solar innovations, particularly, in the Indian context. The Indian government has taken several initiatives to make the country the cheapest producer of solar power, with a total installed solar capacity of 30 GW; this is 30% of their 2022 target of achieving 38% contribution to the renewable energy mix with 100 gigawatts of solar power (Karan, 2019). By the end of 2015, around one million solar lanterns were sold, 118,700 solar lighting systems were installed, and nearly 1.4 million solar cookers were given to households in India (Annual report from Ministry of new and renewable energy, 2015-16). Despite such tremendous efforts, the voluntary adoption of solar-related innovations by Indian households remains low, making it an interesting topic of study.

Researchers over the last three decades have consistently found that one-third of the new products result in failure (Bedenk and Mieg, 2018; Cooper and Kleinschmidt, 1987; Suwannaporn and Speece, 2003). This makes understanding the reasons for failure of an innovative product a critical topic of interest, which has direct consequences on the overall acceptance of an innovation. Modern day research is keenly investigating the acceptance and diffusion of new age innovations (Dwivedi et al., 2013a). A universally accepted idea is that greater user satisfaction related to an innovation propagates faster adoption of that innovation (Mishra and Shekhar, 2013). It thus becomes important for marketers of an innovation, in this case, solar innovations, to identify and target those specific innovation attributes that motivate consumers to use an innovative product/service (Lockett and Littler, 1997).

This paper, therefore, proposes and validates the conceptual model for evaluating the adoption of green innovations in the Indian context. To begin with, the existing literature on models of innovation adoption are reviewed to shortlist innovation attributes most appropriate for examining the adoption of green innovations. A conceptual model accompanied with hypotheses is proposed, and the methodology adopted for gathering quantitative data is explained. The data is analyzed using structural equation modelling (Amos IBM SPSS), the results from which are discussed and explained. Towards the end, we present overall implications, and identify the limitations of this study to suggest future directions for further work on this topic.

2. Literature Review

Evaluating the diffusion of environment-friendly innovations has recently gained increased attention in academia. The solar industry is one of the most promising industries with governments, policy makers, researchers, and industry pioneers investing particular interest in bringing global good (Kim et al., 2014). Agnew et al. (2018) study the causal loop modelling of residential solar to deliver insights on residential battery deployment. Elmustapha et al (2018) use some of Rogers' innovation attributes to evaluate solar water heater adoption in Lebanon.

Particularly in the Indian context, whilst Sasikumar and Jayasubramaniam (2013) studied the power generation through solar systems, Purohit and Michaelowa (2008) chose to explore how much potential the solar heating systems held in India. Rehman et al (2010) focused on energy transition within the country, and Chaurey and Kandpal (2009) concentrated on the country's potential for carbon abatement. Purohit and Purohit (2007) explored the prospects for solar cookers. There are a few other studies, but none offers any empirical insights on the green innovation adoption in India. Therefore, the findings disclosed in this paper will be the first insights revealing the influences of innovation characteristics on the acceptance of solar equipment within Indian households.

Implementers and managers hope households will become a significant buyer base for solar innovations, and interestingly, the most widely accepted solar innovation is the solar water heater (Islam, 2014). High initial costs, low consumer awareness, climate and land scarcity related challenges, and lack of trained professionals within the solar industry have been broadly identified as some of the barriers to consumer acceptance of solar innovations (Bauner and Crago, 2013). This paper is rooted in understanding the residential/household level challenges/factors preventing large-scale adoption of such green innovations in the Indian context.

India is a fast growing economy, facing massive energy demands across the manufacturing and domestic fronts. The country suffers from power scarcity, and the energy sources, such as coal and usable gases, are fast diminishing. India is one of the top three emitters of carbon dioxide all over the world (Sinha and Shahbaz, 2018). All of these factors, including the future likelihood of carbon constraints (Galbreath, 2011; Sun et al., 2018), are putting the acceptance of solar energy equipped systems at the forefront. India's economic growth, the urbanization that follows, and the perceptible rise in its per capita consumption, are expected to substantially increase the country's overall electricity requirements.

Solar power is generated via photovoltaic cells to convert radiations from the sun into electrical energy. Geographically, India is a tropical country with most of it situated near the equator, characterized with ideal conditions for generating solar power. The country enjoys almost 300 sunshine days a year, which means almost 5000 trillion kilowatt-hour of power generation. Solar power is environment-friendly with a virtually inexhaustible supply, having a vast global spread, making it the most preferred energy source in these critical times of global warming (EAI, 2014; Kabir et al., 2018).

The use of *household solar equipment* is an innovative initiative, where people are encouraged to adopt green innovations. A product/service based on a new idea, offering its target consumers newer and better ways of doing things by dealing with present issues, is regarded an innovation (Damiano, 2011; Rogers, 2003). For instance, India's recent emphasis on the use of solar-equipped systems for lighting, heating, and cooking purposes within households qualifies for an innovation. For achieving higher solar adoption, it is key to learn about the different attributes that significantly influence user intentions towards their use, directly affecting the adoption of solar equipment in their households.

Home lighting systems, water-heating systems, and solar cooking systems are some of the easily available household solar equipment in India (SolarPanels, 2014). The lighting systems require simple installation, without any wiring issues and so on. These generally are garden lights, torches or lanterns, and security lights. These are exposed to direct sunlight, available in the well-lit areas of the house, such as roof, fence, patio etc. Their initial costs are competitive, but there are zero maintenance costs, making them economically feasible over a considerable period of use-time (SolarLighting, 2014). Solar panels are also used for heating water, to work as an alternative for electric water heaters. Solar water heaters reduce a monthly electricity bill by almost 50 per cent. They also claim to heat the water faster making it almost instantly available for use (SolarHeating, 2014). The cooking systems arrive in different forms as cookers, kettles, bowls, and grills. They use reflective mirrors to converge sunlight for cooking purposes (Solar-Cooking, 2014). Since there is no fuel or gas burning, these systems have zero costs associated with operation, with no deforestation or fire hazard, making them entirely ecofriendly (SolarLighting, 2014).

3. Research framework

Innovation adoption research is widespread across the areas of education, anthropology, geography, sociology, health, communication, management, marketing, and others (Rogers, 2003). According to Lin and Ho (2011), since the acceptance of green practices imply implementations of newer improved systems, procedures, and techniques to minimize the emission of environment polluting substances, they can be termed as technological innovations. The literature offers various theoretical models highly concentrated in the sociology and psychology theories (Alalwan et al., 2017; Dwivedi et al., 2019;2017; Rana et al. 2017; 2016; Shareef et al., 2017; Venkatesh et al., 2012) to study the acceptance of such technological innovations. These models include – Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), Perceived

Characteristics of Innovating (PCI), Unified Theory of Acceptance and Use of Technology (UTAUT), Diffusion of Innovation (DOI), and others.

All aforementioned models have a tendency to use comparable innovation characteristics. While TPB is an extended version of TRA, the decomposed version of TPB has commonalities with TAM, and TAM is adapted from TRA. *Perceived usefulness* of TAM is very close to *relative advantage* of DOI (Moore and Benbasat, 1991). Similarly, *ease of use* from TAM is an exact opposite of *complexity* from DOI, making TAM close to the attributes of DOI (Wu and Wang, 2005). In summary, all aforementioned models are more or less similar, serving the same purpose of examining innovation adoptions. We therefore carefully study the theoretical frameworks to shortlist a set of innovation attributes best suited to evaluate green innovations to develop a fitting conceptual model.

In his DOI theory, Rogers (2003) assimilates research on innovation adoption over a period of 60 years. He processed the enormous amount of information into five innovation characteristics – (a) relative advantage, (b) compatibility, (c) complexity, (d) trialability, and (e) observability. He proposed that these five attributes were capable of explaining 49% - 87% variance in the adoption rates of different innovations (Rogers, 2003). Literature recognizes these attributes for their extensive usage in innovation adoption research (Chen et al., 2011; Fang et al. 2017; Hall et al., 2008; Haneem et al. 2019; Hughes et al. 2019; Jaakkola and Renko, 2007; Jung et al., 2012; Khemthong and Roberts, 2006; Kapoor et al. 2014ab; 2015ab; Panigrahi et al. 2018; Panopoulos and Sarri, 2013; Roh and Park, 2019;). Of all the above listed adoption models and theories, the most established, highly recognized, and most used innovation theory is Rogers' DOI (Tornatzky and Klein, 1982; Legare et al., 2008; Kapoor et al., 2013). As Dillon and Morris (1996) suggest, the DOI theory is also recognized as the primary theoretical perspective on technological innovation adoption (both at the individual and organizational levels), extending a conceptual framework for understanding innovation adoption and diffusion, globally. This study, thus, borrows the attributes from Rogers' DOI theory (2003) to undertake the proposed empirical investigation. The five attributes were carefully looked into from the solar innovation perspective, and specific revelations on *trialability* emerged.

Trialability intends using the innovation for a limited period before having to make the actual adoption decision. The extant literature is filled with studies that claim trialability is not an important innovation attribute, and that there are other attributes far more important for making an innovation adoption decision (Al-Jabri and Sohail, 2012; Iriana et al., 2013; Slyke et al., 2002; Zhu and He, 2002). Jaakkola and Renko (2007) also point out that the current literature contains very little empirical evidences for trialability. The contemporary innovation studies thus tend to skip evaluating this attribute in their research (see Lin, 2011; Papies and Clement, 2008; Wang et al., 2010; Zhang et al., 2012). Arts et al (2011) suggest that trialability does not offer any direct benefits, but may help users evaluate an innovation's advantages. Furthermore, Karahanna et al (1999) suggest that the concept of trialability fades out as the innovation comes to be in use. Rogers (2003) himself supports the idea that trialability will appear more attractive to the early adopters in comparison to the late adopters.

The idea of using solar-equipped systems is not new to Indian consumers. Also, the household solar equipment, as a matter of fact, are not trialable (Faiers and Neame, 2006), which is why papers on green innovations generally exclude trialability from their studies. Tapaninen et al (2009a) elaborate that these green systems become non-trialable owing to their high long-term investments and intricate nature. Claudy et al (2011) reemphasize that such household solar equipment is impossible to be tried beforehand. Therefore, for this study, it was deemed appropriate to exclude trialability, leaving the following four attributes to be evaluated – (a) relative advantage, (b) compatibility, (c) complexity, and (d) observability.

3.1. Hypotheses development

Uncertainty in the consequences of using a technological innovation often hinders the adoption process. This is generally relieved by developing an understanding of – what the innovation does, what benefits and limitations it entails, and how it works. This study measures the aforementioned questions using Rogers' innovation attributes (Rogers, 2003). We develop and test several hypotheses, and analyze customers' behavioral intentions to measure the adoption of solar equipment in Indian households.

Relative advantage

Rogers (2003) describes relative advantage to be the extent to which the introduced innovation manifests itself as more advantageous in comparison to the existing product/service/system that it is superseding. Solar energy equipped systems are cost effective over a long term, whilst helping minimize electricity-related costs. Overall, they serve a bigger purpose of contributing towards environmental preservation by helping retain a greener environment, and at the same time, save the resources fast reaching their extinction.

Studies on green innovations have recorded the behavior of this attribute: Chou et al (2012) investigated the acceptance of green practice; Faiers et al (2007) explored the acceptance of household solar systems; Tapaninen et al (2009b) studied the acceptance of household renewable energy systems; and Vollink et al (2002) investigated the adoption of electronic indicators for household energy. All of these studies recorded a significant impact of relative advantage on consumer intention. Thus, we propose the following hypothesis:

H1: *Relative advantage will significantly influence consumers' behavioral intentions towards the use of green innovations.*

Compatibility

Rogers (2003) considers compatibility as the extent to which an innovation establishes itself to be consistent with prior experiences, current values, and forthcoming needs of the potential consumers of that innovation (Parthasarathy et al., 2019). Innovations fitting with consumers' extant lifestyles, or upgrading and meeting their future needs, seem more attractive to them. With heating and electricity, consumers tend to be more apprehensive, thinking they would have to make significant changes every day by adopting a new micro-generation technology, such as the household solar equipment (Claudy et al., 2011). Many studies on green innovations have recorded the behavior of this characteristic: Ozaki (2011) studied the adoption of green electricity; Vollink et al (2002) studied the acceptance of energy conservation interventions; Labay and Kinnear (1981) studied the acceptance of solar eqiupped systems; and Faiers et al (2007) and Claudy et al (2011) studied the acceptance of microgeneration-related technologies. All of these studies reported a significant influence of compatibility on consumer intention.

Interestingly, Muller and Rode (2013) in their study on the acceptance of photovoltaic systems (based on solar energy) suggested that these systems tend to be compatible with extant norms also tends to show how simple they are to use. This relationship between compatibility and complexity has received great interest in the existing research across different innovations (Agarwal and Karahanna, 1998; Shin, 2010, Wu and Wang, 2005). However, studies on solar innovations have not studied this relationship. This study, therefore, proposes to evaluate the impact of compatibility on the complexity of using solar innovations. This innovation attribute was thus hypothesized as:

H2: *Compatibility will significantly influence consumers' behavioral intentions towards the use of green innovations.*

H3: *Compatibility will significantly influence the complexity involved in using green innovations.*

Complexity

Rogers (2003) considers complexity as the extent to which the introduced innovation manifests itself to be comparatively difficult to use. Consumer knowhow of an innovation often dictates how they perceive the effort involved with the use of an innovation; the less complex it is, the more attractive its acceptance becomes (Kapoor et al., 2014ab). A study on household green power adoption reported that – easy to use green power equipped systems have a higher probability of being adopted by potential consumers (Arkesteijn and Oerlemans, 2005). Like for relative advantage and compatibility, studies on green innovations also showed that complexity has a significant impact on behavioral intentions (Vollink et al., 2002; Faiers et al., 2007; Chou et al., 2012).

A popular relationship extensively explored in the innovation adoption context is of that of complexity (ease of use) on relative advantage (perceived usefulness) (Ha et al., 2009; Weigner, 2010). Cowan and Daim (2011) hint towards this relationship in their study on energy efficient technologies, but supporting empirical evidences of this much-used relationship in the literature on solar/sustainable innovations is little to none. This study thus proposes to explore the impact of complexity on the relative advantage of using a solar innovation. Therefore, the hypotheses proposed in this regard were:

H4: *Complexity will significantly influence consumers' behavioral intentions towards the use of green innovations.*

H5: *Complexity will have a significant influence on the relative advantage of green innovations.*

Observability

Rogers (2003) considers observability as the extent to which the results of using an innovation are visible to target consumers, resulting in its widespread adoption (Mascia and Mills, 2018). Plenty of studies on green innovations that have examined the effects of this attribute have reported both its significant and non-significant influences on consumer intentions. Instances of its non-significant impact were captured by studies like Tapaninen et al (2009a) on the adoption of renewable energy systems, and Labay and Kinnear (1981) on the acceptance of solar-equipped systems. Similarly, instances of its significant impact were captured by studies, such as Faiers et al (2007) on household solar adoption, the study by Claudy et al (2011) on the acceptance of household microgeneration technologies, and the study on acceptance of green practices by Chou et al (2012).

Another aspect worthy of attention here is of perceived complexity. Sustainable innovations, such as household solar equipment, are relatively bigger investments and consumers prefer careful and thorough evaluation of such equipment prior to adoption. The complexity of using a product can be evaluated either by using it, which is possible only post adoption or on a trial basis (Kapoor et al., 2015ab). Given that the nature of solar equipment prevents them from being available for a trial period, the other potential method for consumers to evaluate perceived complexity is through observation. Though there is no evidence of earlier literature studying this relationship, this study proposes to study the effect of observability on complexity. This attribute was thus hypothesized as:

H6: *Observability will significantly influence consumers' behavioral intentions towards the use of green innovations.*

H7: *Observability will significantly influence the complexity involved in using green innovations.*

Behavioral Intention

As Chiu (2003) suggests, behavioral intention is instinct based, which consumers often associate with a specific behavior. Some models of innovation diffusion (TRA and TPB) recognize this characteristic as the preeminent predictor of an innovation's adoption (Ozaki, 2011). Other studies like Islam and Meade (2013) have also acknowledged that intention has a significant influence on innovation adoption. Past studies on solar systems' adoptions and other sustainable technologies have recorded the same significant impact between the two attributes (Michelsen and Madlener, 2012; Warkov and Monnier, 1985). Hence, we hypothesize this attribute as:

H8: *Behavioral intention has a significant influence on the adoption of green innovations.*

The conceptual model in figure 1 shows all eight hypothesized relationships proposed in this section.

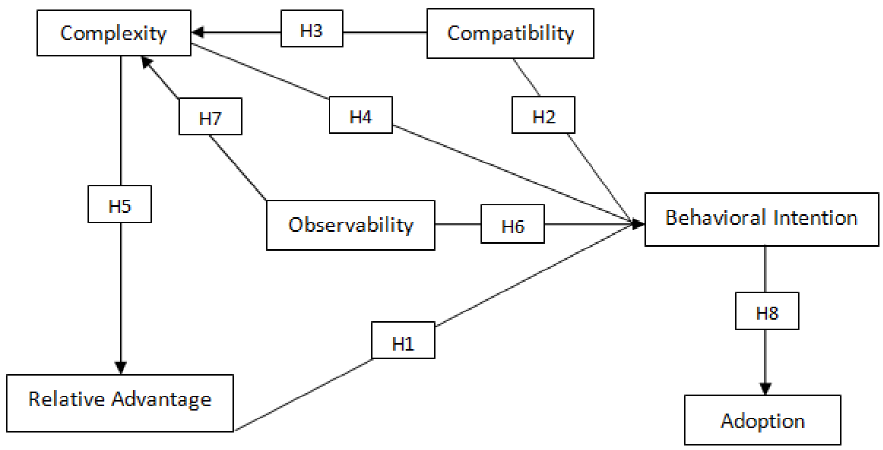

Figure 1. Conceptual model (Adapted from Rogers (2003)**; Sources:** Karahanna et al (1991); Moore and Benbasat (1991); Teo and Pok (2003); Meuter et al. (2005); Richardson (2009))

4. Methodology and survey data

This study collected the required empirical data from the active adopters, prospective consumers, and the present non-adopters of household solar equipment to deduce valid conclusions in the Indian context. Given that the data from all respondents was gathered at approximately one/same point in time (Spector, 2004), this study used the cross-sectional field survey for the intended task (Cohen et al., 2000). The nature of this innovation makes all Indian citizens valid respondents for this study, but following ethical guidelines, the targeted population were citizens over 18 years of age. In sampling from this enormous population size, and keeping time and cost considerations in check, convenience sampling (non-probability sampling) and the survey method were considered appropriate.

With the aim of analyzing data representative of all of India, and bearing the resource availability in mind, one city from each of the southern (S), northern (N), western (W), and eastern (E) parts of the country were targeted. The data from the latest available census (Census, 2011) were extracted, and it was found that Delhi (N), Bangalore (S), Kolkata (E), and Mumbai (W) were the most populous cities in these four parts of India (CensusIndia, 2011). These four cities were thus labelled as the four data collection points for this study. Moving on, it is suggested that a number of 300 and above is a respectable sample size, resulting in valid statistical estimates and reliable results (Comrey and Lee, 1992; Stevens, 1996). It was, therefore, considered appropriate to aim for a minimum of 75 responses from each of aforementioned cities to ensure a sample size of 300.

The survey questionnaire comprised of statements with options available to be marked on a Likert scale. As Bhattacherjee (2012) suggests these Likert items allow fine-tuned responses, and have allowance for neutral responses. A 7-point Likert scale was adopted for this study. There were 20 Likert items altogether to be marked on – (7) Extremely Agree (6) Quite Agree (5) Slightly Agree (4) Neutral (3) Slightly Disagree (2) Quite Disagree (1) Extremely Disagree. The four innovation attributes and behavioral intentions had four items each to their account (five innovation attributes * four items = 20 items). Items for every attribute were derived from the existing literature, which alongside the sources of their items have been tabulated in table 1.

Overall, the questionnaire comprised of 27 questions. Two of these questions were dichotomous by nature that gathered information on respondents' gender and the adoption status of the innovation being examined. There was one nominal question that enquired about the type of solar equipment in use, that is, if it was the solar heating, lighting, or cooking, or any other household solar system. There were four ordinal questions aimed at recording the respondents' age, educational background, duration of use, and frequency of its use. The remaining 20 questions, as mentioned earlier, were Likert type items representing the four innovation attributes and behavioral intention.

Before circulating the questionnaires to the full respondent population, it was both pretested and pilot tested. Pretesting involved ten test respondents, who were - academics, researchers, and consumers (from India). The respondents were asked to complete the questionnaires with a keen eye for errors in questions and the questionnaire design, difficulty in understandability of the items, and so on. One of the suggestions made at the end of pretesting was associated with the following issue – initially, a 5-point Likert scale (Dwivedi et al. 2013b) was employed. However, during pretesting, academics proposed a 7-point scale as they prevent respondents from being neutral in their response (Bhattacherjee, 2012), and they are more reliable. We then changed from a 5-point to a 7-point Likert scale, that is,

Previously, *1 (Extremely Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), 5 (Extremely Agree)*

After pretesting, *1 (Extremely Disagree), 2 (Quite Disagree), 3 (Slightly Disagree), 4 (Neutral), 5 (Slightly Agree), 6 (Quite Agree), 7 (Extremely Agree)*

We had 30 respondents for the pilot test, and the consumers were from different gender, age and education groups to test the understandability of the questionnaire at all levels by all consumer types. All suggestions made during both the tests were all adequately addressed and suitable changes were incorporated, wherever necessary, to improve the respondent-understandability of the questionnaires. For example, some respondents, after the pilot test, commented on some questions appearing to be repetitive, in that, they were only worded differently. Given different items were being used to measure a single attribute, some questions might have appeared similar to the respondents. In response to the reported issue, in the questionnaires sent to the sampling frame, a general note was added at the start of the questionnaire informing them that some questions may appear similar, but are intended to be measured differently, and hence they are requested to respond to every question appearing on the questionnaire. These questionnaires were both self and group administered based on respondent availability. These were made available both as hard copies and as online questionnaires.

This study received the required approval from the concerned ethics committee, and the survey was pursued in line with ethical guidelines identified in the 1964 Declaration of Helsinki. All survey questionnaires clearly read that the participation was voluntary. In total, 345 responses were received, 25 of which were either partially filled or empty, and hence discarded. The remaining 320 fully valid questionnaires were used for further analyses.

Table 1. Mapping characteristics and their items

Characteristics	Items	Sources
Relative Advantage	RA1: Solar equipment makes electricity easily and readily available. RA2: The disadvantages of using solar equipment far outweigh their advantages. RA3: Overall, solar equipment is advantageous in meeting my electricity needs. RA4: Using solar equipment leads to effective energy usage.	Moore and Benbasat (1991)
Compatibility	CT1: The solar equipment is compatible with	Moore and Benbasat (1991)

	my requirements of that electricity-type. CT2: The solar equipment fits well in successfully providing the amount of that electricity-type I need. CT3: The geographic and environmental conditions at my home location are suitable for/ compatible with my choice of solar equipment. CT4: Using solar equipment fits my lifestyle.	
Complexity	CP1: Setting up of solar equipment is challenging. CP2: Understanding to use solar equipment is easy. CP3: Easy to use solar equipment is important for me. CP4: I am adequately skilled to use solar equipment.	Moore and Benbasat (1991)
Observability	OB1: I have observed how others use their solar equipment. OB2: In my society one sees solar equipment in many houses. OB3: I have seen solar equipment in use outside my society. OB4: It is easy to observe others, who use solar equipment in my society.	Meuter et al. (2005); Richardson (2009)
Behavioral Intention	BI1: I will continue using the solar equipment. BI2: My willingness to remain using solar equipment is high. BI3: I want to carry on using solar equipment. BI4: The possibility of me continuing using solar equipment is high.	Karahanna et al (1991); Shih and Fang (2004); Teo and Pok (2003)

5. Findings

This section presents findings across exclusive sections of demographics, descriptive statistics, structural equation modeling, and logistic regression.

5.1. Demographics

Most participants (62.8%) were of 18-34 years of age. The male respondents (54.4%) were considerably higher than the female respondents, with most respondents turning out to be graduates (47.6%) by their educational qualifications. Most people were non-adopters (79.4%) of this green innovation. Of the 20.6% adopters, most preferred using solar heating (9.7%) and lighting (8.4%) systems. While majority adopters (8.1%) reported using such equipment for less than a year, most (10%) of them said they used it many times in a day.

5.2. Descriptive Statistics

While behavioral intention scored most highly on the descriptive scale, observability scored lowly (table 2). All characteristics were rated above 4.50, close to 5, implying respondent agreement.

Table 2. Descriptive test

Innovation-Attributes	Items	N	Average Mean	Average Std. Deviation
Behavioral Intention	4	320	5.20	1.422
Relative Advantage	4	320	4.73	1.107
Complexity	4	320	4.68	0.995
Compatibility	4	320	4.66	1.171
Observability	4	320	4.50	1.289

Behavioral intention showed excellent reliability and the remaining four attributes showed high reliabilities (table 3). These good Cronbach alpha values are representative of the idea that the items building all four innovation attributes are internally consistent to a good degree, in effect, rendering the instrument of this study reliable and fit. The items within parentheses in the improvised α column represent items that were deleted to improve the alpha value for those attributes.

Table 3. Test for Reliability

Constructs	Sample	Items	Cronbach's α	Items	Improvised α	Reliability
Relative Advantage	320	4	0.682	3	0.770 (RA2)	High
Compatibility	320	4	0.810	4	0.810	High
Complexity	320	4	0.588	3	0.733 (CP1)	High
Observability	320	4	0.746	4	0.746	High
Behavioral Intention	320	4	0.923	4	0.923	Excellent

5.3. Structural Equation Modeling

This measurement model resulted in a recursive over-identified model. It has a significant chi-square of 159.818 (p=0.000, df=65). It is suitable, and the fit indices will be examined to assess its overall fit.

The normed chi-square stayed at 2.459 (< 3); this statistic is thus acceptable (Kline, 2005). The RMSEA also remained within the recommended value at 0.068 (< 0.07) (Steiger, 2007; Tabachnick and Fidell, 2007). The GFI and AGFI values are above 0.9 (0.931) and 0.8 (0.889), respectively (Gefen et al., 2000). For the incremental fit indices, CFI is at par with the desired 0.95 (and above) level at 0.959 (Gefen et al., 2000); the NFI value is also acceptable at 0.934 (>0.9) (Gefen et al., 2000). In summary, the measurement model for household solar is of a good fit, overall.

Under assessment next are the convergent and discriminant validities. In this case, the AGFI and GFI values should desirably be over 0.80 and 0.90, respectively, which as discussed in the previous section are satisfactorily above the recommended values. The NFI is recommended to be over 0.90, which at 0.934 meets the set criterion. The chi-square value should be statistically insignificant (Hair et al., 1998; Gefen et al., 2000). However, an exception is made for large sample sizes. The sample size for this study is large at 320, and given that the other statistics show good fit values, a significant chi-square in this case is acceptable (Hooper et al., 2008). The item loadings are all above 0.5, with most of them over 0.7. In addition, the t-values are all two-tailed at 0.001, and hence significant.

The Composite Reliability (CR) and Average Variance Estimates (AVE) values for all latent variables are also calculated (table 4). All CR values, except for complexity, are well above 0.7, as required (Fornell and Larcker, 1981; Hair et al., 2010). The CR value for complexity was close to 0.7 (0.671), and considering all other latent variables had good CR values, one exception was considered acceptable for this model.

Table 4. CR and AVE values

Latent Variables	CR Values	BI	CP	CT	RA	VS
Behavioral Intention (BI)	0.919	**0.741**				
Complexity (CP)	0.671	0.478	**0.505**			

Compatibility (CT)	0.774	0.288	0.710	**0.535**		
Relative Advantage (RA)	0.774	0.271	0.582	0.499	**0.533**	
Observability (VS)	0.723	0.211	0.418	0.319	0.223	**0.581**

Legend: CR–Composite Reliability; **Bold Font Values**–AVE; Values in normal font–Squared Correlations.

The diagonal in the matrix represents AVE values, all of which are satisfactory (above 0.5). The values under this diagonal are squared correlations for the pair of latent variables (table 4). A high majority of the paired correlations are lower than their corresponding AVEs, which positively favors the model. The check for standardized residual covariance confirmed that all residuals, except one (2.682) is below the set limit of 2.56; one exception was made. Therefore, all conditions confirming the *discriminant* and *convergent* validities were satisfied. This confirms construct validity for the measurement model.

We employ Harman's single factor test to conduct a Principal Component Analysis (PCA). The maximum variance reported by a single variable is 44.37%, comfortably within the 50% limit (Harman, 1976; Podsakoff et al., 2003). Therefore, this measurement model is free of the common method bias, which also meant that the model was now fit to be transformed into a structural model.

5.4. Structural Model

The hypothesized relationships for this innovation were introduced amongst the latent variables that were finalized in the measurement model. The structural model (figure 2) with fit statistics is presented in table 5.

Table 5. Statistical estimates for Structural Model

Independent and Dependent Variable Relationships		**Estimates**		
Independent Variables	Dependent Variables	β	C.R.	P
Compatibility	Complexity	0.77	7.881	***
Observability	Complexity	0.20	2.576	0.010
Complexity	Relative Advantage	0.78	8.660	***
Relative Advantage	Behavioral Intention	0.21	2.100	0.036

Compatibility	Behavioral Intention	0.32	2.845	0.004
Observability	Behavioral Intention	0.19	2.295	0.022
R-Square for Behavioral Intention		0.38		
R-Square for Relative Advantage		0.61		
R-Square for Complexity		0.81		
Chi-Square (χ^2)		174.180		
Probability Level		0.000		
Degrees of Freedom		68		
CMIN/df (χ^2/df)		2.561		
Comparative Fit Index, CFI		0.955		
Goodness of Fit, GFI		0.923		
Adjusted Goodness of Fit, AGFI		0.881		
Normed Fit Index, NFI		0.928		
Root Mean Square Error of Approximation, RMSEA		0.070		
Sample Size		320		

Eight hypotheses were proposed for examining the adoption of household solar in the Indian context (table 6). Of these eight, one was dedicated to evaluate the impact of behavioral intention on the actual adoption (examined using logistic regression in the following section). Of the remaining seven hypotheses, six emerged significant; one hypothesis H4 turned out to be non-significant.

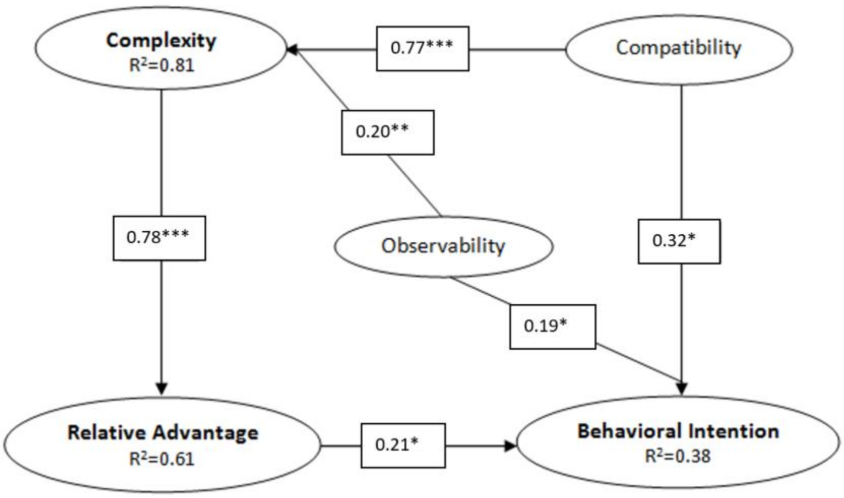

Figure 2. Structural model

**Legend: ***** p-values < 0.001; ** p-values<0.01; * p-values<0.05

The chi-square for this model is significant at 174.180 (p=0.000) with 68 degrees of freedom. Other fit indices were also examined - CFI (0.955>0.95), GFI (0.923>0.9), AGFI

(0.881>0.8), and RMSEA (0.070=0.070) values are all satisfactorily aligned with their recommended values. CMIN/df value at 2.561 is also well below 3. The NFI value, as with the measurement model, here as well, is above 0.90 at 0.928. The same being the case with the significant chi-square reported for this model. Again, owing to the facts that all fit statistics met their recommended values, and that a big sample of 320 was used, the significant chi-square of 174.180 is acceptable for this model. Overall, this structural model displays a good model fit.

This model was built using three endogenous and two exogenous latent variables (Table 5). Of the three endogenous variables, *behavioral intention* explained 38% variance, *relative advantage* explained 61%, and *complexity* explained the highest of the three with 81% variance. Figure 2 showed that *compatibility* (β=0.32, p=0.004), *relative advantage* (β=0.21, p=0.036), and *observability* (β=0.19, p=0.022) significantly influenced behavioral intention; *compatibility* (β=0.77, p<0.001) and *observability* (β=0.20, p=0.010) significantly influenced complexity; and lastly, *complexity* significantly influenced relative advantage (β=0.78, p<0.001).

5.5. Logistic Regression

With the measurement and structural models for this innovation in place, and with seven of the eight hypotheses examined using SEM in the previous section, the eighth hypothesis for the influence of behavioral intention on the acceptance of household solar was tested. Logistic regression was undertaken, whereby behavioral intention was treated as the independent variable, and adoption was treated as the dependent variable. This regression run confirmed that the resultant model significantly predicted the adoption of household solar (Omnibus Chi-square = 5.376; df = 1; p = 0.020). The Cox and Snell and the Nagelkerke R^2 values showed that this model accounted for 1.7% to 2.6% variance. Whilst 100% non-adopters were successfully predicted, 79.4% predictions, overall, were found to be accurate. Behavioral intentions of the consumers towards the use of household solar equipment significantly ($p=0.019$) predicted its adoption. In addition, the derived C.I. values showed that a unit rise in the consumer's intentions was directly related to a unit decline in the odds that the consumer will adopt solar equipment in their households by a factor of 1.228 (95% CI: 1.035 and 1.457).

6. Discussion

The literature, overall, has been reporting low squared multiple correlations (SMC) values (Gefen et al, 2000), and there appears to be no consensus on the acceptable value for this statistic. Where Straub et al (2004) have suggested 0.40 and higher is the acceptable adjusted R^2 value, studies like that of Holmes-Smith et al (2005) and Arambewela and Hall (2009) have vouched for an SMC value of 0.30 and above to be acceptable. As recorded in table 5 above, the SMC values for behavioral intention, relative advantage, and complexity were 0.38, 0.61, and 0.81, respectively. The recommended lower acceptable limit for this statistic in the literature varies between 0.30 and 0.40, which in the existing literature are regarded as substantial shares of variances (Hall et al., 2010; Holmes-Smith et al., 2005; Jang and Noh, 2011; Lu et al., 2005; Puschel et al., 2010; Straub et al., 2004; Tanakinjal et al., 2010; Teo and Pok, 2003). Therefore, the SMC values for the three endogenous latent variables can be concluded to be contributory towards the structural model's acceptable level of predictability.

There were eight hypothesized relationships in total, with seven being supported (H1, H2, H3, H5, H6, H7, and H8) and one unsupported (H4) (Table 6). Many studies confirm that relative advantage is key to consumers developing favorable intentions towards the use of green innovations (Chou et al., 2012; Tapaninen et al., 2009b). In line with the past studies, this study confirms the significant impact of *relative advantage* on *behavioral intentions* (H1

Supported; figure 3) of the consumers – β=0.21 (p=0.036). Solar energy is universally acknowledged as a superior source of energy. In addition to contributing towards a safer and healthier environment (reduced to no carbon footprint), the household solar equipment help reduce overall electricity costs, and given their longer life, come with nearly no maintenance costs. All of these factors make solar powered equipment relatively advantageous than the other existing electricity powered equipment.

Table 6. Summary of hypotheses testing

Hypotheses	Exogenous Variables	Endogenous Variables	Hypotheses Supported
H1	Relative Advantage	Behavioural Intention	Yes
H2	Compatibility	Behavioural Intention	Yes
H3	Compatibility	Complexity	Yes
H4	Complexity	Behavioural Intention	No
H5	Complexity	Relative Advantage	Yes
H6	Observability	Behavioural Intention	Yes
H7	Observability	Complexity	Yes
H8	Behavioural Intention	Adoption	Yes

Compatibility is often acknowledged as a critical predictor of consumer intentions (Putzer and Park, 2010). This study confirms a significant impact of *compatibility* on *behavioral intentions* (H2 Supported) – β=0.32 (p=0.004). Like relative advantage, compatibility is also found across many studies on green innovation (Lazzarotti, 2013; Talke and Snelders, 2013). The technicalities of household solar equipment are apparently compatible with the local electricity needs of the consumers. As Huetink et al (2010) suggest in discussing sustainable mobility, compatibility in this regard will be the degree to which adopting the solar equipment within a consumer household would require consumers to change their behavior in using the new equipment. The answer to this concern is – barely any change, or no change. Since this study mainly focused on solar heating, lighting, and cooking systems, aside from the cooking systems, the heating and lighting systems required only the initial installation of the solar panels in either consumers' front yards/patios or rooftops, i.e. whichever area is best exposed to sunlight. With the cooking systems, only solar cookers had to be placed in sunlight. Apart from this, there were no changes involved in consumers having to use solar powered electricity inside their houses. Solar powered electricity is available for use in a manner similar to that of conventional electricity, hence the evident compatibility of the solar systems.

This study also witnessed significant influence of *compatibility* on *complexity* (H3 Supported; figure 3) – $\beta=0.77$ ($p<0.001$). Any system that justifies itself as compatible with users' extant lifestyles (personal and professional) directly implies that using this new compatible innovation will not demand huge changes in their existing lifestyles, and since they are accustomed and well-tuned with their lifestyles, using these new systems then tend to be perceived as 'not complex' to use. Our study supports this view, and shows that compatibility exerts a significant and positive influence on complexity.

Complexity was also hypothesized to significantly influence consumers' behavioral intentions. However, this study witnessed its non-significant impact (H4 not supported). The use of solar equipment requires installation of solar panels for water heating and lighting, and buying solar cookers for cooking. Professionals (usually the same people who sell the panels) install solar panels, and all consumers have to do is turn on a switch for hot water and lights, and to cook, they only have to put the cooker in direct sunlight. All three instances show that the factor of complexity in these cases is irrelevant. There is no complexity involved in turning on a switch, or putting the equipment in the sun, indicating the use of solar equipment involving no degree of complexity. Using solar equipment at home does not require an expert cognitive effort; this could be why the respondents rejected complexity as an influencer of their intentions towards the use of this innovation.

Such non-significance of complexity on behavioral intention is not new to research. Although unconventional, past studies have encountered such behavior of this attribute, to which while some succeeded in providing satisfactory explanations, others just dismissed it to be different from the expected behavior (Ajzen 1988, Ramayah et al., 2002; Shareef et al., 2009, and others). Bauer et al (2005) illustrated how existing knowledge of users on the use of a technological innovation determines their ability to understand and use that innovation, in turn determining how they perceive complexity of using an innovation. For this study, consumers already had extensive knowledge on how to operate the household solar equipment to reap electricity (which is not any different from using conventional electricity), which potentially might have eliminated user perceptions of complexity in this case.

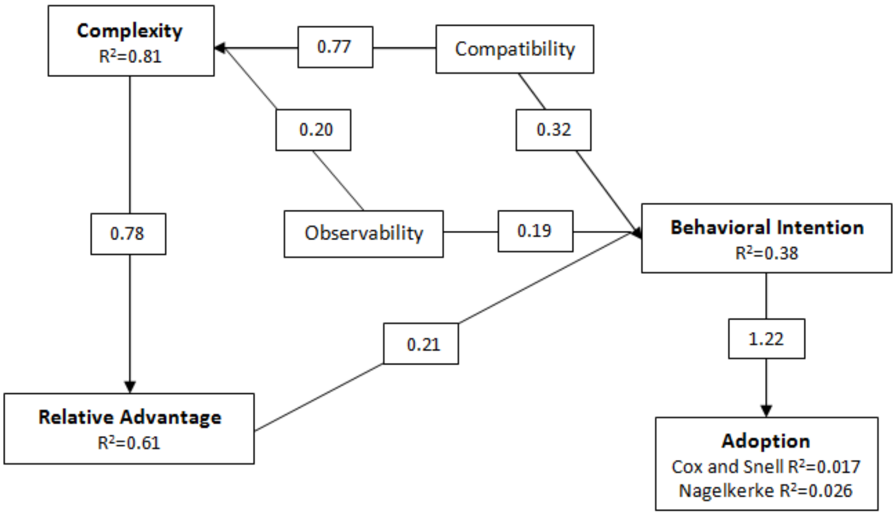

Figure 3. Validated model

The effect of complexity on relative advantage emerged as a significant relationship (H5 supported). Given that once installed (in case of solar electricity and heating, where solar panels are installed in areas directly exposed to the sun), or once bought (in case of solar cookers, solar torches, solar lanterns, or other solar light emitting devices), there is no question of complexity involved. To use any of the above, they only needed exposure to sunlight. Adding to the ease of using such equipment is the already stated fact that they come with almost no maintenance. These characteristics correlate to the idea of being relatively advantageous, justifying the significant impact of complexity on relative advantage. In simple terms, lower the complexity, higher becomes the relative advantage of the solar equipment, which is obvious in the significant relationship between these two attributes in this case.

Observability had a significant effect on behavioral intention (H6 Supported)– $\beta=0.19$ ($p=0.022$). Wustenhagen et al (2007) emphasizes that harnessing solar power occurs in close proximity of consumer homes, such as their rooftop, backyard or patio, which results in increased visibility of this innovation. Panels used for solar heating and lighting are clearly visible, making them a very easily observable equipment, which in this case contributed positively towards consumer intentions. As proposed, observability significantly influenced complexity (H7 Supported) – $\beta=0.20$ ($p=0.010$) and improved the overall performance of the structural model. Given an opportunity to see what the equipment is capable of can potentially help consumers in assessing the ease/complexities associated with its use, probably hence the significance.

Lastly, the empirical results revealed that H8 was supported, i.e. behavioral intentions of consumers towards this innovation significantly and positively influenced their adoption decisions. In alignment with the findings of this study, the literature houses abundant evidence in supporting a similar effect of this attribute across green innovations (Michelsen and Madlener, 2011; Sopha and Klockner, 2011; Warkov and Monnier, 1985).

The Cox and Snell and Nagelkerke R square values were also recorded here (figure 3). The R square values show poor variances. The literature has been reporting fairly higher Cox and Snell and Nagelkerke R square values (Gounaris and Koritos, 2008; Li. 2008; Wang et al., 2010). There are, however, studies with low Cox and Snell and Nagelkerke R square values as well, for instance, Baker and Hudson (2013), Donnelly et al (2013), Harcourt et al (2013), Inglis et al (2011), Weiss et al (2013), and many more. In conclusion, in alignment with the previous studies (Fishbein and Ajzen, 1975; Islam and Meade, 2013; Ozaki, 2011), this study reports behavioral intention as a significant predictor of adoption.

6.1. Theoretical implications

Given that this technology has not been empirically evaluated for its acceptance in the Indian context to date, this study becomes the first of its kind to offer empirical insights into the behavior of Rogers' innovation characteristics in a new context. This study's results thus become foundational to future research related to this innovation. The findings add to the existing knowledge on Rogers' DOI theory from a new perspective of green innovation adoption in India. The conceptual model formulated in this study can be used and modified by future researchers to undertake empirical investigations for validating the influences of the hypothesized paths on the adoption of household solar or other green innovations.

This framework can be applied worldwide per se, in that, although this research applies a conceptualized model in the Indian context, it builds from the existing knowledge of how the adoption of green innovations is spread around the world. Thereby, this model holds profound applicability to be accountable for similar ecofriendly innovations in different countries and societies. The conceptual model reveals the few key characteristics of green innovation adoption. From the academic perspective, this study evaluates the effects of five attributes for both intention and adoption, and in addition, identifies relative advantage and complexity as the dependent variables based on past evidence.

Despite limited evidence in the extant literature on solar innovations, three relationships – (a) complexity on relative advantage (b) compatibility on complexity, and (c) observability on complexity were proposed based on logical reasoning, all of which turned out to be significant, in effect, leading to comprehensive interpretative results, overall. Therefore, the outcomes of this research widen learnings via new behaviors of the involved characteristics, which enhance the current understanding across a theoretical paradigm by adding supplementary insights.

6.2. Practical implications

India has been introducing subsidies and other programs to promote the usage of solar energy in households; one such initiative is the production-based subsidy (Nandi, 2013). According to this policy, the government will pay back consumers for the units of energy they will have saved by using solar power. Many other policies are in the pipeline, which will be released to promote solar power in India. This shows that household solar is of keen interest to the Indian government. Having received important considerations from the Indian government, the first insights from this study offer substantial contributions.

The demographic statistics from the survey can play a considerable role in profiling and segmenting consumers based on their interests (Diamantopoulos et al., 2003). Therefore, from the managerial perspective, these demographic factors can help obtain an overview of existing customer segments and offer insights on the division in the adopter and non-adopter segments to help managers better direct their strategies by tweaking and tailoring them to appear more attractive to the different customer segments.

Given that compatibility and relative advantage of solar equipment had the strongest impacts on consumer intentions, they should particularly be promoted along the lines of the advantages that solar equipment offers, alongside their compatibility with the daily needs of the consumers. More specifically, the other side of marketing should focus more on showing consumers that the acceptance of household solar equipment will need them to bring no major changes in their lifestyles, and give them quality living instead.

6.3. Limitations and future research

Taking time and resource constraints into consideration, this study, although aimed at achieving all India data, restricted its data collection to only four states of the total 28 Indian states. Jaakkola and Renko (2007) suggest that contextual factors may have substantial influences on such innovation adoptions. To evaluate the plausible cultural bearings on the acceptance of household solar, future scholars (in the Indian context) might want to consider a larger number of states within their studies. Testing the moderating effects of education level and gender on consumer intentions may reveal interesting insights on consumer adoption of solar innovations. This study chose to eliminate one innovation attribute, trialability, based on past evidence. Future researchers, however, might still want to consider empirically validating the behavior of this attribute to confirm its expected non-significance in similar innovation adoption studies.

As mentioned during the discussions in the previous section, the Cox and Snell and Nagelkerke R-square values were comparatively lower than the other similar studies. Future studies might thus want to include higher number of latent variables that may help better the variance explanation of the validated model. In addition, this study restricts focus to innovation attributes from Rogers' DOI theory. The literature is rich with evidence of many other innovation attributes being in use that have performed notably in the acceptance of different innovations. Future scholars might want to study the impact of these other innovation attributes (for instance – those identified by Tornatzky and Klein (1981), Moore and Benbasat (1991), and others) to identify if any other factors more significantly influence the acceptance of such innovations.

7. Conclusions

Global warming is one the persistent and most complex problem faced by the human race, with sustainable development being one of the biggest challenges accompanying it (Song et al., 2015b). Environmental concerns have been receiving increased recognition worldwide. As people are becoming more aware and conscious of their own environment and its effects on their daily lives, they are becoming interested in technologies that suit their idea of better and smarter ways of living. Sustainable innovations are being introduced in the consumer markets to serve the purpose of propagating the use of environment-friendly technologies to meet daily needs. The adoption of such sustainable technologies can be propelled by attaining considerable understanding of the factors that make these technologies either attractive or unattractive to target consumers. Lin and Ho (2011) suggest that very few studies on green innovations have evaluated the influences of technological factors (innovation attributes) on green innovation adoptions; they recommend for research in this area to account for such factors. In line with their suggestions, this study empirically evaluates the acceptance of a sustainable technology – household solar equipment.

Relative advantage, observability, and compatibility of household solar equipment were found to have a significant effect on consumers' behavioral intentions towards its adoption. While compatibility and observability significantly influenced the consumer perceptions of the level of complexity involved in using the aforementioned equipment, the same level of complexity significantly affected the relative advantage of the equipment. On the other hand, complexity had no influence on use intentions. Overall, behavioral intentions significantly and positively influenced the adoption of household solar equipment.

The innovative idea of using solar equipment within households for everyday heating, lighting, and cooking purposes is diffusing at a slow pace in the Indian context. This leaves room for a potential possibility that the influences of these innovation attributes will change over time (Rogers, 2003). Therefore, it would be of worth to duplicate this study at another time in the future to capture any probable changes in attribute behaviors, in effect accounting for the time factor in the adoption of green innovations.

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