Taylor & Francis
Taylor & Francis Group

Behaviour & Information Technology

ISSN: 0144-929X (Print) 1362-3001 (Online) Journal homepage: http://www.tandfonline.com/loi/tbit20

Factors affecting adoption of smart meters in the post-Fukushima era in Taiwan: an extended protection motivation theory perspective

Kai-Ying Chen & Chih-Feng Yeh

To cite this article: Kai-Ying Chen & Chih-Feng Yeh (2017): Factors affecting adoption of smart meters in the post-Fukushima era in Taiwan: an extended protection motivation theory perspective, Behaviour & Information Technology, DOI: 10.1080/0144929X.2017.1317363

To link to this article: http://dx.doi.org/10.1080/0144929X.2017.1317363

BEHAVIOUR & INFORMATION TECHNOLOGY, 2017
https://doi.org/10.1080/0144929X.2017.1317363

Taylor & Francis
Taylor & Francis Group

Factors affecting adoption of smart meters in the post-Fukushima era in Taiwan: an extended protection motivation theory perspective

Kai-Ying Chen[a] and Chih-Feng Yeh[b]

[a]Department of Industrial Engineering and Management, National Taipei University of Technology, Taipei, Taiwan, R.O.C.; [b]College of Management, National Taipei University of Technology, Taipei, Taiwan, R.O.C.

ABSTRACT

This study aims to understand factors influencing the intention to adopt smart meters (SM) to save energy in the face of expected increases in electricity costs, stemming from the impact of Taiwan's plans to increase the proportion of renewable energy in the post-Fukushima era demand. As far as we know, compared to previous relevant studies based on constructs of perceived usefulness, perceived ease of use, and attitudes, this study is the first one based on the application of protection motivation theory (PMT), which uses threat appraisal, coping appraisal, Social Influence, Secondary Data Influence constructs, and control variables to explain the correlation and impact of residential communities' intention to adopt SM. With 292 valid questionnaires, this study applies SmartPLS 3 software in model analysis, and finds that the impact of coping appraisal variables is more significant than that of threat appraisal variables, while Secondary Data Influence, Age, and Electricity Cost variables have a significant influence on the intention to adopt SM. The relevant results and practical contributions are discussed.

ARTICLE HISTORY
Received 9 February 2016
Accepted 4 April 2017

KEYWORDS
Smart meter; nuclear energy; Fukushima accident; energy-saving; protection motivation theory

1. Introduction

1.1. Taiwan's nuclear energy perception change and energy pattern shift after the Fukushima accident

On 11 March 2011, an earthquake (Richter scale 9.0) struck Japan and triggered a tsunami, causing major damage, many thousands of casualties in Japan, and a serious accident of radioactive release at the Fukushima nuclear power plant (NPP). The disaster was the largest nuclear disaster since Chernobyl in 1986, calling attention to nuclear safety around the world once again (Butler, Parkhill, and Pidgeon 2011; Hayashi and Hughes 2012; Visschers and Siegrist 2012; Huang et al. 2013). Many studies have reported that the trend of public opposition to nuclear energy has significantly increased (Kessides 2012; Srinivasan and Gopi Rethinaraj 2013; Lee and Wang 2014) and nuclear safety-related moral concerns (e.g. pollution, environment, health, etc.) have also become hot topics (Butler, Parkhill, and Pidgeon 2011). The Fukushima accident also affected the nuclear energy policies of many countries, and many governments have changed their policies on investment in nuclear energy, or suspended many new NPPs under construction (Lee and Wang 2014). For example, the German government shut down the 7 oldest reactors within a few months after the event and announced the intention to close 17 NPPs by 2022. The Swiss government announced that existing NPPs would not be updated, and all NPPs would be closed by 2034. Other countries (e.g. France, Japan, Korea, etc.) re-evaluated the safety of existing NPPs, while some countries (e.g. Taiwan, Chile, Israel, and Venezuela) decided not to enter or re-enter nuclear power-related industries (Butler, Parkhill, and Pidgeon 2011; Joskow and Parsons 2012; Kim, Kim, and Kim 2013). According to a survey by Laes, Meskens, and van der Sluijs (2011) in May 2011, of 18,787 adults in 24 countries, 62% respondents were opposed to nuclear power, and 26% of opponents reported that the Fukushima accident had changed their original views. Some studies indicated that most people do not support nuclear power, and strongly support renewable energy sources (McGowan and Sauter 2005; Pidgeon, Lorenzoni, and Poortinga 2008; Schneider, Froggatt, and Thomas 2012). Wallard, Duffy, and Cornick (2012) argued that the public has a strong preference for renewable energy sources such as solar (97%), wind (93%), and hydroelectric (91%) over nuclear power (38%). After the Fukushima accident, the Taiwanese government has announced its new energy policy: 'Steadily Reduce Nuclear Dependency, Gradually Move Towards a Nuclear-free Homeland, and Create a Low-carbon Green Energy Environment.' As part of this policy, it plans to mothball the No. 1 reactor and to halt the

CONTACT Chih-Feng Yeh t9749001@ntut.org.tw

No. 2 reactor at the Lungmen NPP. Moreover, the current three NPPs in operation (with capacity accounting for 18% of the total installed electrical power generation capacity of Taiwan) will be decommissioned in 2018–2019 (Chinshan NPP), 2021–2023 (Kuosheng NPP), and 2024–2025 (Maanshan NPP).

1.2. Taiwan's new energy policy

The installed capacity of renewable energy was 4314 megawatts (MWs) in 2015 in Taiwan. Taiwan's new energy policy includes the goal of a 'nuclear-power-free homeland' in 2025 and lays out a substantive plan for Taiwan's next stage of power development without nuclear power, including energy sector reforms, energy conservation and carbon emission cuts, the development of green energy, technological innovation, and an increased ratio of clean energy. In the face of possible power demand in the future, the development of renewable energy sources will be accelerated and sources of renewable energy will be expanded in response (Bureau of Energy, Ministry of Economic Affairs, Taiwan 2015a). Table 1 shows that the targeted renewable power generation capacity will be 12.5 gigawatts (GW) by 2030, raising it from the 8.9 GWs in 2012. With the policy of renewable energy resources to replace nuclear power generation, it is expected that electricity prices will rise by 40% if the NPPs are fully decommissioned. As a result, people will have to spend more on electricity.

1.3. Research purpose

Most previous studies concerning green technology have focused on climate change and energy consumption issues, and explored environmental sustainability and energy-saving behaviour (Stern et al. 1999; Watson, Boudreau, and Chen 2010; López-Mosquera and Sánchez 2012). Stewart et al. (2013) showed a statistically significant mean reduction of 15.40 L (27%) in water consumption shortly after the implementation of shower water-usage monitoring by smart metering. Some studies have pointed out that smart grids (SGs) are expected to play an important role both in reducing the impact of environmental and climatic change and in energy security (Hledik 2009; Clastres 2011; Gungor et al. 2011). SGs are electricity networks that can intelligently integrate the behaviour and actions of all users connected to them – generators, consumers, and those that do both – in order to efficiently deliver sustainable, economic, and secure electricity supplies. They include a variety of operational and energy measures including SM, smart appliances, and energy-efficient resources. The SM, an electronic device that records consumption of electric energy and communicates the information back to the utility for monitoring and billing, can help users to improve energy efficiency and reduce their environmental impact (Hledik 2009; Corbett 2013). Taiwan's government has started a master plan for a smart grid from 2011 to 2030 to increase the use of renewable energy as well as the reliability and efficiency in power plants, and this includes advance planning of service to end users. Previous studies on the intention to adopt SM have mainly been based on the technology acceptance model (TAM) (Kranz, Gallenkamp, and Picot 2010), the belief-action-outcome model (Melville 2010), and the theory of planned behaviour (TPB) (Kranz and Picot 2011). Wunderlich (2013) combined the perceived locus of causality (PLOC) and TAM model to develop an integrated SM acceptance model. Pullinger, Lovell, and Webb (2014) drew on theories of social practice to discuss the UK smart metering programme, which has fulfilled its domestic energy demand reduction objectives. However, most of these studies are based on variables including perceived usefulness, perceived ease of use, attitudes, intention, and personal norms, as the acceptance behaviour of

Table 1. Capacity of Taiwan's New Renewable Energy.

Energy	source\Year	2012	2015	2020	2025	2030
Wind	On-shore	621	866	1200	1200	1200
	Off-shore	0	15	600	1800	3000
Hydro Power		2060	2052	2112	2502	2502
Solar PV		201	492	1020	2500	3100
Geothermal		0	4	66	150	200
Biogas		9	29	29	31	31
Waste to Energy		792	848	925	1369	1369
Ocean Energy		0	1	30	200	600
H_2 and Fuel cells		0	7	60	200	500
Total		3683	4314	6042	9952	12,502
Percentage of total installed capacity		7.7%	10.0%	10.6%	14.8%	16.1%

Unit: MWs.
Source: Bureau of Energy, Ministry of Economic Affairs, Taiwan (2015b).

forecasting models, while discussions on the intention to accept SM from the perspectives of threat and coping appraisals are rare. Rogers (1975) proposed that people will initiate threat and coping appraisals in the face of fear communication and constructed the theoretical basis for individual protection motivation theory (PMT). PMT was first applied in promoting health and social psychological behaviours (Floyd, Prentice-Dunn, and Rogers 2000; Milne, Sheeran, and Orbell 2000), and argues that fear can generate 'protection motivation', that is, behavioural intention that may affect whether the person will take protective action (Rippetoe and Rogers 1987). Later, PMT was widely applied in studies of risk communication, actions to protect against natural and technological disasters (Grothmann and Patt 2005), and functional food and supplements (Cox, Koster, and Russell 2004). In recent years, studies which apply PMT have been expanded to the field of information systems, such as home wireless network security (Woon, Tan, and Low 2005), anti-malware software (Lee and Larsen 2009), healthcare technology (Chen and Lee 2008), anti-plagiarism software (Lee 2011), online safety (Boehmer et al. 2015), and nuclear threats and green power acceptance (Hartmann et al. 2013). This study applies PMT to explore the impact of threat appraisal and coping appraisal variables on the intention to adopt SM to reduce energy consumption under the threat of a high electricity prices scenario in Taiwan.

2. Methods

2.1. Literature review

As international energy and climate issues continue to simmer, many countries (e.g. the US, France, Ireland, the Netherlands, Spain, the UK, China, Japan, Taiwan, etc.) have aggressively promoted smart grid construction, and hope to promote optimal configuration and operation of power resources through instant control and demand-side management in order to save energy and reduce carbon emissions (Hledik 2009; Mohsenian-Rad et al. 2010; Clastres 2011; Olmos et al. 2011; Corbett 2013). Advanced Metering Infrastructure is an integrated system of SGs, communications networks, and data management systems that enables two-way communication between utilities (supply side) and customers (demand side) (Hart 2008; Adebanjo 2009; Corbett 2013). In terms of consumption, SGs can provide better control of expenses (Meeus et al. 2010) and opportunities to create a better awareness of energy use among consumers (Stragier et al. 2013). Venables (2007) pointed out that the use of SM allows people to see how much electricity is being consumed by a family, and thus encourages them to reduce energy use. Faruqui, Harris, and Hledik (2010) stated that technical and economic factors can increase SM acceptance behaviour, and potentially save costs through demand-side management. Stragier et al. (2013) argued that when smart meters (SM) are connected in a home area network with home energy management systems, personal energy use data can provide guidance to households on how to become more energy efficient.

PMT is often used to construct the theoretical basis for individual protection action. It was first proposed by Rogers (1975), and was theoretically partially modified in 1983 (Maddux and Rogers 1983). PMT argues that people will initiate threat and coping appraisals in the face of fear communication. 'Threat appraisal' is the assessment of current maladaptive behaviours (the severity and the vulnerability of maladaptive behaviour), which includes the reward of maladaptive behaviour. When the fear generated by threat is greater than the benefit, it can trigger 'coping appraisal'. This stage includes assessment using the good adaptive behaviour of response efficacy, self-efficacy, and response costs. PMT consists of two elements in sequence: threat appraisal and coping appraisal, and argues that the individual motivation (intention) to take protective action will be affected by threat. After an assessment of threat, people will further consider whether they are capable of coping and whether to take protective action. If people cannot cope with the perceived threat, they will not intend to take protective action. Threat appraisal concerns the process of evaluating the components of a fear appeal that are relevant to an individual's perception of how threatened he or she feels (Milne, Sheeran, and Orbell 2000), and includes the following four variables: intrinsic reward, extrinsic rewards, perceived vulnerability, and perceived severity. The coping appraisal evaluates the components of a fear appeal that are relevant to an individual's assessment of the recommended coping response to the appraised threat (Milne, Sheeran, and Orbell 2000), and includes the three following variables: self-efficacy, response efficacy, and response costs.

2.2. Hypotheses

Based on the findings of the PMT meta-analytic of Floyd, Prentice-Dunn, and Rogers (2000) and Milne, Sheeran, and Orbell (2000), this study hypothesises that perceived severity, perceived vulnerability, self-efficacy, and response efficacy factors have positive interrelationships and that the response costs factor has a negative functional relationship to intention to adopt SM. In addition to the basic construct of PMT, this study explores the

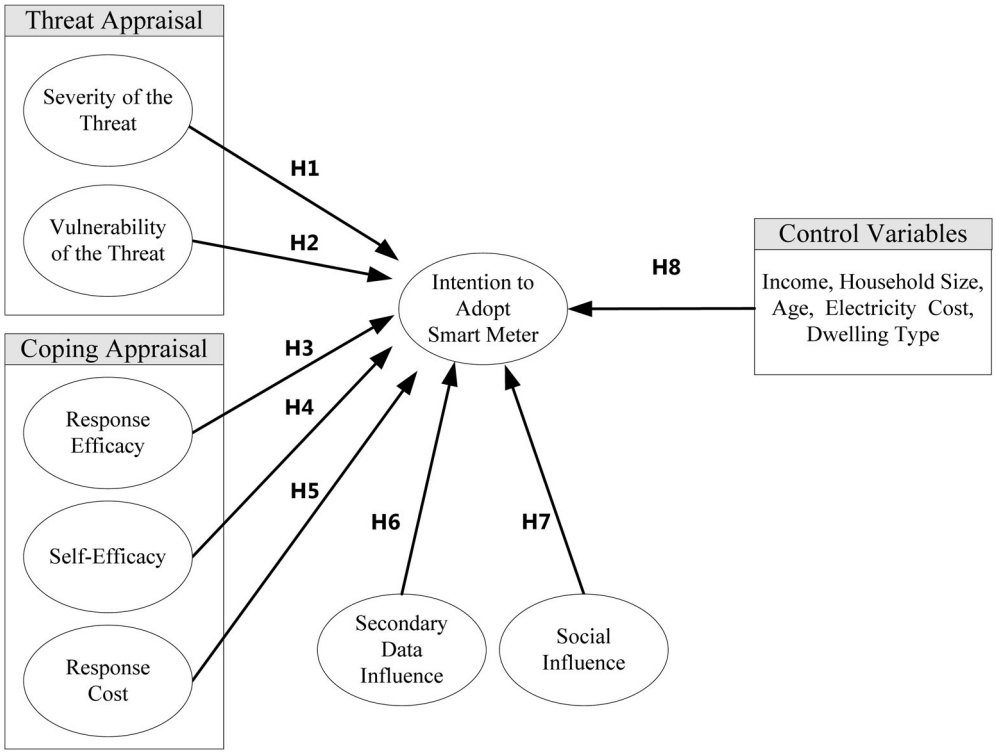

Figure 1. Research model.

impact of Social Influence and Secondary Data Influence on use intention, and explains the relationship with other control variables (see Figure 1).

2.2.1. Severity of the threat

Perceived severity assesses how serious the individual believes the threat would be to his or her own life (Milne, Sheeran, and Orbell 2000), and refers to 'the degree of physical harm, psychological harm, social threats, economic harm, dangers to others rather oneself, and even threats to other species' (Rogers and Prentice-Dunn 1997). In this study, we define the social cost of nuclear power as referring to the sum of external and private costs (Rabl and Rabl 2013), and assume that the capacity of alternative energy sources to replace nuclear power (about 40.118 billion kWh) may cause a considerable increase in total social cost and will be directly reflected in electricity prices increasing in the future in Taiwan. We summarise the costs (external, private, and social) of NPP in Table 2, and define them in Table 2.

Rabl and Rabl (2013) stated that the central total external cost of nuclear power, considering only its use in regions or countries that have a well-established culture of safety and adequate safeguards against proliferation (the EU, the US, Canada, Japan, South Korea, and Taiwan), is about 0.79 £cent/kWh, while the external costs of wind, solar, and hydro are so low that they can be neglected in view of the uncertainties of the much larger cost elements; the central total social cost of existing NPPs is 2.55 £cent/kWh, while the central total social cost of alternative energy sources such as wind and natural gas (based on combined cycle technology for the latter) is 6.93 £cent/kWh.

Hass, Bagley, and Rogers (1975) pointed out that the seriousness of the threat has a significant impact on energy conservation and people will take security measures and behaviours. Faruqui, Harris, and Hledik (2010) indicated that technological and economic

Table 2. Cost Elements of nuclear power.

Cost elements	Central	Low	High
External cost[a] of accidents	0.38	0.08	2.29
External cost of current operation	0.21	0.07	0.63
External cost of waste management	0.20	0.10	0.30
External cost of normal operation	0.41	0.17	0.93
Total external cost of nuclear	0.79	0.25	3.22
Existing nuclear plant, total social cost[b]	2.55	2.01	4.98
Continued operation of nuclear plant, private[c]	1.76	1.76	1.76
Continued operation of nuclear plant, external	0.79	0.25	3.22
Alternative, total social cost	6.93	6.09	9.76
Alternative, private	5.71	5.71	5.71
Alternative, external	1.22	0.38	4.05

Unit: £cent/kWh.
Source: Markandya, Bigano, and Porchia (2010) and Rabl and Rabl (2013).
[a]The external costs associated with damages to human health, the environment, crops, materials, and those related to the consequences of climate change.
[b]Assessed by adding to the private generation costs.
[c]The private costs are estimated for two options: (A) continue operating an existing nuclear plant and (B) replace it by the alternative based on NGCC and wind.

factors can increase SM acceptance behaviour, and can potentially save costs through management of the demand side. Hence, the hypothesis is proposed as follows:

H1: Perceived severity of electricity price rising positively influences individuals' intention to adopt SM.

2.2.2. Vulnerability of the threat

Perceived vulnerability assesses how personally susceptible an individual feels to the threat (Milne, Sheeran, and Orbell 2000), and refers to 'the conditional probability that the threatening event will occur provided that no adaptive behaviour is performed or there is no modification of an existing behavioural disposition' (Rogers and Prentice-Dunn 1997, 115). When perceived vulnerability is higher, it will increase the probability of adopting appropriate behaviour. Previous studies have found that perceived vulnerability has a significant impact on the intention to conduct self-examination of skin cancer or breast cancer patients (Rippetoe and Rogers 1987; McClendon and Prentice-Dunn 2001). Rabl and Rabl (2013) argued that the replacement of NPPs by other alternative energy sources can generate higher social costs. Therefore, this study assumes that a high social cost will lead to a high increase of electricity price in Taiwan. Under the perceived threat of insufficient natural resources, and constrained by limited environment carrying capacity, people may adopt SM to save energy. Hence, the hypothesis is proposed as follows:

H2: Perceived vulnerability to electricity price rising positively influences individuals' intention to adopt SM.

2.2.3. Response efficacy

Response efficacy concerns beliefs about whether the recommended coping response will be effective in reducing a threat to the individual (Milne, Sheeran, and Orbell 2000), or to avoid an unexpected threat (Gochman 1997). When the personally perceived response efficacy is higher, the probability of triggering adaptive behaviour will increase accordingly. Many countries (France, Ireland, New Zealand, Spain, the UK, Italy, and America) have set firm targets for smart grid development (Clastres 2011). SM allow people to see how much electricity is being consumed by a family, and thus encourages them to reduce energy use. Therefore, perceived higher response efficacy and believing that SM can help to decrease energy consumption will result in a higher degree of intention to adopt SM. Hence, the hypothesis is proposed as follows:

H3: Response efficacy positively influences individuals' intention to adopt SM.

2.2.4. Self-efficacy

Self-efficacy concerns an individual's beliefs about whether he or she would be able to make the recommended coping response (Rogers and Prentice-Dunn 1997; Milne, Sheeran, and Orbell 2000). Torkzadeh and Van Dyke (2001) developed an Internet self-efficacy scale of surfing (browsing), encryption and decryption, and system manipulation. Chang and Chou (2011) stated that post-training self-efficacy is an important antecedent factor of post-implementation learning. Lee, Larose, and Rifon (2008) suggested that perceived self-efficacy in using virus protection measures was one of the most important predictors of the intention to adopt virus protection behaviour. According to previous studies, self-efficacy has a significant influence on the intention to take protective behaviour in different behaviour scenarios. When a person believes they are capable of using the SM, and it can improve energy efficiency, the intention to adopt SM will be higher. Hence, the hypothesis is proposed as follows:

H4: Self-efficacy positively influences individuals' intention to adopt SM.

2.2.5. Response cost

Response cost involves beliefs about how costly performing the recommended response will be to the individual (Milne, Sheeran, and Orbell 2000), and extensively refers to any costs of taking adaptive behaviour (including money, time, effort, inconvenience, unhappiness, etc.) (Maddux and Rogers 1983). According to the meta-analysis conducted by Floyd, Prentice-Dunn, and Rogers (2000) and Milne, Sheeran, and Orbell (2000), response cost can reduce the probability of selecting adaptive behaviour. Previous studies also suggest that response cost has a significant negative impact on adaptive behaviour. In Taiwan, households applying for the installation of an SM assume some of the costs to install the equipment. Moreover, they may have to ask for leave from their own workplace to be present at home during the installation. In addition, efficiency after the installation of SM may not be apparent within a short period of time, which may give rise to doubts and a feeling of waste of efforts. SM transmits the power consumption data of consumers via the Internet; therefore, it may result in the potential of illegal leaking of personal data (Featherman and Pavlou 2003). Khurana et al. (2010) have argued that the use of SM has many security issues and risk

concerns to be considered. Therefore, the higher people perceive such costs to be, the less likely they are to adopt the SM. Hence, the hypothesis is proposed as follows:

H5: Response cost negatively influences individuals' intention to adopt SM.

2.2.6. Secondary Data Influence

Secondary Data Influence (including newspapers, TV media, magazines, governmental publications, etc.) have been regarded as an important factor in studies on the adoption and diffusion process (Rogers 2010). Brown and Venkatesh (2005) studied PC purchases and found that mass media generally affect the process of adoption in the early stage of creativity and decision-making procedures. The secondary data have a more significant impact on people early in the decision-making process (e.g. those who have not yet decided to buy a PC). Moreover, McQuail (1979) pointed out that individuals can learn information from mass media regarding social environments and the knowledge they need. Winkler von Mohrenfels and Klapper (2012) indicated that information on green products, such as that learnt from mobile phones, can deepen consumer perceptions of the basic brand and increase the intention to purchase. When the mass media is highly influential, consumers may become more motivated to purchase. The media can help consumers to obtain information regarding the products, and provide moral and economic opportunities to use green products. Hence, the hypothesis is proposed as follows:

H6: Secondary data positively influence individuals' intention to adopt SM.

2.2.7. Social Influence

Social Influence, like the subjective norm of the TPB (Venkatesh et al. 2003), refers to the perceived social or peer group pressure regarding the adoption of a specific behaviour or not (Ajzen 1991). Karaiskos et al. (2012) showed that intention to use mobile data services can be predicted by cognitive and affective factors under the lens of Social Influences. van Schaik, Radford, and Hogg (2010) pointed out that Social Influence was one of the predictors of intention to use websites with information on domestic violence. Many studies relating to information TAMs, such as the theories of TPB, TAM, TAM2, the belief-action-outcome model, and the decomposed theory of planned behaviour, have suggested that the subjective norm positively influences acceptance intention (Shen, Yu, and Khalifa 2010; van Schaik, Radford, and Hogg 2010; Karaiskos et al. 2012; Wunderlich 2013). Ibtissem (2010) studied energy protection and found that personal norms have a positive impact on energy protection behaviour. Hence, the hypothesis is proposed as follows:

H7: Social Influence positively influences individuals' intention to adopt SM.

2.2.8. Control variables

Wunderlich (2013) investigated SM acceptance behaviour and found that the social demographic variables affecting individuals' SM acceptance intention include Income, Household Size, Age, Monthly Electricity Costs, interest in new technology, and the intention to pay to use innovative energy-efficient products. Carlsson Kanyama, Lindén, and Eriksson (2005) explored residential community energy behaviours and used variables including Age, Dwelling Type, and Income. To capture the characteristics of households in Taiwan, the control variables used in this study include (a) Income; (b) Household Size; (c) Age; (d) Electricity Costs (monthly); and (e) Dwelling Type. With increasingly serious global energy and climatic issues, many studies relating to energy saving have pointed out that environmental protection awareness and energy saving have a significant positive relationship (Dieperink, Brand, and Vermeulen 2004; Tompros et al. 2009; Ibtissem 2010). Higher-income households may have the opportunities to engage in environmentally friendly activities (Gatersleben, Steg, and Vlek 2002) and have the luxury to invest in environmentally friendly devices such as SM (Wunderlich 2013). Hence, the hypothesis is proposed as follows:

H8a: Income has a significant influence on intention to adopt SM

Early studies have pointed out that household size and household energy use have a positive relationship (Gatersleben, Steg, and Vlek 2002). In general, households of more people consume more energy. In this study, we think large households to be more motivated towards SM adoption, due to their greater need to save energy. Hence, the next hypothesis is proposed as follows:

H8b: Household size has a significant influence on intention to adopt SM

According to previous studies, households with older heads have a lower expected rate of return; thus, the probability of adopting energy-efficient technology is lower (Curtis, Simpson-Housley, and Drever 1984; Mahapatra and Gustavsson 2008). Carlsson Kanyama, Lindén, and Eriksson (2005) proposed that households of younger members are generally more likely to use the latest and more efficient technology. Wunderlich

(2013) argued that younger consumers are more flexible in changing life patterns and behaviours. Hence, the next hypothesis is proposed as follows:

H8c: Age has a negative influence on intention to adopt SM

According to previous studies, when energy prices rapidly increase and affect each household, electricity prices will be a problem (Ozaki 2011). SM has been demonstrated to be able to promote the optimal configuration and operation of electricity power resources to achieve energy saving and carbon reduction goals. Hence, they can help reduce electricity costs. In this study, we think households with higher electricity expenditures to be more likely to adopt SM devices. Hence, the next hypothesis is proposed as follows:

H8d: Electricity costs have a significant influence on intention to adopt SM

In Taiwan, dwelling type can be divided into house, apartment, condominium, and townhouse, and different dwelling types may have different privacy rights. In general, houses, old apartments, and townhouses have higher degrees of privacy rights, and their residents would be likely to install the SM display board and other devices. However, in the case of condominiums, due to the regulations of the management committee of the condominium, they are less likely to change the power facilities of the community. Therefore, households with higher degrees of privacy are expected to have a higher degree of intention to adopt SM; and ordering dwelling types according to the degree of privacy (from greatest to least) in Taiwan results in: townhouse > house > old apartment > condominium. Hence, the next hypothesis is proposed as follows:

H8e: Dwelling Type has a significant influence on intention to adopt SM

2.3. Questionnaire design and measurements

The questionnaire for this study was adapted from relevant research questionnaires and scales used by other scholars (see Appendix 1). A group of 32 participants were invited to pre-test the questionnaire. The questionnaire was measured by a 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Questionnaire items with a pre-test Cronbach's α value below 0.7 were deleted (Nunnally 1978). In addition, the maximum variance inflation factor of all variables is 1.854, which is lower than the recommended value of 4 (Neter, Wasserman, and Kutner 1983), suggesting that the collinearity problem is not serious.

The population of interest to this research is residential communities. A total of 332 questionnaires were completed. After eliminating 40 invalid ones, there were 292 valid questionnaires. Table 3 shows the distribution of the basic information of the valid responses.

The measurement model of this study was evaluated by SmartPLS 3 software for model validation. The main advantage of partial least squares (PLS) is that it does not need to consider a multivariate normal distribution of the sample data or total sample (Chin, Marcolin, and Newsted 2003). The measurement evaluation is conducted by the least squares method. PLS is a technique using latent structural equation modelling, and can estimate a structural model and measurement model (Chin 1998). Gefen, Straub, and Rigdon (2011) suggested that PLS-SEM should be selected for the exploration or extension of an existing structural theory.

3. Result

3.1. Measurement model analysis

There are three principles to measure convergent validity, including individual item reliability, composite reliability (CR), and average variance extracted (AVE) (Fornell and Larcker (1981). Individual item reliability is evaluated by factor loadings. If above 0.5, they have reached the significance level; based on the results of the table, the factor loadings of all the questionnaire items in this study are in the range from 0.757 to 0.946, and the p-value has reached the significance level of .05. Therefore, the questionnaire has convergent validity. The CR value consists of the validity values of all the measurement variables, and represents the internal consistency of the construct indicators. Higher validity suggests that the internal consistency of these indicators is higher. The recommended CR value is above 0.7(Fornell and Larcker 1981; Hair et al. 1998). In this study, CR is in the range of 0.865–0.958, which is above the general recommended value of 0.7; AVE is used to compute the average variance explanatory power of various observation variables. If the AVE of a latent variable is higher, it means the latent variable has higher degrees of convergence validity and discriminant validity. When AVE is greater than 0.5, it means the dimension has sufficient convergence validity (Fornell and Larcker 1981). The AVE values of the variables are in the range between 0.649 and 0.883, which reach the threshold of 0.5. Therefore, the measurement questionnaire items of this study have a certain degree of convergent validity, as shown in Table 4.

In general, estimation of the discriminant validity of the PLS measurement model is tested by a cross-loading

Table 3. Demographic information of respondents.

		$n = 292$				$n = 292$	
Item	Descriptions	*N*	%	Item	Descriptions	*N*	%
Gender	Male	228	78.1	Electricity Cost (NTD)	Below 5000	177	60.6
	Female	64	21.9		5001–10,000	109	37.3
Age	20–30	40	13.7		10,001–15,000	2	0.7
	31–40	67	22.9		15,001–20,000	2	0.7
	41–50	81	27.7		20,001–25,000	2	0.7
	51–60	65	22.3	Household Size[a]	1	16	5.5
	more than 61	39	13.4		2–3	102	34.9
Education	High school	47	16.1		4–5	144	41.3
	College	146	50.0		6–7	30	10.3
	Graduate or above	99	33.9		8–9	0	0
Income (NTD)	Below 25,000	8	2.7		more than 10	0	0
	25,001–50,000	65	22.3	Dwelling Type	Townhouse[b]	61	20.9
	50,001–100,000	129	44.2		House	33	11.3
	100,001–150,000	66	22.6		Apartment	92	31.5
	150,001–200,000	19	6.5		Condominium[c]	106	36.3
	Over 200,000	5	1.7				

[a]Household size: number of people in the household.
[b]Townhouses are the 3-to-5-floor- buildings owned by individual owners in Taiwan.
[c]Condominiums are apartment buildings or complexes in which the owners of individual units also collectively own the shared areas such as lobbies, elevators and greenery, with management services and corresponding fees attached in Taiwan.

matrix and the Fornell-Larcker criterion (Henseler, Ringle, and Sinkovics 2009). In this study, the loadings of the individual questionnaire items are higher than the loadings of other variables. Moreover, the square root of the AVE of the variables is greater than the correlation coefficient of the different constructs (Chin 1998), suggesting that the results of the variables in various dimensions have discriminant validity, as shown in Table 5.

3.2. Structural model analysis

Structural model analysis is used mainly to explain research hypotheses and estimate the path coefficient of constructs, and the purpose is to explain the relationship between independent variables and dependent variables. In the structural model, the quality of the model is determined by the dependent variables' overall explanatory power (R^2) and standardised path coefficient (β). Its values of 0.19, 0.33, and 0.67 represent low, medium, and high explanatory power (Chin 1998). This study used Bootstrap Resampling to estimate the values of the dimensions of PLS, and *t*-tests to estimate the standard error and significance of the path coefficient. The predictive relevance (Q^2) values of 0.02, 0.15, and 0.35, represent low, medium, and high impact. Greater value means that the model forecasting correlation is stronger (Chin 1998). The value is obtained by using the function of blindfolding. Goodness of Fit (GoF) represents the model fitness; its values of 0.35, 0.50, and 0.61 represent low, medium, and high degrees of fit (Latan and Ramli 2013). In this study, $R^2 = 0.477$ means that it has 47.7% total variance explanatory power in terms of SM adoption intention. Therefore, it has moderate model explanatory power; predictive relevance $(Q^2) = 0.415$ represents strong model forecasting correlation. In terms of model fitness, the variable commonality average is 0.487. By computation, GoF = 0.475, which is close to 0.5, indicates that the model has moderate fit.

According to the path analysis results (shown in Table 6), all hypotheses relating to the PMT variable are confirmed. Four variables have a significant impact on the intention to adopt SM. The variables of Perceived Severity (H1: $\beta = 0.231$, $p < .001$), Response Efficacy (H3: $\beta = 0.160$, $p < .001$), Self-Efficacy (H4: $\beta = 0.128$, $p < .01$), Response Cost (H5: $\beta = -0.179$, $p < .01$), and Secondary Data Influence (H7: $\beta = 0.339$, $p < .001$) all have a significant impact on adoption intention. The impact of the

Table 4. Interconstruct correlations.

	Construct	Cronbach's *a*	CR	AVE	1	2	3	4	5	6	7	8
1	Intention	0.934	0.958	0.883	0.940							
2	Perceived Severity	0.729	0.845	0.649	0.301	0.805						
3	Perceived Vulnerability	0.797	0.882	0.715	0.289	0.339	0.846					
4	Response Cost	0.810	0.885	0.720	−0.168	0.206	0.065	0.849				
5	Response Efficacy	0.859	0.913	0.778	0.384	0.115	0.334	−0.005	0.882			
6	Self-Efficacy	0.780	0.868	0.688	0.452	0.124	0.153	0.062	0.408	0.829		
7	Secondary Data Influence	0.910	0.944	0.848	0.569	0.078	0.144	−0.145	0.320	0.527	0.921	
8	Social Influence	0.772	0.897	0.813	0.434	0.184	0.213	−0.028	0.293	0.348	0.554	0.902

The values on the diagonal represent the square root of the AVE.

Table 5. Factor structure matrix of loadings and cross-loadings.

		Items	1	2	3	4	5	6	7	8
1	Intention	INT1	0.927	0.298	0.264	−0.174	0.366	0.431	0.564	0.452
		INT2	0.946	0.265	0.257	−0.158	0.364	0.415	0.526	0.370
		INT3	0.946	0.284	0.292	−0.142	0.352	0.427	0.512	0.398
2	Perceived Severity	PS1	0.276	0.868	0.397	0.170	0.170	0.119	0.047	0.211
		PS2	0.267	0.872	0.223	0.166	0.101	0.143	0.107	0.158
		PS3	0.166	0.757	0.171	0.174	−0.041	0.006	0.023	0.040
3	Perceived Vulnerability	PV1	0.248	0.280	0.893	0.077	0.336	0.172	0.139	0.199
		PV2	0.263	0.326	0.893	0.036	0.359	0.198	0.200	0.220
		PV3	0.219	0.251	0.743	0.054	0.132	−0.000	0.010	0.111
4	Response Cost	RC1	−0.181	0.170	0.052	0.923	−0.024	0.059	−0.150	−0.069
		RC2	−0.136	0.233	0.093	0.867	−0.032	0.019	−0.090	0.009
		RC3	−0.092	0.116	0.010	0.746	0.074	0.094	−0.128	0.015
5	Response Efficacy	RE1	0.278	0.103	0.367	−0.010	0.848	0.249	0.211	0.234
		RE2	0.316	0.074	0.243	−0.046	0.895	0.339	0.273	0.207
		RE3	0.401	0.122	0.287	0.032	0.902	0.456	0.342	0.319
6	Self-Efficacy	SE1	0.214	0.013	0.055	0.105	0.203	0.718	0.365	0.159
		SE2	0.431	0.058	0.065	0.020	0.311	0.902	0.523	0.395
		SE3	0.419	0.200	0.234	0.060	0.454	0.857	0.410	0.261
7	Secondary Data Influence	SDI1	0.543	0.064	0.113	−0.173	0.334	0.548	0.925	0.502
		SDI2	0.485	0.054	0.130	−0.148	0.301	0.502	0.935	0.508
		SDI3	0.539	0.096	0.155	−0.079	0.249	0.407	0.902	0.518
8	Social Influence	SI1	0.348	0.147	0.169	0.014	0.265	0.337	0.497	0.880
		SI2	0.428	0.181	0.211	−0.057	0.266	0.296	0.503	0.923

variables of Perceived Vulnerability (H2: $\beta = 0.087$) and Social Influence (H6: $\beta = 0.087$) is not significant.

Regarding the control variables, Age ($\beta = -0.09$, $p < .01$) and Electricity Costs ($\beta = 0.084$, $p < .05$) confirm hypotheses H8c and H8d. Although Dwelling Type (H8e: $\beta = 0.034$) has a positive correlation to support the hypotheses, the relationship is not significant. The variables of Income (H8a: $\beta = -0.023$) and Household Size (H8b: $\beta = -0.041$) have negative correlations and thus do not confirm the hypotheses.

4. Discussion

This study applied and extended the PMT model to explore SM adoption intention among residents of residential communities as the research subjects. Based on results, this study offers the following findings: Regarding threat appraisal variables, the Perceived Severity variable has a significant impact on SM adoption intention of residents; however, the impact of the Perceived Vulnerability variable is not significant. This study assumes a scenario in which in the post-nuclear era in Taiwan, nuclear power generation will be replaced by conventional fuels or alternative energy sources for power generation, and electricity prices will rise sharply in the future. The increase in electricity prices will have a potential impact on the life of Taiwanese citizens. Therefore, it expected to strongly influence the Perceived Severity variable regarding the intention to adopt SM. However, as Taiwan's power supplier (Taiwan Power Company) is now government-owned (although it will be privatised after Amendment to the Electricity Act is approved), the government currently controls electricity prices to stabilise consumer commodity prices. In the past, the fuel costs were absorbed by the government, and rarely shared by increasing electricity prices. As a result, there is no deep knowledge of the impact of rising electricity prices on households. Although the Perceived Vulnerability variable has a positive impact, the impact is not significant. Whether the government continues to control prices is the dominant factor.

Table 6. Results of structural model analysis.

Hypotheses	Path coefficients	*t*-Value
Intention $R^2 = 0.477$, $Q^2 = 0.415$		
H: Perceived Severity → Intention	0.231***	4.115
H2: Perceived Vulnerability → Intention	0.087	1.845
H3: Response Efficacy → Intention	0.160***	3.438
H4: Self-Efficacy → Intention	0.128**	3.090
H5: Response Cost → Intention	−0.179*	2.399
H6: Secondary Data Influence → Intention	0.339***	5.901
H7: Social Influence → Intention	0.087	1.607
H8a: Income → Intention	−0.023	0.768
H8b: Household Size → Intention	−0.041	1.176
H8c: Age → Intention	−0.09**	2.660
H8d: Electricity Costs→ Intention	0.084*	2.406
H8e: Dwelling Type → Intention	0.034	1.025

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

Regarding the coping appraisal variables, three variables have a significant impact on the intention to adopt SM, as suggest by the hypotheses. As international energy and climate issues continue to simmer, Taiwan, like many countries, has been vigorously promoting smart grid construction, and hopes to promote the optimal configuration and operation of power resources through instant control and demand-side management in order to save energy and reduce carbon emissions. With the implementation of governmental policies, people can recognise the energy-saving benefits of SM.

Therefore, when personal perceived response efficacy is higher, the possibility of triggering adaptive behaviour will increase accordingly. Therefore, in this situation, it has a strong and significant impact on the adaptive behaviour of using SM to save electricity costs.

Regarding Self-Efficacy, as a system of time-of-use prices will be implemented in Taiwan, the promotion of SM is based on voluntary application and installation. Due to such voluntary application and installation in the early stage, the installation fees are funded by the government. Thus, Self-Efficacy has a positive and significant impact on the intention to adopt SM in response to increasing electricity prices. Regarding Response Cost, although the SM application and installation is free of charge, users must spend some money on the installation of other equipment, and have to ask for leave to be at home during installation. In addition, the benefits of installation of SM cannot be seen in a short period of time and people still are concerned about privacy and network security issues. Thus, when the Response Cost is higher, the probability of adopting SM will be lower. This will have a significant negative impact on the intention towards the adaptive behaviour of SM adoption to save electricity prices.

The Secondary Data Influence variable has a strong and significantly positive impact on the intention towards adaptive behaviour of SM adoption to save electricity prices. Since most people obtain SM information from secondary data (e.g. newspapers, TV media, magazines, governmental publications, etc.), after the Fukushima Accident, many media outlets discussed and compared the advantages and disadvantages of alternative energy sources. Through the media, people can obtain the necessary information and recognise that a rise in electricity prices is unavoidable. Therefore, with the expectation of high increases in electricity prices, Secondary Data have a strong and significant impact on the intention to adopt SM.

The Social Influence variable has no significant impact on the intention towards adaptive behaviour of SM adoption to save electricity prices. This is possibly because those participants in the residential sector do not seriously consider the SM intention behaviours of others. For example, different salary levels, dwelling types, and household sizes may have different impacts on comparisons with others. Due to current energy-saving benefits, many high-voltage consumers (24,123 consumers) have installed SM; few residential households (10,000) have installed SM at the early stage of developing the smart grid in Taiwan. Regarding control variables, Age and Electricity Costs have a significant impact on the intention towards adaptive behaviour of SM adoption to save electricity prices, which suggests that young subjects are more likely to accept new energy-saving technology, and households with higher electricity price expenditures are more willing to adopt SM. However, the findings of this study suggest a negative correlation, meaning people with a higher income are less likely to adopt SM, possibly because electricity prices are relatively low. Therefore, high-income households are not concerned about the rise in electricity price, which has an impact on adoption intention. The Household Size variable also suggests the same negative correlation, possibly because the paternal authority in a large family is stronger. In particular, in a family of three generations under the same roof, the acceptance degree of family elders is relatively low. The findings confirm that older people are less likely to adopt SM. Although Dwelling Type has an impact on adoption intention, the impact is not significant, as the metropolitan area is usually densely populated. The area of an apartment in a general building is very small, which may reduce the intention to install the SM display board and other devices. On the contrary, as people living in townhouses have larger living space, the intention to adopt SM will be stronger. In general, people in Taiwan are not used to having an electronic display board on their walls.

5. Conclusions and implications

5.1. Conclusions

This study aims to understand the impact of increasing the proportion of renewable energy to cope with Taiwan's post-nuclear era demand for electricity, and regarding the intention to adopt SM to save energy in the face of expected increases in electricity costs. Based on the results of analysing questionnaires, this study offers the following findings: Regarding threat appraisal variables, the Perceived Severity variable has a significant impact on SM adoption intention of residents; however, the impact of the Perceived Vulnerability variable is not significant. Regarding the coping appraisal variables, three variables have a significant impact on the intention of SM adoption, as suggested by the hypotheses. In control variables, Age and Electricity Costs have a significant impact on the intention towards adaptive behaviour of SM adoption to save electricity prices. As compared to previous relevant studies on SM adoption intention, as based on TAM (Kranz, Gallenkamp, and Picot 2010), the belief-action-outcome model (Melville 2010), TPB (Kranz and Picot 2011), and the combined PLOC (perceived causality) and TAM model (Wunderlich 2013). From the perspective of PMT, this study explores the correlations of intention, threat appraisal variables, and coping appraisal variables, while SM acceptance-related

areas have not been explored. Therefore, the practical contributions of this study include:

(1) Compared with previous studies in the field of PMT, for example, the promotion of health and social psychological behaviour (Floyd, Prentice-Dunn, and Rogers 2000; Milne, Sheeran, and Orbell 2000), risk communication, protective action against natural and technological disasters (Grothmann and Patt 2005), functional food and supplements (Cox, Koster, and Russell 2004), online safety (Boehmer et al. 2015), and information systems, this study, from the perspective of threat appraisal and coping appraisal variables, explores the correlations with SM adoption intention that provide a reference to subsequent TAM researchers in the development of behaviour models from different viewpoints;
(2) Compared to the original model, this study adds Secondary Data Influence, Social Influence, and control variables in order to expand the model to explain the impact of groups and media on adoption intention, and explores the impact of control variables on adoption intention. The results can be a reference for Taiwan's government in considering the use of different incentives to increase the adoption intention in the case of different demographic variable types. For example, different rewards and persuasive messages can be provided for different dwelling types;
(3) The findings of this study can be used to evaluate energy-saving intention and behaviour from different perspectives, as compared to previous studies, which focused on ease of use and applicability in the case of rising electricity prices in the post-nuclear-power era. Moreover, it can provide a reference for the future implementation of a time-of-use pricing system.

5.2. Implications

According to the results from the proposed model, threat appraisal variables have a significant influence on residential community users' intent to use SM. It is suggested that any future plan combining SM and time-pricing ensures stable power costs for users of high off-peak and peak hour power consumption, provides energy-saving incentives, and offers exit mechanisms and power consumption analysis, as well as additional services, such as warnings for power consumption over a threshold, so that the intent of users to accept SM can be enhanced. Regarding heavy users of electricity, their power consumption behaviour should be positively changed. Regarding small-sized households or low-income households, for users with average monthly power consumption, more publicity and promotional activities should be conducted. In the design of the time-pricing mechanism, the accepted principle is to reflect a reasonable cost of the actual power generated, and fair fee rates for different groups of users to achieve the purpose of effective management of the power load by the time-pricing mechanism. In the future, based on the power system conditions in the post-nuclear-power era in Taiwan, the planning strategies that can be implemented include: (1) a peak and off-peak electricity fee differential to transfer more of the cost to high-usage customers, and to provide them further incentive to install SM and reduce power consumption; (2) during the peak period, an electricity price feedback mechanism should be considered to encourage power saving through use of the SM.

Regarding the coping appraisal variables, Response Efficacy and Self-Efficacy have a significant impact on the intention of residential community residents to adopt the SM. The smart grid and SM strengthens the positive effects of time-pricing through technological factors. Therefore, the development of SM and time-pricing can achieve the goals of improving energy use efficiency, as well as effective management of the load. Thus, a future time-pricing mechanism can allow residential community users to adjust electricity usage based on different prices for different periods. Regarding Response Efficacy, through the time-pricing mechanism of the special (peak usage) period, based on agreement with users and reference to the experience of foreign power companies, Critical Peak Pricing or Peak Time Rebate Program mechanisms can be used to encourage minimised power consumption to reduce power costs. At the same time, in response to the impact of high prices in the post-nuclear-power era of Taiwan, residential community users may adjust their power consumption structure and demand for power, through both overall reduction in usage and transferring power consumption from peak to off-peak times. As the power consumption behaviours of residential community users are habit-based, incentives should be provided to change their behaviours. If some power usage of the peak period can be transferred to the off-peak period, the power cost will be reduced due to the gap between the peak and off-peak prices, which can also help the power company improve power supply stability and reduce power supply cost. With the combination of power saving and power transfer, the power load of peak time will be alleviated due to reduced demand on power.

In addition, regarding the promotion of SM and a new time-pricing mechanism in the post-nuclear-power era,

as the Secondary Data variable has a positive impact on SM acceptance, integrated yet diverse publicity, promotions, and proactive services should be conducted to provide users with correct power consumption concepts, as well as an understanding of the advantages of SM and the time-pricing mechanism. Moreover, more value-added services provided by the SM can help users to select more advantageous pricing programmes based on analysis of the behaviour and customs of power consumption, while providing users with power-savings and cost reduction suggestions to increase their intention to adopt SM.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Adebanjo, Dotun. 2009. "Understanding Demand Management Challenges in Intermediary Food Trading: A Case Study." *Supply Chain Management: An International Journal* 14 (3): 224–233. doi:10.1108/13598540910954566.

Ajzen, Icek. 1991. "The Theory of Planned Behavior." *Organizational Behavior and Human Decision Processes* 50 (2): 179–211. doi:10.1016/0749-5978(91)90020-T.

Boehmer, Jan, Robert LaRose, Nora Rifon, Saleem Alhabash, and Shelia Cotten. 2015. "Determinants of Online Safety Behaviour: Towards an Intervention Strategy for College Students." *Behaviour & Information Technology* 34 (10): 1022–1035. doi:10.1080/0144929X.2015.1028448.

Brown, Susan A, and Viswanath Venkatesh. 2005. "Model of Adoption of Technology in Households: A Baseline Model Test and Extension Incorporating Household Life Cycle." *MIS Quarterly*, 399–426. http://www.jstor.org/stable/25148690.

Bureau of Energy, Ministry of Economic Affairs, Taiwan. 2015a. "Energy Policy& Program." http://www.moea.gov.tw/MNS/english/content/ContentMenu.aspx?menu_id3886.

Bureau of Energy, Ministry of Economic Affairs, Taiwan. 2015b. "Policy for Promoting Renewable Energy & Current Status in Taiwan." http://www.mofa.gov.tw/Upload/RelFile/2508/111035/2e9e6ebe-d594-4d46-822b-1110f07f8482.pdf.

Butler, Catherine, Karen A Parkhill, and Nicholas F. Pidgeon. 2011. "Nuclear Power after Japan: The Social Dimensions." *Environment: Science and Policy for Sustainable Development* 53 (6): 3–14. doi:10.1080/00139157.2011.623051.

Carlsson Kanyama, Annika, Anna Lisa Lindén, and Björn Eriksson. 2005. "Residential Energy Behaviour: Does Generation Matter?" *International Journal of Consumer Studies* 29 (3): 239–253. doi:10.1111/j.1470-6431.2005.00409.x.

Chang, Hsiu-Hua, and Huey-Wen Chou. 2011. "Drivers and Effects of Enterprise Resource Planning Post-implementation Learning." *Behaviour & Information Technology* 30 (2): 251–259. doi:10.1080 /014492909 -03300923.

Chen, Andrew N. K., and Younghwa Gabe Lee. 2008. "Healthcare Information Technology Adoption and Protection Motivation: A Study of Computerized Physicial Order Entry Systems." http://aisel.aisnet.org/amcis2008/369.

Chin, Wynne W. 1998. "The Partial Least Squares Approach to Structural Equation Modeling." *Modern Methods for Business Research* 295 (2): 295–336.

Chin, Wynne W, Barbara L. Marcolin, and Peter R. Newsted. 2003. "A Partial Least Squares Latent Variable Modeling Approach for Measuring Interaction Effects: Results from a Monte Carlo Simulation Study and an Electronic-mail Emotion/Adoption Study." *Information Systems Research* 14 (2): 189–217. http://pubsonline.informs.org/doi/ref/10.1287/isre.14.2.189.16018.

Clastres, Cédric. 2011. "Smart Grids: Another Step Towards Competition, Energy Security and Climate Change Objectives." *Energy Policy* 39 (9): 5399–5408. doi:10.1016/j.enpol.2011.05.024.

Compeau, Deborah R., and Christopher A. Higgins. 1995. "Computer Self-efficacy: Development of a Measure and Initial Test." *MIS quarterly* 19 (2): 189–211. doi:10.2307/249688.

Corbett, Jacqueline. 2013. "Using Information Systems to Improve Energy Efficiency: Do Smart Meters Make a Difference?" *Information Systems Frontiers* 15 (5): 747–760. doi:10.1007/s10796-013-9414-0.

Cox, D. N., A. Koster, and C. G. Russell. 2004. "Predicting Intentions to Consume Functional Foods and Supplements to Offset Memory Loss Using an Adaptation of Protection Motivation Theory." *Appetite* 43 (1): 55–64. doi:10.1016/ j.appet.2004.02.003.

Curtis, F. A., P. Simpson-Housley, and S. Drever. 1984. Communications on Energy Household Energy Conservation." *Energy Policy* 12 (4): 452–456. doi:10.1016/0301-4215(84)90109-5.

Dieperink, Carel, Iemy Brand, and Walter Vermeulen. 2004. "Diffusion of Energy-saving Innovations in Industry and the Built Environment: Dutch Studies as Inputs for a More Integrated Analytical Framework." *Energy Policy* 32 (6): 773–784. doi:10.1016/S0301-4215(02)00341-5.

Faruqui, Ahmad, Dan Harris, and Ryan Hledik. 2010. "Unlocking the€ 53 Billion Savings from Smart Meters in the EU: How Increasing the Adoption of Dynamic Tariffs Could Make or Break the EU's Smart Grid Investment." *Energy Policy* 38 (10): 6222–6231. doi:10.1016/j.enpol.2010.06.010.

Featherman, Mauricio S., and Paul A. Pavlou. 2003. "Predicting E-services Adoption: A Perceived Risk Facets Perspective." *International Journal of Human-Computer Studies* 59 (4): 451–474. doi:10.1016/S1071-5819(03)00111-3.

Floyd, Donna L, Steven Prentice-Dunn, and Ronald W. Rogers. 2000. "A Meta Analysis of Research on Protection Motivation Theory." *Journal of Applied Social Psychology* 30 (2): 407–429. doi:10.1111/j.1559-1816.2000.tb02323.x.

Fornell, Claes, and David F. Larcker. 1981. "Evaluating Structural Equation Models with Unobservable Variables and Measurement Error." *Journal of Marketing Research* 18 (1): 39–50. doi:10.2307/3151312.

Gatersleben, Birgitta, Linda Steg, and Charles Vlek. 2002. "Measurement and Determinants of Environmentally Significant Consumer Behavior." *Environment and Behavior* 34 (3): 335–362. doi:10.1177/0013916502034003004.

Gefen, David, Detmar W. Straub, and Edward E. Rigdon. 2011. "An Update and Extension to SEM Guidelines for Administrative and Social Science Research." *Management Information Systems Quarterly* 35 (2): iii–xiv.

Gochman, David S. 1997. *Handbook of Health Behavior Research IV: Relevance for Professionals and Issues for the Future*. New York: Springer.

Grothmann, Torsten, and Anthony Patt. 2005. "Adaptive Capacity and Human Cognition: The Process of Individual Adaptation to Climate Change." *Global Environmental Change* 15 (3): 199–213. doi:10.1016/j.gloenvcha.2005.01.002.

Gungor, Vehbi C, Dilan Sahin, Taskin Kocak, Salih Ergut, Concettina Buccella, Carlo Cecati, and Gerhard P. Hancke. 2011. "Smart Grid Technologies: Communication Technologies and Standards." *IEEE Transactions on Industrial Informatics* 7 (4): 529–539. doi:10.1109/TII.2011.2166794.

Hair, Joseph F., Rolph E. Anderson, Ronaid L. Tatham, and W. C. Black. 1998. *Multivariate Data Analysis*. 5th ed. Upper Saddle River, NJ: Prentice Hall.

Hart, David G. 2008. "Using AMI to realize the Smart Grid." Paper Read at Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE. doi:10.1109/PES.2008.4596961.

Hartmann, Patrick, Vanessa Apaolaza, Clare D'Souza, Carmen Echebarria, and Jose M. Barrutia. 2013. "Nuclear Power Threats, Public Opposition and Green Electricity Adoption: Effects of Threat Belief Appraisal and Fear Arousal." *Energy Policy* 62: 1366–1376. doi:10.1016/j.enpol.2013.07.058.

Hass, Jane W, Gerrold S. Bagley, and Ronald W. Rogers. 1975. "Coping with the Energy Crisis: Effects of Fear Appeals upon Attitudes Toward Energy Consumption." *Journal of Applied Psychology* 60 (6): 754–756. doi:10.1037/0021-9010.60.6.754.

Hayashi, Masatsugu, and Larry Hughes. 2012. "The Fukushima Nuclear Accident and its Effect on Global Energy Security." *Energy Policy*. doi:10.1016/j.enpol. 2012.11.046.

Henseler, Jörg, Christian M. Ringle, and Rudolf R. Sinkovics. 2009. "The Use of Partial Least Squares Path Modeling in International Marketing." *Advances in international marketing* 20: 277–319.

Hledik, Ryan. 2009. "How Green is the Smart Grid?" *The Electricity Journal* 22 (3): 29–41. doi:10.1016/j.tej.2009.03.001.

Huang, Lei, Ying Zhou, Yuting Han, James K. Hammitt, Jun Bi, and Yang Liu. 2013. "Effect of the Fukushima Nuclear Accident on the Risk Perception of Residents Near a Nuclear Power Plant in China." *Proceedings of the National Academy of Sciences* 110 (49): 19742–19747. doi:10.1073/pnas.1313825110.

Ibtissem, Mustapha Harzallah. 2010. "Application of Value Beliefs Norms Theory to the Energy Conservation Behaviour." *Journal of Sustainable Development* 3 (2). doi:10.5539/jsd.v3n2p129.

Joskow, Paul L., and John E. Parsons. 2012. "The Future of Nuclear Power after Fukushima." http://hdl.handle.net/1721.1/70857.

Karaiskos, Dimitrios C., Dimitris A. Drossos, Alexandros S. Tsiaousis, George M. Giaglis, and Konstantinos G. Fouskas. 2012. "Affective and Social Determinants of Mobile Data Services Adoption." *Behaviour & Information Technology* 31 (3): 209–219. doi:10.1080/0144929X.2011.563792.

Kessides, Ioannis N. 2012. "The Future of the Nuclear Industry Reconsidered: Risks, Uncertainties, and Continued Promise." *Energy Policy* 48: 185–208. doi:10.1016/j.enpol.2012.05.008.

Khurana, H., Mark Hadley, Ning Lu, and D. A. Frincke. 2010. "Smart-grid Security Issues." *IEEE Security & Privacy Magazine* 8 (1): 81–85. doi: 10.1109/MSP.2010.49.

Kim, Younghwan, Minki Kim, and Wonjoon Kim. 2013. "Effect of the Fukushima Nuclear Disaster on Global Public Acceptance of Nuclear Energy." *Energy Policy* 61: 822–828. doi:10.1016/j.enpol.2013.06.107.

Kranz, L. M. U. Munich, Julia V. Gallenkamp, and Arnold Picot. 2010. "Exploring the Role of Control-Smart Meter Acceptance of Residential Consumers." Paper read at AMCIS. http://aisel.aisnet.org/amcis2010/315.

Kranz, Johann, and Arnold Picot. 2011. "Why Are Consumers Going Green? The Role of Environmental Concerns in Private Green-IS Adoption." Paper read at ECIS. http://aisel.aisnet.org/ecis2011/104.

Laes, Erik, Gaston Meskens, and Jeroen P. van der Sluijs. 2011. "On the Contribution of External Cost Calculations to Energy System Governance: The Case of a Potential Large-scale Nuclear Accident." *Energy Policy* 39 (9): 5664–5673. doi:10.1016/ j.enpol.2011.04.016.

Latan, Hengky, and Nur Ainna Ramli. 2013. "The Results of Partial Least Squares-Structural Equation Modelling Analyses (PLS-SEM)." Available at SSRN 2364191. doi:10.2139/ssrn.2364191.

Lee, Younghwa. 2011. "Understanding Anti-plagiarism Software Adoption: An Extended Protection Motivation Theory Perspective." *Decision Support Systems* 50 (2): 361–369. doi:10.1016/j.dss.2010.07.009.

Lee, Doohwang, Robert Larose, and Nora Rifon. 2008. "Keeping our Network Safe: A Model of Online Protection Behaviour." *Behaviour & Information Technology* 27 (5): 445–454. doi:10.1080/01449290600879344.

Lee, Younghwa, and Kai R. Larsen. 2009. "Threat or Coping Appraisal: Determinants of SMB Executives' Decision to Adopt Anti-malware Software." *European Journal of Information Systems* 18 (2): 177–187. doi:10.1057/ejis.2009.11.

Lee, Yueh-Uua, and Chu-Ching Wang. 2014. "An Evaluation of Public Attitude Toward Nuclear Power after Fukushima Accident: Evidence from Taiwan." *Asian Journal of Humanities and Social Studies* 02 (02): 7. http://tkuir.lib.tku.edu.tw:8080/dspace/handle/987654321/99212.

López-Mosquera, Natalia, and Mercedes Sánchez. 2012. "Theory of Planned Behavior and the Value-Belief-Norm Theory Explaining Willingness to Pay for a Suburban Park." *Journal of Environmental Management* 113: 251–262. doi:10.1016/ j.jenvman.2012.08.029.

Maddux, James E, and Ronald W. Rogers. 1983. "Protection Motivation and Self-efficacy: A Revised Theory of Fear Appeals and Attitude Change." *Journal of Experimental Social Psychology* 19 (5): 469–479. doi:10.1016/0022 -1031(83)90023-9.

Mahapatra, Krushna, and Leif Gustavsson. 2008. "An Adopter-centric Approach to Analyze the Diffusion Patterns of Innovative Residential Heating Systems in Sweden." *Energy Policy* 36 (2): 577–590. doi:10.1016/j.enpol.2007.10.006.

Markandya, Anil, Andrea Bigano, and Roberto Porchia. 2010. "The Social Cost of Electricity. Scenarios and Policy Implications." http://www.e-elgar.com/ bookentry_main.-lasso?id = 13446.

McClendon, Brian T, and Steven Prentice-Dunn. 2001. "Reducing Skin Cancer Risk: An Intervention Based on Protection Motivation Theory." *Journal of Health Psychology* 6 (3): 321–328. doi:10.1177/135910530100600305.

McGowan, Francis, and Raphael Sauter. 2005. *Public Opinion on Energy Research: A Desk Study for the Research Councils*. Brighton: University of Sussex.

McQuail, Denis. 1979. "The Influence and Effects of Mass Media." In *Mass Communication and Society*, edited by J. Curran, M. Gurevitch, and J. Woolacott, 70–93. Beverly Hills, CA: Sage.

Meeus, Leonardo, Marcelo Saguan, Jean-Michel Glachant, and Ronnie Belmans. 2010. "Smart Regulation for Smart Grids." http://hdl.handle.net/1814/14043.

Melville, Nigel P. 2010. "Information Systems Innovation for Environmental Sustainability." *MIS Quarterly* 34 (1): 1–21. http://www.misq.org/ downloadable/download/ linkSample/link_id/838/In.

Milne, Sarah, Paschal Sheeran, and Sheina Orbell. 2000. "Prediction and Intervention in Health-Related Behavior: A Meta analytic Review of Protection Motivation Theory." *Journal of Applied Social Psychology* 30 (1): 106–143. doi:10.1111/j.1559-1816.2000.tb02308.x.

Mohsenian-Rad, A.-H., Vincent W. S. Wong, Juri Jatskevich, Robert Schober, and Alberto Leon-Garcia. 2010. "Autonomous Demand-side Management Based on Game-theoretic Energy Consumption Scheduling for the Future Smart Grid." *IEEE Transactions on Smart Grid* 1 (3): 320–331. doi:10.1109/TSG.2010 .2089069.

Neter, John, W. Wasserman, and M. H. Kutner. 1983. *Applied Linear Regression Models*. Homewood, IL: Richard D. Irwin Inc.

Nunnally, Jum. 1978. *Psychometric Methods*. New York: McGraw.

Olmos, Luis, Sophia Ruester, Siok-Jen Liong, and Jean-Michel Glachant. 2011. "Energy Efficiency Actions Related to the Rollout of Smart Meters for Small Consumers, Application to the Austrian System." *Energy* 36 (7): 4396–4409. doi:10.1016 /j.energy.2011.04.003.

Ozaki, Ritsuko. 2011. "Adopting Sustainable Innovation: What Makes Consumers Sign up to Green Electricity?" *Business Strategy and the Environment* 20 (1): 1–17. doi:10.1002/ bse.650.

Pidgeon, Nick F, Irene Lorenzoni, and Wouter Poortinga. 2008. "Climate Change or Nuclear Power – No Thanks! A Quantitative Study of Public Perceptions and Risk Framing in Britain." *Global Environmental Change* 18 (1): 69–85. doi:10.1016 /j.gloenvcha.2007.09.005.

Pullinger, Martin, Heather Lovell, and Janette Webb. 2014. "Influencing Household Energy Practices: A Critical Review of UK Smart Metering Standards and Commercial Feedback Devices." *Technology Analysis & Strategic Management* 26 (10): 1144–1162. doi:10.1080/09537325. 2014.977245.

Rabl, Ari, and Veronika A. Rabl. 2013. "External Costs of Nuclear: Greater or Less than the Alternatives?" *Energy Policy* 57: 575–584. doi:10.1016/j.enpol.2013.02.028.

Rippetoe, Patricia A., and Ronald W. Rogers. 1987. "Effects of Components of Protection-motivation Theory on Adaptive and Maladaptive Coping with a Health Threat." *Journal of Personality and Social Psychology* 52 (3): 596–604. doi:10. 1037/0022-3514.52.3.596.

Rogers, Ronald W. 1975. "A Protection Motivation Theory of Fear Appeals and Attitude Change1." *The Journal of Psychology* 91 (1): 93–114. doi:10.1080/00223980. 1975. 9915803.

Rogers, Everett M. 2010. *Diffusion of Innovations*. New York: Simon and Schuster.

Rogers, Ronald W., and Steven Prentice-Dunn. 1997. "Protection Motivation Theory." In *Handbook of Health Behavior Research I: Personal and Social Determinants*, edited by D. S. Gochman, 113–132. New York: Plenum Press.

Schneider, Mycle, Antony Froggatt, and Steve Thomas. 2012. *Nuclear Power in a Post-Fukushima World*. Washington, DC: Worldwatch Institute.

Shen, Kathy Ning, Angela Yan Yu, and Mohamed Khalifa. 2010. "Knowledge Contribution in Virtual Communities: Accounting for Multiple Dimensions of Social Presence Through Social Identity." *Behaviour & Information Technology* 29 (4): 337–348. doi:10.1080/014492909031566 22.

Srinivasan, T. N., and T. S. Gopi Rethinaraj. 2013. "Fukushima and Thereafter: Reassessment of Risks of Nuclear Power." *Energy Policy* 52: 726–736. doi:10.1016/j.enpol.2012.10.036.

Stern, Paul C, Thomas Dietz, Troy Abel, Gregory A. Guagnano, and Linda Kalof. 1999. "A Value-belief-norm Theory of Support for Social Movements: The Case of Environmentalism." *Human Ecology Review* 6 (2): 81–98. http://cedar.wwu.edu/hcop_facpubs/1.

Stewart, Rodney A., Rachelle M. Willis, Kriengsak Panuwatwanich, and Oz Sahin. 2013. "Showering Behavioural Response to Alarming Visual Display Monitors: Longitudinal Mixed Method Study." *Behaviour & Information Technology* 32 (7): 695–711. doi:10.1080/ 0144929X.2011.577195.

Stragier, Jeroen, Jan Derboven, Lieve Laporte, Laurence Hauttekeete, and Lieven De Marez. 2013. "Kilowhat? A Multidisciplinary Approach on the Development of a Home Energy Management System." *Behaviour & Information Technology* 32 (11): 1086–1104. doi:10.1080/ 0144929X.2012.740638.

Tanner Jr, John F, James B. Hunt, and David R. Eppright. 1991. "The Protection Motivation Model: A Normative Model of Fear Appeals." *The Journal of Marketing* 55 (3): 36–45. doi:10.2307/1252146.

Tompros, Spyridon, Nikolaos Mouratidis, Maurice Draaijer, Andreas Foglar, and Halid Hrasnica. 2009. "Enabling Applicability of Energy Saving Applications on the Appliances of the Home Environment." *Network, IEEE* 23 (6): 8–16. doi:10.1109 /MNET.2009.5350347.

Torkzadeh, Gholamreza, and Thomas P. Van Dyke. 2001. "Development and Validation of an Internet Self-efficacy Scale." *Behaviour & Information Technology* 20 (4): 275–280. doi:10.1080/01449290110050293.

van Schaik, Paul, Jill Radford, and Leanne Hogg. 2010. "Modelling the Acceptance of Internet Sites With Domestic-violence Information." *Behaviour & Information Technology* 29 (6): 615–620. doi:10.1080/01449290110050293.

Venables, Mark. 2007. "Smart Meters Make Smart Consumers." *Engineering & Technology* 2 (4): 23–23. doi:10.1049/et:20070401.

Venkatesh, Viswanath, Michael G. Morris, Gordon B. Davis, and Fred D. Davis. 2003. "User Acceptance of Information Technology: Toward a Unified View." *MIS quarterly*, 425–478. http://www.jstor.org/stable/30036540.

Visschers, Vivianne H. M., and Michael Siegrist. 2012. "How a Nuclear Power Plant Accident Influences Acceptance of Nuclear Power: Results of a Longitudinal Study Before and After the Fukushima Disaster." *Risk Analysis*. doi:10.1111 /j.1539-6924.2012.01861.x.

Wallard, H., B. Duffy, and P. Cornick. 2012. *After Fukushima: Global Opinion on Energy Policy*. Ipsos Social Research Institute. http://www.ipsos.com/ public-affairs/after-fukushima-global-opinion-energy-policy/.

Watson, Richard T., Marie-Claude Boudreau, and Adela J. Chen. 2010. "Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community." *MIS Quarterly* 34 (1): 20–38. http://www.jstor.org/stable/20721413.

Winkler von Mohrenfels, Hannah, and Daniel Klapper. 2012. "The Influence of Mobile Product Information on Brand Perception and Willingness to Pay for Green and Sustainable Products." http://aisel.aisnet.org/icis2012/ proceedings/GreenIS/3/.

Woon, Irene, Gek-Woo Tan, and R. Low. 2005. "A protection Motivation Theory Approach to Home Wireless Security." ICIS 2005 Proceedings. 31. http://aisel.aisnet.org/icis2005/31.

Wunderlich, Philipp. 2013. *Green Information Systems in the Residential Sector*. Springer. doi:10.1007/978-3-642-36769-4.

Appendix 1. Questionnaire items.

Construct	Code	Reference	Instrument items
Perceived Severity	PS	Woon, Tan, and Low (2005) and Lee (2011)	1. Electricity price increase may seriously affect my family. 2. If there is no price increase, I've got the opportunity to consume more electrical energy. 3. I do not care about the price hike without energy-saving measures; it may affect my image in the community.
Perceived Vulnerability	PV	Cox et al. (2004) and Lee (2011)	4. My family could be vulnerable in terms of electricity price impacts. 5. My family could be susceptible to electricity price increase. 6. My family has to face the possibility of price increase in the near future.
Response Efficacy	RE	Woon, Tan, and Low (2005) and Lee (2011)	7. Adapting the SM device can detect the electricity consumption behaviour of my family. 8. Installing the SM device in my home is an effective way to decrease electricity expenditures. 9. If I adopt the SM device, my family can minimise the use of electricity.
Self-Efficacy	SE	Compeau and Higgins (1995) and Lee (2011)	10. The application for the installation of SM device is easy and simple for my family. 11. I could adopt the SM device even if there is no one around to tell me what to do about the increasing electricity prices. 12. I may choose an SM device if I am in need of help because of increased electricity price.
Response Cost	RS	Tanner, Hunt, and Eppright (1991), Lee (2011), and Wunderlich (2013)	13. Using the SM device will have much additional cost. 14. It takes a considerable amount of time and effort to be familiar with and use the SM device. 15. Using an SM may result in loss of personal data and privacy.
Social Influence	SI	Ozaki (2011)	16. Most people who are important to me agree to my use of the SM. 17. Most people who are important to me believe that I should use the SM.
Secondary data	SDI	Brown and Venkatesh (2005)	18. Information from newspapers or magazines suggests that I should use the SM device. 19. Information that I gather by watching TV encourages me to use the SM device. 20. Based on what I have heard on the radio, I am encouraged to use the SM device.
Intention	INT	Brown and Venkatesh (2005)	21. I intend to use the SM device. 22. I predict that the SM device will be used after the electricity price increase. 23. I plan to use the SM device after the electricity price increase.

Note: Question items of the questionnaire were adopted from the questionnaires of relevant PMT and TAM studies, and were modified to comply with the research scenario of this study.