CRITICAL INFLUENTIAL FACTORS AND INCENTIVE SCHEMES FOR THE ADOPTION OF SMART HOME ENERGY TECHNOLOGY BY URBAN RESIDENTS IN CHINA

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Critical Influential Factors and Incentive Schemes for the Adoption of Smart Home Energy Technology by Urban Residents in China

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CERTIFICATE OF ORIGINALITY

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Abstract

In an era of flourishing development of information and communication technology, building smart city has been recognized as a promising strategy to achieve the sustainability and equality of future society. From the micro-aspect, smart home is a vital constituent part of smart city, relating to the health and quality of life of urban residents, and the effectiveness of smart home energy technology has been convinced by lots of research in saving residential energy as well as improving the safety, living comfort and convenience. China has a huge market for the development of SHET; however, the household penetration rate in China is still at a low level. If to accelerate the diffusion of SHET through urban residents, some critical issues must be figured out, including resident's perceptions about smart technology, the significant driving factors of adoption intention, as well as the possible incentive schemes formulated by government, which is the aim of this study. To achieve the aim, the study has four objectives: 1) to investigate the KPI representing the complicated performance of SHET; 2) to develop measurement scales for investigating the urban resident's adoption intention about SHET; 3) to identify the critical factors influencing the adoption intention of SHET; 4) to propose the incentive schemes that will facilitate the urban residents to adopt SHET. Considering about the macro-environment of economy, policy, industry development and demographic, Guangdong is the most suitable to be selected as a targeting area to conduct this study among the 34 provincial regions in China. The outcome of the study will not only be beneficial to the local residents and industry of Guangdong province, but also could become an example for other provinces in China.

The research objectives have been achieved by comprehensive literature review, questionnaire survey, contingent valuation and various data analysis techniques. Through literature review,

totally twelve key performance indicators (KPIs) were identified to represent the performance of SHET; and the integration of theory of planned behavior with norm activation model was developed to compose the theoretical backbone of the study. On the basis of the KPIs and theoretical backbone, a measurement scale was developed to evaluate respondent's attitude and perceptions relevant with the adoption intention of SHET. After data collection, the exploratory factor analysis (EFA) was applied, whose results finalized the six factors relating with adoption intention, and named as attitude towards technical performance (ATTP), attitude towards economic performance (ATEP), attitude towards risk resistance (ATRR), perceived behavior control (PBC), subjective norm (SN), and personal norm (PN); besides, the measurement indicators associated with each factor were also confirmed by EFA.

The PLS-SEM results specified four significant positive factors influencing the adoption intention of SHET: ATTP, PBC, SN, and PN. However, another two factors, including ATEP and ATRR did not exhibit any significant impact onto the adoption intention. Based on the PLS-SEM results, three incentive schemes were proposed, including price subsidy, time of use (TOU) pricing plan, and community energy saving campaign. Together with the scenario of business as usual (BAU), the four scenarios were analyzed to discover the effects of the proposed incentive schemes onto resident's willingness to pay for SHET. The results of ordered logit regression revealed that all the three proposed schemes would be effective and price subsidy appeared to be the strongest.

This study not only contributes to the literature on the topic of social acceptance of smart technology, but also helps the smart technology providers to understand the users of SHET and provide suggestions to policy makers on the promotion of smart technology into urban residents.

Publications

Journal papers

1. Ji, W. and E. H. W. Chan (2020). "Between users, functions, and evaluations: Exploring the social acceptance of smart energy homes in China." Energy Research & Social Science 69: 101637. (SSCI Index, Impact factor: 4.77)

2. Ji, W., & Chan, E. H. (2019). Critical Factors Influencing the Adoption of Smart Home Energy Technology in China: A Guangdong Province Case Study. Energies, 12(21), 4180. (SCI Index, Impact factor: 2.702)

Conference papers

1. Weiyu Ji, Edwin,Chan, Investigation of Factors Influencing the Adoption of Smart Home Energy Technology, CIB World Building Congress 2019, Hong Kong SAR, China, 17-21 June 2019

2. Weiyu Ji, Nan Guo, Edwin HW Chan, Comparative review of assessment methodologies of building embodied energy, Creative Construction Conference 2018, CCC 2018, 30 June 3 July 2018, Ljubljana, Slovenia

3. Nan Guo, Weiyu JI, et al. Carbon-emission Considerations in Built Heritage Conservation to Address the Climate Change, CIB World Building Congress 2019, Hong Kong SAR, China, 17-21 June 2019

4. Weiyu Ji, The adoption and willingness to pay for smart home energy technology by urban residents, International Workshop on Putting Sustainability into Convergence: Connecting Data, People, and Systems, Singapore, January 28-29, 2019

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Chapter 1 Introduction[1]

1.1 Background

1.1.1 Introduction to smart home energy technology

The residential sector accounts for 20% of total energy consumption worldwide, and is expected to increase continuously by 10% per year until 2040, resulting from the growth of population, economic development and improvement of living standards (IEA 2018). In recent years, with the rapid development of information and communication technology (ICT), building smart cities has been accepted as a promising strategy to mitigate the residential energy consumption and improve the living environment of urban residents (Shen, Huang et al. 2018).

At a micro-level, the smart home is a preliminary component of the smart city and promoting smart home technology (SHT) to urban residents has been an important part of government's smart city blue prints, with the purpose of providing residents with some benefits introduced by smart home, such as living comfort, energy efficiency, security, health, etc. (Balta-Ozkan, Davidson et al. 2013, Wilson, Hargreaves et al. 2017). Many authors in the literature have provided definitions of the smart home. For example, according to (Balta-Ozkan, Davidson et al. 2013):

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“A smart home is a residence equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants; and the term “smart home” may refer to any form of residence, including apartment, single house, town house, etc.” (Balta-Ozkan, Davidson et al. 2013)

In the literature, there are different perspectives on the concept of SHT. For example, SHT can be divided into three types by application (De Silva, Morikawa et al. 2012): detecting and recognizing occupants’ actions or health conditions; storing and retrieving of multimedia information captured in household; and capturing household data for surveillance. It can also be classified into four categories by service type: safety; e-health and assisted living; energy consumption and management; and entertainment (Balta-Ozkan, Davidson et al. 2013).

Among the four types of SHT, smart home energy technology (SHET) is a large and important category, offering energy management solutions to residents through its various functions, such as automation, remote control, energy feedback, and scheduling (Zhou, Li et al. 2016, Sanguinetti, Karlin et al. 2018). The overall framework for SHET is composed of smart meter, home energy management system (HEMS), user interface, and smart appliances (Zhou, Li et al. 2016). (Karlin, Ford et al. 2015) categorized the distinct SHET into three main groups: user interfaces, smart hardware and software platforms, as shown in Figure 1.1.

Figure 1.1 Classification of smart home products (Karlin, Ford et al. 2015)

In a smart home environment, the residents not only enjoy the energy conservation, indoor comfort, or convenience provided by SHET, but also switch their roles from passive energy consumers to active energy managers. SHET achieves its energy management goals in two ways: 1) providing residents with energy consumption information, to help residents cultivate energy saving behavior; and 2) providing residents with the ability to control their domestic appliances which can be scheduled or optimized via smart devices, so as to take advantage of electricity tariff policies to cut their energy bills (Karlin, Ford et al. 2015, Zhou, Li et al. 2016, Ford, Pritoni et al. 2017).

The capacity for energy savings from SHET has been demonstrated in many previous studies. In relation to user interface, the main products include energy portal, load monitor, and in home display (IHD). Energy feedback is the most important technical feature of these products for energy savings, providing users with information about their energy consumption. However, most of the products do not have control functions. Such products have been found to have the potential to save as much as 18% of energy use (Ford, Pritoni et al. 2017).

Smart hardware products include smart appliances, smart light, smart thermostat, smart plug/ switch and hubs. Smart appliances can be schedulable or non-schedulable. The first are those such as washing machines, air conditioners etc., which operation can be scheduled for designated time with the appliance finishing the task on time without manual operation. The second are those such as televisions and refrigerators, whose operation still relies on manual instruction (Zhou, Li et al. 2016, Mert and Tritthart 2018).

Through the load monitor, smart appliances can provide appliance-level energy consumption information to the user, which was found through a series of experiments to generate energy savings from 10 to 20% (Seligman and Darley 1977, Vassileva, Dahlquist et al. 2013, Ford, Pritoni et al. 2017). For example, (Wood and Newborough 2003) carried out a field study in the United Kingdom (UK) involving 44 households, and reported an average 15% energy reduction for households employing electronic energy feedback technology for their domestic cooking appliances. Moreover, smart appliances alone could also provide benefit through peak-load reduction by scheduling operation time to an off-peak period. This is an application of smart grid technology, known as demand side management (DSM). Together with a time of use (TOU) electricity price scheme offered by the utility company, DSM could assist households to achieve savings (Arun and Selvan 2018).

As for smart lighting, many previous studies focused on the smart lighting control systems with occupancy or illumination sensors in commercial buildings and office environments. The energy saving potential has been convincing (Soori and Vishwas 2013, Haq, Hassan et al. 2014).

However, the attention given to home lighting has been less compared with lighting in the commercial sector. (Tang, Kalavally et al. 2017) proposed a prototype of a smart home lighting system and achieved power savings of 54.7% from lab simulation.

The home energy management system (HEMS) is a platform for demand side management (DSM), that can optimize and schedule the operation of household appliances by communicating within the devices, and receiving external information (e.g., renewable energy generation or grid tariff) , so as to monitor, manage and improve the energy consumption of the smart home (Son, Pulkkinen et al. 2010, Beaudin and Zareipour 2015, Zhou, Li et al. 2016). In their review about the HEMS, (Beaudin and Zareipour 2015) summarized that HEMS could reduce the operational cost of electricity by 23.1%, or reduce residential peak demand by 29.6%. Other research pointed out the energy saving capability of HEMS depends on the extent of system integration, implying that an integrated system connected with more smart appliances could save more (Meyers, Williams et al. 2010, Ford, Pritoni et al. 2017).

1.1.2 Social acceptance of smart home energy technology

Despite the huge potential market of smart technologies in residential sector, with a global penetration rate of 1.67% (Statista 2019), the adoption of SHET is still at a low level. The Netherlands and Norway are the top two countries with penetration rates of 15.3% and 11.4%, respectively, compared with China which has a rate of only 4.1% (Statista 2019) . The previous research about SHET have been predominantly technology-centric, focusing on the improvement and expansion of technical functions, including optimization of operating or control system, increasing the capability of energy storage or energy saving, and development of uniform data transmission protocol, etc. (Beaudin and Zareipour 2015, Ford, Pritoni et al. 2017). However, the technology alone cannot achieve the goal of energy saving. It is necessary to promote the adoption and diffusion of SHET through the residents and cultivate of their energy-saving behavioral habits, which is a multi-disciplinary problem relevant with technical, economic, social, and behavioral factors. Currently, there has not been much research in this area, especially in the context of China. This paper will try to fill this gap by investigating the set of technical, economic, social and psychological factors affecting the adoption behavior of residents towards SHET.

In recent years, academia has realized the importance of user's role in the social acceptance of SHT. Some studies have begun to center on issues relevant to users, such as user's perceptions, attitudes, or expectations about the technology service provided by SHET. According to past findings, benefits introduced by SHET that have been perceived by users include energy conversation, saving on energy bills, improving the quality of life, comfort, convenience, being environment friendly and, flexibility. The barriers or risks hindering the implementation of SHET include fitting it into current life styles, difficulties over administration, interoperability, and reliability, loss of control, technical complexity, privacy and security; lack of trust in the utility company or government, acquisition and maintenance costs, and lack of knowledge (Mah, van der Vleuten et al. 2012, Paetz, Dütschke et al. 2012, Balta-Ozkan, Davidson et al. 2013, Balta-Ozkan, Davidson et al. 2013, Balta-Ozkan, Boteler et al. 2014, Bhati, Hansen et al. 2017, Wilson, Hargreaves et al. 2017, Parag and Butbul 2018, Marikyan, Papagiannidis et al. 2019).

Some other research has investigated the factors influencing the adoption of SHET through theories of behavioral and psychological science, including the Technology Acceptance Model (TAM) (Davis 1989) and Theory of Planned Behavior (TPB) (Ajzen 1991). Based on these theoretical backbones, some factors facilitating SHET adoption have been investigated, including in relation to perception or attitude, such as perceived usefulness, perceived ease of use, attitude, perceived cost, perceived risk to privacy (Park, Kim et al. 2014, Raimi and Carrico 2016, Chen, Xu et al. 2017, Kim, Park et al. 2017, Park, Cho et al. 2017, Yang, Lee et al. 2017, Ji and Chan 2019). Some factors involved in social and personal norms, such as environmental awareness, social contribution, innovativeness (Park, Hwang et al. 2017, Milchram, van de Kaa et al. 2018, Ji and Chan 2019). Others related to facilitating conditional factors, such as knowledge, experience and financial capability (Chen, Xu et al. 2017, Kim, Park et al. 2017, Milchram, van de Kaa et al. 2018, Ji and Chan 2019). However, all these findings were based on research methodologies that used questionnaire surveys, focus groups and interviews by experts or local residents, which have inherent constraints in terms of demographic information, regional culture, living habits, or life styles etc. These previous findings thus have limitations in relation to applicability to other regions.

1.1.3 Incentive policies for SHET promotion

Under pressure to reduce the energy consumption of the residential sector, several countries' governments have proposed various policies or strategies to promote smart technology in home energy saving, such as European Commission's "Create technologies and services for smart homes that provide smart solutions to energy consumers" (Balta-Ozkan, Boteler et al. 2014) and the Hong Kong Smart City Blueprint 2017: “Promote and support households to utilize smart home mobile apps to monitor household energy consumption and set targets” (HKSAR 2017). In Singapore, some households were selected to install HEMS, in a collaboration between the Singapore government and Panasonic (Bhati, Hansen et al. 2017).

In China, the government has also announced several strategies to support the development of the smart home industry. The 13th Five-Year Plan was the first time the national government has announced to develop the smart home industry. In 2016, the “Guideline for building a comprehensive and standardization system for smart homes” was jointly issued by the Ministry of Industry and Information Technology (MIIT) and the Standardization Administration of China (SAC) (MIIT 2016). This proposed that a standard system for meeting the requirements of development for China’s smart home industry should be preliminarily established by 2020. In (State Council 2017), the smart home was designated as one of the six key areas for future development. In October 2018, the State Council issued “Opinions on improving the system and mechanism for promoting consumption and stimulating the consumption potential of residents” (State Council 2018) , which also explicitly mentioned upgrading intelligent, high-end and integrated information products, focusing on developing smart home and other information technology products, and promoting green, low carbon products.

Nevertheless, all the strategies planned by the Chinese government remain at the national and industry level, and have not considered the micro-level of the consumer and households. To successfully realize the social contribution that can be brought about by smart technology, a wide adoption of technology through the whole of society is needed, which must address the psychological, behavioral and economic requirements of consumers. Regrettably, so far, there have not so far been any policies specifically targeting consumers to promote smart home technology.

1.2 Research Scope

1.2.1 Adoption behavior of SHET

Generally, energy saving behavior can be classified into two fundamental types: habitual behavior and purchasing behavior (Barr, Gilg et al. 2005). Habitual energy-saving behavior, also known as curtailment behavior (Gardner and Stern 1996) refers to some repetitive daily activities related to direct reduction of household energy consumption, such as thermostat setting, turning off lights when leaving the house, unplugging appliances after use, etc. (Van Raaij and Verhallen 1983, Barr, Gilg et al. 2005).

The other type of energy-saving behavior is purchasing related, also known as "technology choice" (Stern 1992), or "energy efficiency choice" (Black, Stern et al. 1985) or efficiency behavior (Gardner and Stern 1996) . This kind of behavior is one-time behavior related to a purchase (Abrahamse, Steg et al. 2005). For example, making which makes some changes to the exterior or interior of the house, which requires financial investment or utilization of technical resources (Barr, Gilg et al. 2005), including the adoption of new energy efficiency technologies in the household (Blommestein and Daim 2013), home energy renovation (Gyberg and Palm 2009), installation of home energy management system (Washizu, Nakano et al. 2019, Yang and Lam 2019) or purchasing energy labeled appliances (Zhou and Bukenya 2016), etc.

The thesis will focus on the second type of energy saving behavior- technology choice, targeting to the adoption behavior of smart home energy technology.

1.2.2 Why focus on Chinese urban residents

China has a huge population of 1.4 billion, and is experiencing a period of rapid economy development. In line with the improvement in living standards, the residential sector in China has been accounting for an increasing percentage of total primary energy consumption (Zhou 2009). It has been convinced that the extensive adoption of SHET will be beneficial to relieving the energy problem of residential buildings, and the Chinese government also has deemed smart home technology as a new industry with a national focus of attention, with a series of policies being implemented for future development.

In 2016, the Chinese national government has definitely announced to support the development of the smart home industry, including to promote smart manufacture in the household appliance industry, and to accelerate the application and industrialization of smart hardware and software products (MIIT 2016). (MIIT 2016) put forward a standard system meeting the development needs of China's smart households industry would be preliminarily established by 2020. In 2017, the smart home industry was defined by the State Council to be one of the six strategic key areas with priority development (Council 2017). In October 2018, the State Council issued several proposals for improving the mechanisms to stimulate the consumption potential of residents (Council 2018), which explicitly mentioned upgrading intelligent, high-end and integrated information products, focusing on developing smart household products.

With these policies implemented, the SHT industry in China has achieved rapid progress, with lots of products launched in the market. However, the current household penetration rate of SHET in China is only 4.1%, far behind that of the USA and some European countries (Statista 2019). There is a gap between the SHET industry and actual adoption by Chinese urban residents. As SHET is highly involved in the way a household lives through its various functions, , it is necessary to accurately understand the user's need for, expectations of and perceptions towards SHET in order to boost the adoption rate.

Moreover, the smart city is part of the strategic planning of the Chinese government to achieve its goal of sustainable development. Until now, a total of 290 cities have announced that they will join the smart city strategy, and a series of policies have been released (Shen, Huang et al. 2018). As one elementary component of the smart city, smart homes relates to the successful implementation of the smart gird, the growth in smart technology consumer goods, and the cultivation of a low carbon, environmental and smart life style by urban residents. The wide adoption of SHET by city dwellers is a significant step in the development of the smart home and smart city.

Against this background, this paper will take one category of SHT- SHET as the object of study. The research scope is limited to the investigation of the issues relevant to the adoption of SHET by urban residents in China.

1.2.3 Why select Guangdong as the study area?

Figure 1.2 Location of Guangdong Province (Economist 2011)

In this thesis, the Guangdong province of China is selected as the research area. Guangdong is located in the southern part of China, bordering with Hong Kong and Macau, as shown by Figure 1.2 (Economist 2011). It is the birthplace of the policy for the reform and opening-up of China. As the first pilot area for the market economy, Guangdong has been the driving force for the growth of the Chinese economy and has achieved the highest GDP of all the provinces and municipalities for several years (Kroll and Tagscherer 2009). High-tech industry is a significant and strategic component of Guangdong's economy, especially the electronic, and ICT industries, which have been ranked first in China for twenty years. Through years of rapid development, Guangdong has secured the headquarters of several famous high tech giants, such as Huawei, Tecent, ZTE, and also has plenty of growing small and medium-sized technology companies.

From the perspective of policy, the Guangdong provincial government has formulated a series of policies to support the development of the electronic and ICT industry, such as “Opinions on accelerating the development of the IOT and building smart Guangdong” in 2010; and “The 12th five-year plan for the development of high-end electronic information industry in Guangdong” in 2012. Both policies emphasized the future research and development of Internet of Things (IOT) technology and its application for the smart city and the smart living of urban residents. Additionally, in 2010, Guangdong became one of the low-carbon pilot provinces in China. Since then, the Guangdong government has begun to actively formulate policies to reduce carbon emission. Compared to the national policies, the low-carbon policies of Guangdong are more ambitious and Guangdong has become the frontrunner in energy conservation and emission reduction (Cheng, Dai et al. 2016). In 2018, the provincial government issued “The 13th five-year plan for controlling greenhouse gas emissions in Guangdong”, including new targets for energy saving for industry, building, transportation and public institutions; the development of non-fossil energy; the construction of low carbon building, and the promotion of low carbon living style by residents, such as energy-saving behavior, adoption of energy-saving appliances, etc.(G.D. 2017). Correspondingly, the building authority in Guangdong also released “The 13th five-year plan of building energy conservation and green building development”, underlying the core work including improvement of new green buildings and the renovation of existing buildings, promotion of energy-saving building technology and materials, and utilization of renewable energy in buildings, etc. (G.D. 2017) All these government plans have provided a good policy environment for the research and development of IOT technology, green building and energy efficiency technology.

In addition to the government, the state monopoly power enterprise, which is in charge of the electricity supply for the whole of Guangdong, the China Southern Power Grid (CSPG) published its “The 13th five-year plan for smart grid development”. Under the vision of the CSPG, a comprehensive smart grid system will be built in Guangdong, to provide clean electricity generation, flexible electricity distribution, interactive electricity consumption and integration with internet and information technology (CSPG 2017).

As for the demographic factor, Guangdong is the most populous province in China, having 8% of the total population, among which 75.4 % are young and middle aged (15~64 years old), higher than the national average level (71.8%); and only 7.7% are the old group (> 65 years old) (China 2018). Guangdong has the largest proportion of young and middle aged compared to other provinces. Lots of previous studies, such as the Diffusion of Innovation Theory, pointed out that the younger people are more likely to be early adopters of new technology (Rogers 2010). (Venkatesh, Morris et al. 2003) empirically verified that the younger would have a stronger perception about the performance of new information technology. Besides, some previous studies also found that the younger generation had higher intention to use the energy efficient technology, including the heating innovation facilities (Mahapatra and Gustavsson 2008), micro-generation technology (Willis, Scarpa et al. 2011), and energy management system (Yang and Lam 2019).

Therefore, of the 34 provinces in China, Guangdong is the most suitable to be a frontier region to promote SHET to urban residents; because of its ambitious policy environment for smart industry and smart city (Cheng, Dai et al. 2016, Ji and Chan 2019), as well as the conglomeration of high-tech companies covering all categories of smart technology, and its demographic situation. Research on Guangdong as the target area could provide policy implications for government and market strategies for industry to promote the diffusion of SHET; however, taking Guangdong as the study area will not only benefit the local residents and industry, but the results can also be used as a paradigm for other provinces in China. Under the national strategy of smart city development (Shen, Huang et al. 2018), in the near future, other provinces will have to resolve the current issues faced by Guangdong Province.

1.2.4 Concept map

The research topic in this study and the research scope are illustrated by Figure 1.3:

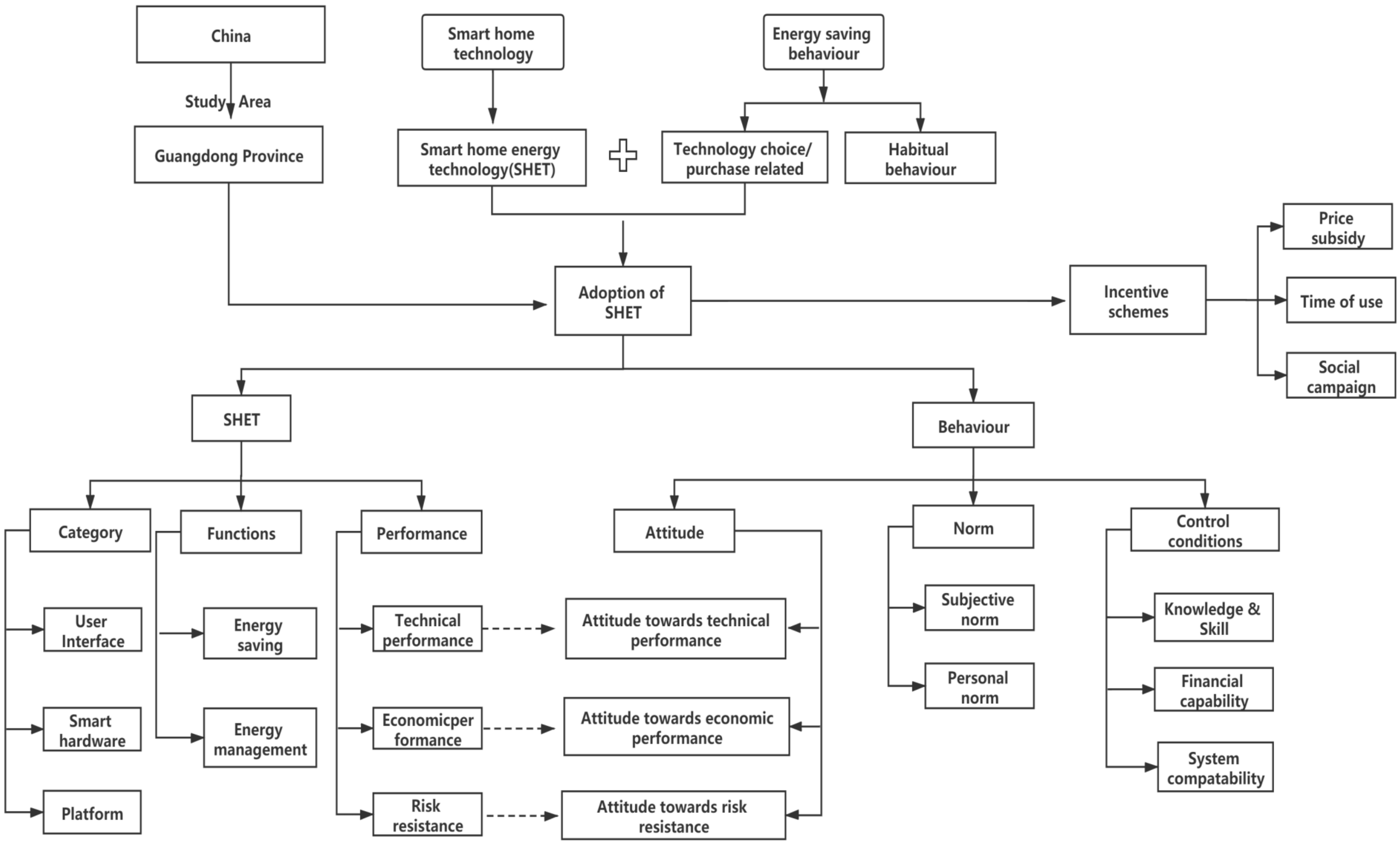

Figure 1.3 Concept map of the research topic

1.3 Research Aim and Objective

1.3.1 Research aim

The aim of this thesis is to contribute to the understanding of perceptions about the smart home energy technology by Chinese urban residents and provide analysis of the behavioral, social, psychological factors that explain people's adoption intentions, in order to provide some suggestions about incentive schemes to government and industry for promoting the diffusion of smart home energy technology through urban residents.

1.3.2 Study objective

In order to achieve the research aim, through the process of the whole research, the specific study objectives are as below:

1) To investigate the key performance indicators representing the complicated attributes of smart home energy technology;
2) To develop measurement scales for investigating the urban resident's adoption intentions about smart home energy technology;
3) To identify the critical factors influencing the adoption of smart home energy technology;
4) Discussion of the incentive schemes that will facilitate urban residents to adopt smart home energy technology.

1.4 Research Method in Brief

This section presents a brief overview of the overall research process and the methodologies adopted in each research phase. The research methodologies have been described in detail in Chapter 3. In order to achieve the research aim and objectives established for the thesis, the research process was divided into five sequential phases, covering preliminary research and four formal phases, as illustrated in Figure 1.4.

In the preliminary research phase, through a literature review and discussions, this study decided on the adoption of SHET by urban residents in China as the research topic, established the research aim and objectives, and understood the research background.

The formal research work started after the preliminary research. The task of Phase 1 was to conduct a comprehensive literature review relating to the research objectives, including the investigation of the key performance indicators for smart home energy technology and a review of the attitude and behavioral theories explaining environmentally friendly behavior. Additionally, incentive policies and previous social experiments for the promotion of energy efficiency were also reviewed. The literature reviewed in Phase 1 included journal and conference papers, books, industry reports and government reports. The preliminary theoretical framework for this study was established after the comprehensive literature review in Phase 1.

The task of Phase 2 was data collection by organizing a structured questionnaire survey in the targeted study area. The structured questionnaire contained three parts. The first part collected demographic information, including gender, age, education, household income, the number of household members and property ownership. The second part surveyed respondents' attitudes towards technology performance, economic performance and risk resistance to SHET, as well as the respondents' perceptions about subjective norms, personal norms and perceived behavioral control. The measurement items and measurement scale of the questionnaire referred to the questionnaires developed for the Theory of Planned Behavior study (Ajzen 1991) and the widely used manual written by Francis et al. (Francis, Eccles et al. 2004). The third part of the structured survey was based on scenario analysis, in the form of contingent valuation, and the survey item was to ask the respondents to indicate the maximum they were willing to pay (WTP) for SHET under various incentive scheme scenarios. The third part of the data collection was in preparation for Phase 4.

The tasks of Phase 3 were to undertake a quantitative analysis of the data collected in the structured questionnaire survey in Phase 2. The first task was to conduct an exploratory factor analysis (EFA) to investigate the underlying structure of all the indicators surveyed through the questionnaire and determine the factors which could be explained by the retained indicators. After finishing the EFA, the preliminary theoretical framework was constructed and finalized, and seven research hypotheses established. The second task was to test the research hypotheses with PLS-SEM, aiming to find out the significant critical factors influencing the adoption intentions for SHET of urban residents. After completing the quantitative analysis, a comprehensive discussion about the critical influential factors was undertaken.

The objective of Phase 4 was to provide suggestions about incentive schemes to promote the adoption of SHET by urban residents. To achieve this, a literature review of the current policies and previous social experiments for the promotion of energy efficiency technology had been done in Phase 1, and data on respondents' WTP for SHET under each scheme scenario had been collected in the third part of the survey in Phase 2. Therefore, based on the preparatory work completed in previous phases, an ordered logit regression was adopted for data analysis and calculating the expected value of respondents' WTP for SHET under each proposed scheme scenario. A comparison and discussion of the proposed schemes were then produced, and, finally, the conclusion of this study was reached based on the findings from Phases 3 and 4.

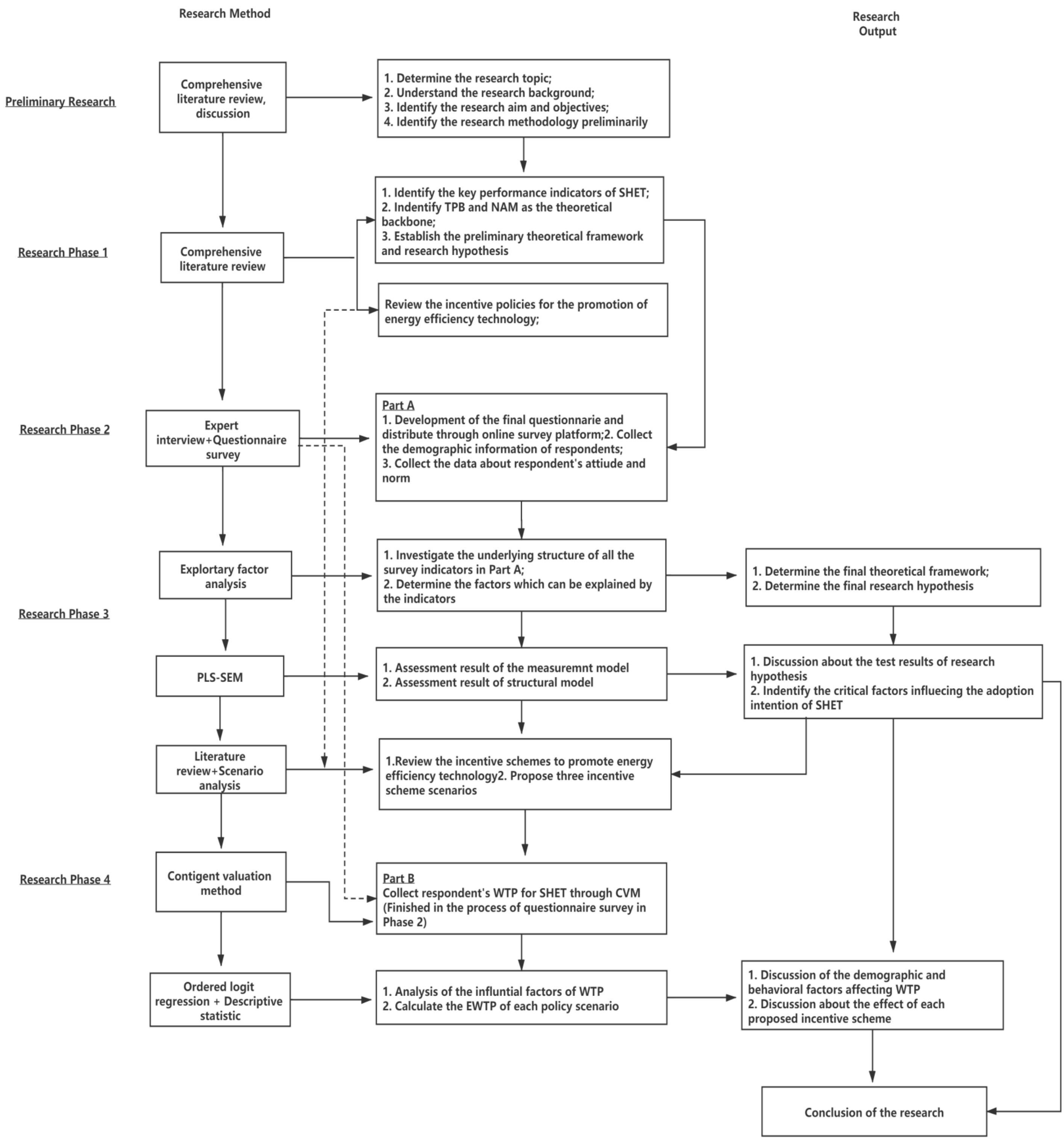

Figure 1.4 The overall research process of the study

1.5 Structure of Thesis

This thesis is structured by eight chapters:

Chapter 1 introduces the research background, including the concepts of the smart home and SHET, the categories and functions of SHET, with a focus on the energy-saving potential, the social acceptance of SHET and the incentive policies implemented by various country governments for SHET promotion. After the background introduction, the research scope is defined as the adoption behavior for SHET of urban residents in China, taking Guangdong as the study area, considering the macro-environment of policy, economy, industry development and demographic structure, in hopes of using Guangdong as a paradigm for other regions of China. In Chapter 1, the overall research aim and objectives are also established, followed by a description of the overall research procedure and a simple introduction to the research methodologies employed in each research phase.

Chapter 2 presents a comprehensive literature review relevant to the research topic. The review is in three parts: key performance indicators representing the attributes of SHET, the attitude, norms and behavior theories to explain energy-saving behavior in technology choice, and policies that have been implemented by governments or social experiments by researchers to promote energy efficiency. Through the literature review, twelve indicators are identified to represent the various performances of SHET: indicators associated with technical performance-automation, controllability, feedback, improving living comfort, convenient operation and system interoperability; indicators of economic performance-saving energy expense, inexpensive maintenance and cost effectiveness; and indicators of risk resistance-reliability, safety and privacy protection. The theoretical backbone of this study is also determined: to integrate the personal norm from the Norm Activation Model (NAM) with the TPB. Additionally, the review of incentive policies and social experiments provides references to design the scenario of incentive schemes to facilitate the adoption of SHET by urban residents. After the literature review, the preliminary research framework for this study is established.

Chapter 3 gives a detail description about the research methodologies applied in each research phase, and the rationales for the methodology selection. In line with the research procedure, the research methodologies include comprehensive literature review, questionnaire survey, exploratory factor analysis, structural equation modeling, scenario analysis, contingent valuation method, and the ordered logit regression.

Chapter 4 presents the development of theoretical framework and proposing research hypothesis for this study. On the basis of the theoretical backbone, and review of the performance of SHET, people's adoption intention is expected to be influenced by seven factors, including attitude towards the technical performance (ATTP), attitude towards economic performance (ATEP), attitude towards risk resistance (ATRR), perceived behavioral control (PBC), subjective norm (SN), and personal norm (PN), and demographic background containing gender, age, education, household income, property ownership. Correspondingly, seven research hypotheses are proposed: 1) ATTP is positively related with urban resident's adoption intention of SHET; 2) ATEP is positively related with urban resident's adoption intention of SHET; 3) ATRR will influence the adoption intention of SHET positively; 4) PBC will have a positive influence onto the adoption intention of SHET by urban residents; 5) SN has a positive relation with the adoption intention of SHET by urban residents; 6) PN will affect the adoption intention of SHET positively; 7) demographic factors will have significant influence onto the adoption intention of SHET.

Chapter 5 describes the detail process of the development of questionnaire survey; introduces the background of survey respondents; presents the descriptive analysis result of respondents' evaluation about the measurement indicator, and also the results of EFA. The development of the measurement items refers to the format of the traditional questionnaires used for a TPB study, and a five-point Likert scale is adopted as the measurement scale in the survey. The questionnaire survey was carried out in 2019 through an online survey platform, with a 92% respondent rate – 2391 responses returned from the total 2600 distributed questionnaires. After data screening with the criteria of the living area (urban), age (18~60 years old); sex ratio (consistent with sex ratio in Guangdong: 109.51 males per 100 females), finally a data sample of 1490 was composed. After the EFA, 19 indicators were retained. Based on the research hypothesis proposed in chapter 4, Factor 1 was labeled as ATTP, with associated indicators of automation, controllability, feedback, convenient operation, improving living comfort and system interoperability. Factor 2 was labeled as ATEP, with the associated indicators of save energy expense, inexpensive maintenance and cost effectiveness. Factor 3 was labeled as ATRR, with indicators of system reliability, safety and privacy. Factor 4 was labeled as PBC, and the relevant indicators were knowledge and skill, financial capability, and system comparability. SN was Factor 5, with indicators of public opinion and support from family and friends, and the indicator of media opinion was deleted. PN was the sixth factor with indicators of environmental concern and innovativeness; the indicator social responsibility was deleted.

Chapter 6 presents the empirical analysis of the surveyed data by PLS-SEM and the results discussion. First it presents the complete PLS-SEM model, composed by a measurement model and a structural model. Then the validity of the measurement model and the structural model is assessed. The validly of the measurement model is assessed by convergent validity and discriminant validly. The structural model is assessed by the R^2 measure, and Stone-Geisser's Q^2 value. The PLS-SEM results reveal that ATTP, PBC, SN and PN have significant positive influence onto the adoption intention of SHET. However, the hypotheses of ATEP and ATRR are rejected. On demographic factors, the only significant impact is from education, with a bachelor degree having a positive influence on the adoption intention. The significance of gender, age, household income and property ownership cannot be supported by the data. A comprehensive discussion is also conducted based on the PLS-SEM results.

Chapter 7 presents the process of the contingent valuation to get the WTP for smart home energy technology under various proposed incentive scheme scenarios and the discussion of the results. Four incentive schemes are proposed, based on the literature review of the policies and social experiments to promote energy efficiency: a price subsidy scheme, a TOU pricing plan scheme and a community energy saving campaign. Data revealing respondents' WTP for SHET was collected by the third part of the questionnaire (described in Chapter 3.7), and an ordered logit regression (OLR) is carried out for data analysis and to calculate the expected value of WTP under each proposed scenario, together with the scenario of business as usual (BAU). Based on the results of the OLR, discussion and comparison of these incentive schemes are provided.

Chapter 8 consolidates all the findings through the whole research process and comes into conclusions about the critical influential factors for the adoption intention on SHET by urban residents in China, as well as providing recommendations to the potential incentive schemes for technology promotion, and pointing out the research limitations and the direction of future efforts.

The structure of the eight chapter of the thesis is illustrated by Figure 1.5.

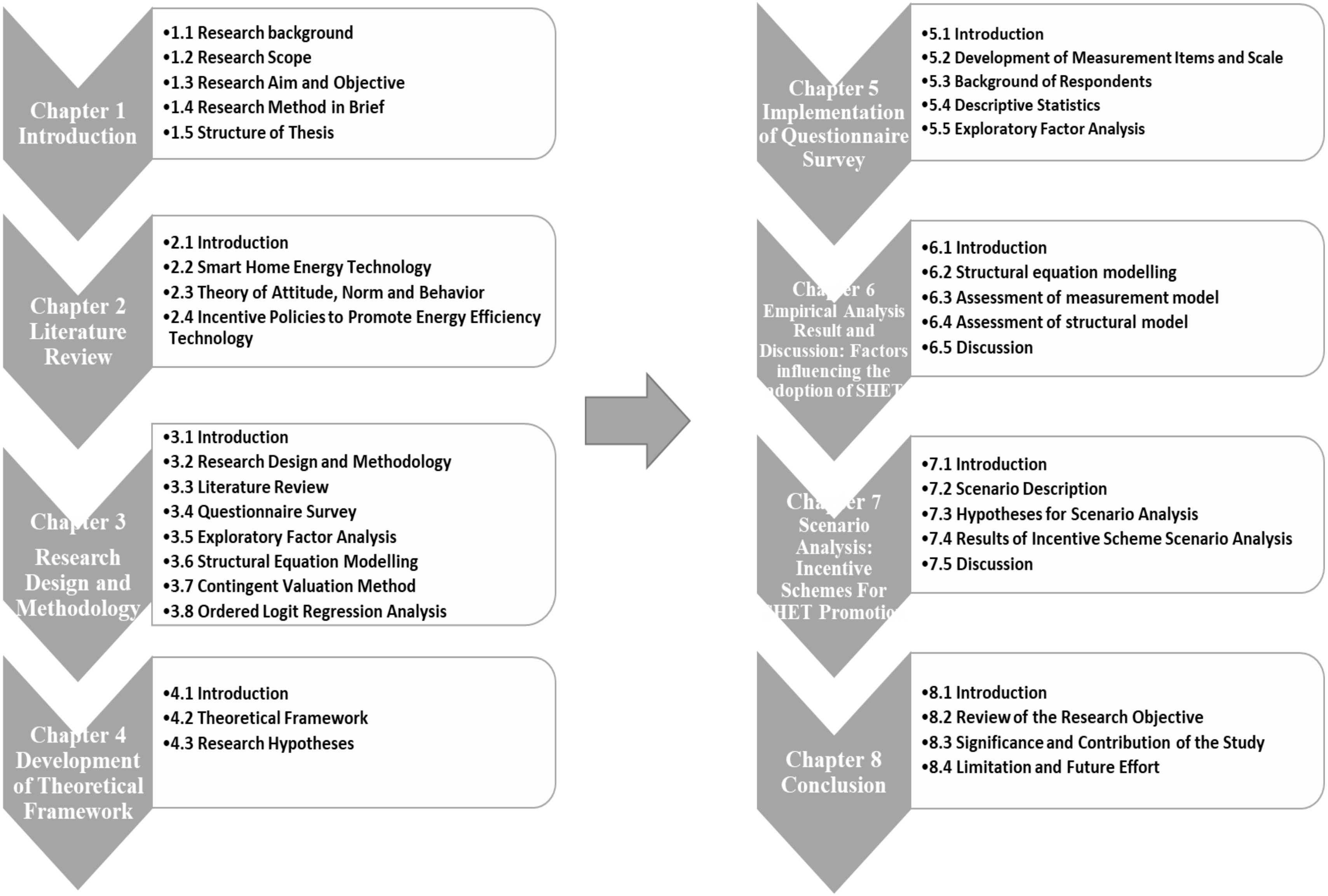

Figure 1.5 The flowchart of the thesis structure

Chapter 2 Literature Review

2.1 Introduction

This chapter presents a comprehensive literature review relevant with the research topic. The review includes three parts: key performance indicators representing the attributes of SHET, the attitude, norm and behavior theories to explain human's energy saving behavior of technology choice, and polices that have been implemented by governments or the social experiments performed by researchers to promote energy efficiency. Through the literature review, twelve indicators investigated to represent the various performances of SHET, including the indicators associated with technical performance, like automation, controllability, feedback, improving living comfort, convenient operation, system interoperability; the indicators involved with the economic performance: saving energy expense, inexpensive maintenance, cost effectiveness; and also the indicators relevant with the capability of risk resistance: reliability, safety, and privacy protection. The theoretical backbone of this study is also determined, which is to integrate the personal norm from Norm Activation Model (NAM) with the theory of planned behavior (TPB). Additionally, the review of incentive measures and social experiments provide reference to design the scenario of incentive schemes to facilitate the adoption of SHET by urban residents. After literature review, the preliminary research framework for this study is established.

2.2 Smart Home Energy Technology[2]

2.2.1 Automation

Automation refers to the ability of a technology to execute types of functions in a self-operative mode with minimum human intervention (Wong, Li et al. 2008, Wong, Leung et al. 2017). (Wong and Li 2006) stated that building automation system had the highest importance compared to other technical attributes of intelligent building. Automation is the heart and the origination of smart technologies to engage end users to monitor and control their household energy use (Wong and So 1997, Withanage, Ashok et al. 2014, Arditi 2015). Home automation system, as the stepping stone of smart home, compromises a number of sub-systems for controlling various aspects of a house, including HVAC, lighting control, energy management, security, entertainment etc. (Humphries, Rasmussen et al. 1997), which is the key point for a smart home to achieve all its benefits for the occupants. Just as suggested by (Parag and Butbul 2018), home automation is one type of seamless technology to realize the interaction between home dweller and smart grid so as to reshape people's energy consumption behaviors.

Because of the significance of home automation, in the industry, some technology companies have deemed this point as the emphasis of their research and development, such as proposing new communication standards, or expanding the automaticity, etc. (Brush, Lee et al. 2011, Asadullah and Raza 2016, Ford, Pritoni et al. 2017). From the user's perspective, the degree of

[2] This part of the thesis has been published in journal paper: Ji, W. and E. H. W. Chan (2020). "Between users, functions, and evaluations: Exploring the social acceptance of smart energy homes in China." Energy Research & Social Science 69: 101637.

smartness that their homes could achieve is deeply related with the level of automation; and of course users would enjoy more convenience from the smarter home (Darby 2018). Upon the above thoughts, automation is determined as a KPI to evaluate the ability of SHET to fulfill self-operating and providing smartness to users.

2.2.2 Controllability

The controllability means the state of being controllable; while automation could engage the home to be much smarter, the controllability is also a significant attribute for automation system, and losing a standard controllable process may even lead to a system failure in the home (Sadrieh and Bahri 2014).

Although users welcome the advantages introduced by home automation, technically, it is hardly to realize the perfect accuracy of automation and some system errors are unavoidable. Even if the errors are uncommon, they will still cause troubles and losses for users without rapid fixing, under which situation, it is necessary for users to interrupt the automatic process, actively control the operation, and restart the system (Roy, Zhang et al. 2019). From user's view, the controllability reveals their requirements to keep the domestic sophisticated technology system under well control (Mert and Tritthart 2012). Controllability also indicates user's concern about losing control of complicated technology system in a smart household environment, therefore, users expect the SHET could work in the mode of adaptable, correctable, schedulable, and plannable (Wong, Leung et al. 2017). The user's worry of controllability is consistent with the finding of (Krishnamurti, Schwartz et al. 2012), that US consumers felt afraid of less control over electricity consumption due to the adoption of smart meters.

Therefore, in this study, controllability is accepted as a KPI to evaluate the capability of smart home system to become controllable under some accidental conditions.

2.2.3 Feedback

Feedback, also named as eco-feedback, energy monitoring, smart energy information, etc., is a technology function assisting the household residents to save energy by providing the information of their energy consumption (Strengers 2013). Based on the place of feedback display (mobile phone APP, appliance embedded, or in-home display) and the information that feedback delivers (energy consumption during a period, energy bill, or associated carbon emission), there are numerous types of feedback function in the market (Wood and Newborough 2007, Strengers 2013).

The feasibility in energy saving of feedback has been empirically confirmed by many past studies (Ehrhardt-Martinez, Donnelly et al. 2010, Beth, Zinger et al. 2015); however, the outcome of saving energy has been found to have significant variations depending on the type of feedback (Wood, Day et al. 2019). (Sanguinetti, Dombrovski et al. 2018) has asserted that the design of feedback technology should be more diverse and effective by integrating human-computer interaction approach and behavioral science. Both (Wood and Newborough 2007) and (Ehrhardt-Martinez, Donnelly et al. 2010) have concluded that some motivational factors, including the goal setting, self-competition and monetary rewards can improve the effectiveness of feedback. The finding of a household trail organized in England suggested that the users would have better understandings of their energy consumptions if to incorporate some contextual information, such as indoor environment conditions into feedback displays (Wood, Day et al. 2019). Here the feedback is deemed as a KPI to evaluate the feedback function of SHET; no doubt users would value higher for the more effective function and user friendly design.

The significance of feedback in energy saving has been confirmed by many studies (Ehrhardt-Martinez, Donnelly et al. 2010, Beth, Zinger et al. 2015); for example, (Ford, Pritoni et al. 2017) summarized that the in-home displays (IHDs) with whole home energy feedback could achieve energy savings by 18%; and the appliance-level feedback could yield savings from 12 to 20%. However, currently, not many users have been able to perceive the importance of feedback technology in their daily energy saving behaviors. In China, government ever enacted several policies to diffuse energy monitor technology through public buildings, but the effect was poor (Liu, Liu et al. 2020); and in residential sector, there is lacking of programs or initiatives to promote the energy feedback technology (Zhang, Shen et al. 2019). Although many smart products with energy feedback function have been launched into market, urban residents have not been able to realize the usefulness of feedback for energy conservation. In future, the government and SHET industry need mutual efforts to educate residents about the effectiveness of energy feedback technology, and enhance the awareness of residents to actively participate in the energy feedback action.

2.2.4 Improving living comfort

One objective of SHET is to improve the indoor comfort for occupants by automatically adjusting room temperature, humidity and illumination (Cook 2012, Balta-Ozkan, Davidson et al. 2013, Gram-Hanssen and Darby 2018). The findings of some previous surveys also showed that comfort was an influential factor for the acceptance of smart technology: for example, (Bhati, Hansen et al. 2017) reported that comfort was one of important motivations for respondents to adopt SHET in Singapore; and (Parag and Butbul 2018) also indicated that expected adopters of smart technology valued the comfort more than the associated risk in Israel.

Currently, there is an argument that the pursuit of maximum home energy saving will sacrifice some indoor comfort, which is not at user's will. The development of SHET system should not only consider to reduce the domestic energy expense but also incorporating home owner's preference about comfort and living habits to achieve an optimal state (Anvari-Moghaddam, Monsef et al. 2015). Obviously, at user's standpoint, they would like to get dual and balanced benefits from indoor comfort and utility bills saving, and they will give a better evaluation for those SHET enabling the automatic energy saving without lowering their comfort levels (Schweizer, Zehnder et al. 2015). Therefore, improving living comfort is selected as a KPI here to measure SHET's technical performance.

2.2.5 Convenient operation

The convenient operation means that it is convenient for users to handle the SHET; whatever the usage experience, the education background, or the age. Technically, achievement of convenient user experience is a significant goal to design and develop smart home products; meanwhile, many studies have been carried out for improving the convenience of user interface, or operating and control system (Koskela, Väänänen-Vainio-Mattila et al. 2004, Pandharipande and Caicedo 2015). (Balta-Ozkan, Davidson et al. 2013) has pointed that the design of smart technology should be fitting to resident's lifestyles, and some opinions also suggest that convenience is more important than financial savings. The focus group study of (Paetz, Dütschke et al. 2012) concluded that integrating consumer experience into the technology design, and providing user high degree of convenience would be a significant incentive for the technology adoption. On the basis of the previous findings, the convenient operation is determined as a KPI here to measure the convenience level for users to operate SHET.

2.2.6 System interoperability

The definition of interoperability is the ability of different products or systems to exchange information and work together without modification or restriction (Dictionary). In a smart home environment, different smart appliances or devices need to communicate and operate collaboratively to realize the goal of one stop energy management for users. Additionally, as the smart technology is evolving, the current SHET will need to be updated for changes in user's requirements and preferences (Balta-Ozkan, Davidson et al. 2013). In user's expectation, as the technology is under development, the existing smart products must be able to exchange information and compatibly operate with future technologies. Therefore, system interoperability is adopted as a KPI for SHET, reflecting the capacity of SHET to be compatible with the existing building internet system, and collaborate with future new smart devices.

2.2.7 Saving energy expense

No doubt saving energy expense is the most important objective to develop, promote and accept SHET from the views of all industry, government as well as urban residents (Balta-Ozkan, Boteler et al. 2014, Bhati, Hansen et al. 2017, Park, Hwang et al. 2017, Strengers and Nicholls 2017, Wilson, Hargreaves et al. 2017, Parag and Butbul 2018, Sanguinetti, Karlin et al. 2018). Technically, the energy saving capability of SHET has been convinced by many studies (Ford, Pritoni et al. 2017), while someone argued that as SHET would bring some changes to living style, it was pointless if the saving is little compared to the troubles (Balta-Ozkan, Davidson et al. 2013). Therefore, the SHET exhibiting better performance in energy saving will get higher assessment from users. In this thesis, saving energy expense is perceived as a KPI to evaluate the capability of SHET to create economic benefits for users.

2.2.8 Inexpensive maintenance

In the highly integrated and connected smart home environment, it is probable that the breakdown of one single equipment causing the failure of whole system, hereby generating a large sum of maintenance fee. The participants of past studies have expressed their concerns about losing control of maintenance cost (Balta-Ozkan, Davidson et al. 2013, Balta-Ozkan, Boteler et al. 2014), and they proposed some solutions to relieve their worries, including paying annual fee for maintenance, repair guarantee, or probation period (Balta-Ozkan, Amerighi et al. 2014). The study of (Ji and Chan 2020) also reflects one concern of residents that even if the SHET would help user to reduce energy expense, the users still feel anxious about the potential large sum of repairing fee might occurring in the usage phase, which is a similar attitude with the participants in the survey of European countries (Balta-Ozkan, Amerighi et al. 2014).

Based on the previous documents, it is expected that the residents would value more for the SHET with low risk of occurring costly maintenance; hence the inexpensive maintenance is chosen as an economic indicator for SHET in this research.

2.2.9 Cost effectiveness

Cost effectiveness means to give good return for the money to be paid. In this research, the cost effectiveness is regarded as a KPI to measure the economic performance of SHET on the basis of the benefits it could provide to home owners comparable to its costs. In the earlier literature, the investment cost of SHET has been recorded as a barrier for the technology acceptance by public (Meyers, Williams et al. 2010, Paetz, Dütschke et al. 2012, Balta-Ozkan, Boteler et al. 2014, Wong and Leung 2016), however, because of the heterogeneity of urban residents, the cost affordability of residents are various, and the benefit they hope to acquire from SHET are also different. It is hard to set a standard criterion to evaluate the level of investment cost of SHET from user's respective; comparatively, considering the return of SHET investment in relation to the cost, the cost effectiveness of SHET can be appropriately judged, which was echoed with the answer of some respondents in the survey of (Balta-Ozkan, Davidson et al. 2013), that the savings from SHET should be substantial enough to be worthwhile.

Unlike those technical indicators, the cost effectiveness is a subjective term standing at the point of the users. As no uniform or unique standard existing to assess the cost effectiveness, the users could make subjective evaluations according to their own situations (annual household income, purchase price, expected energy saving, etc.). For example, the Germany consumers would give better evaluation for the equipment with higher monetary saving and shorter payback time (Mert and Tritthart 2012), and some participants asserted that they could accept those expensive smart appliances if the investment would be payback (Paetz, Dütschke et al. 2012). The cost effectiveness of SHET will only be assessed by users according to their subjective criterion and individual conditions, might be financial capability, willingness to pay, monetary savings, desired benefits returned, user behavior etc. Willingness to pay (WTP) is the upper limit that users would like to pay for the smart home technology (Bateman, Carson et al. 2002), influenced by a series of technical-socio-economic factors, such as the technology functions, user's demographic information, occupant numbers, perception of usefulness, environmental awareness, etc. (Gerpott and Paukert 2013, Washizu, Nakano et al. 2019, Yang and Lam 2019); and thus the judgments of cost effectiveness are also various with users' diversified situations. From user's perspective, no matter the price of SHET is expensive or cheap, what they want is a worthwhile investment.

2.2.10 System reliability

In the Oxford English Dictionary, one definition of reliability refers to the ability of a product to perform in a required manner, or produce a desired result consistently (Dictionary). In this study, system reliability is deemed as a KPI to assess the capability of SHET to maintain smooth running and produce occupant's desired outcomes with high accuracy.

A smart home environment is integrated with many interdependent systems, like control system, sensing system, etc., thus there is a risk that the malfunction of one single system may cause the breakdown of whole system. The technical malfunction may also lead to some unintended consequence for residents (Balta-Ozkan, Davidson et al. 2013). For example, one function of SHET is to schedule operation to utilize the time-of -use (TOU) electricity pricing plan (Bartusch, Wallin et al. 2011): after scheduling, the smart home appliance would automatically turning on during off-peak period for a lower electricity tariff hereby saving utility cost for residents; however, the technical malfunction may drive the smart appliance to work during peak period with a higher electricity rate and increase energy expense, which is a un-expectable loss to residents.

What is more, the reliability of SHET also depends on sensing, interpreting, and predicting occupant's behaviors or external signals with high accuracy as well as triggering right reactions (Chan, Estève et al. 2008). For instance, the sensors installed in a smart home will sense occupant's motions and indoor light, so as to adjust the illumination automatically; if any error is introduced into the sensors, the smart lighting system could not provide desired illumination for the room occupants. In contrast with the advantage in reliability of smart technology asserted by technical publications (Lobaccaro, Carlucci et al. 2016, Raimi and Carrico 2016, Risteska Stojkoska and Trivodaliev 2017), residents deem reliability as a risky factor that the error or malfunction of complicated technology would bring trouble to their homes (Balta-Ozkan, Davidson et al. 2013); hence the reliability level of SHET is a significant indicator to reflect its performance.

2.2.11 Safety

The first type of safety issue of SHET comes from some potential safety hazards involved with smart grid. With all the inherent vulnerabilities (Khurana, Hadley et al. 2010, Flick and Morehouse 2011), smart grid infrastructure system is highly integrated with telecommunication system, computer system, control system, convention electrical grid, sensing and measurement technologies as well as end user smart home applications, thus there is a concern that the malfunction of one single system would propagate to another, consequently causing the blackout of the whole smart grid system. Additionally, the highly integrated system increases the risk of cyber-attack, which has been reported by several country governments that their industrial control systems had been attacked against by hackers endangering their infrastructural systems (Sridhar, Hahn et al. 2012). The other type of safety risk associated with SHET are those accidents may occur in the domestic environment and cause serious damages to resident's life and property, such as fire, losing control of total electricity load, attacking against by malicious parties through smart grid (Mert and Tritthart 2012, Alaa, Zaidan et al. 2017), and exposure to hazardous voltage (Martin 2010).

In the past surveys for public perceptions about smart home technology, numbers of respondents showed their concern about the security issue of smart home environment (Mert and Tritthart 2012, Balta-Ozkan, Davidson et al. 2013, Parag and Butbul 2018); all the government, industry and academia should be involved to mitigate people's concern about the security risk. In this thesis, safety contains two dimensions of meaning: safety of smart gird infrastructure system and safety of domestic smart home environment and is determined as a KPI of SHET to reflect the capability of SHET to ensure the safety of living environment for the users. (Ji and Chan 2020) reported that Chinese users pay high attentions to the safety issues related with smart technology, in line with the research findings conducted in other countries (Balta-Ozkan, Davidson et al. 2013, Balta-Ozkan, Boteler et al. 2014, Wilson, Hargreaves et al. 2017). Because the sense of security is a basic psychological need for human being (Dupuis and Thorns 1998), users would value more for the technology presenting higher capability to assure the security of their personal lives, properties,

2.2.12 Privacy protection

The concern of privacy violation has been concluded as a limiting factor preventing the diffusion of smart technology through previous surveys in different regions (Balta-Ozkan, Boteler et al. 2014, Raimi and Carrico 2016, Bhati, Hansen et al. 2017, Parag and Butbul 2018, Sanguinetti, Karlin et al. 2018). Such privacy concern came from both the worry of illegal usage by criminals and unauthorized usage by commercial institution, law enforcement agency, or even family members, co-inhabitants (Yildiz, Bilbao et al. 2017). People's worry is reasonable: according to the findings of some previous research, except telling the household energy consumption, the smart grid data also could reveal occupants' in-home activities or daily routines (McDaniel and McLaughlin 2009, Khurana, Hadley et al. 2010). In an experiment, (Lisovich, Mulligan et al. 2010) showed that the behavior-extraction algorithm embedded into the demand-response system could engage the smart grid technology to infer people's in-home activities with high accuracy and confidence. However, (McKenna, Richardson et al. 2012) argued that the personal information disclosure was determined by the meter data resolution, and current meter resolution could only indicate house occupancy, but less potentiality to reveal in-home activity, therefore, they suggested that the privacy concerns about smart grid technology should be rational, considering the proper data selection and processing techniques.

For the sake of mitigating the privacy risk, the whole smart grid technology industries have to commit to protect consumer's privacy right. Many studies have been carried out to investigate the privacy protection solutions for smart grid technology, such as new algorithms to combat with privacy invasion (McLaughlin, McDaniel et al. 2011), or privacy friendly alternative method for smart meter data (Chen, Kalra et al. 2015). Beyond technology, lacking sufficient laws to protect people's smart grid data or privacy has been a global issue (Knyrim and Trieb 2011, King and Jessen 2014, Wang and Yu 2015). In China, (Yang and Xu 2018) stated that there was legal deficiency for the personal data collection through smart city infrastructure, but due to the cultural and social difference, as well as the prevalence of surveillance camera, the

Chinese customers were not as sensitive as European or American people about their privacy rights, but they still felt anxious about the possibility of their personal data to be disclosed to criminals (Huang and Wu 2019). What is more, the industry should also adopt self-regulatory mechanisms to make sure the consumer's privacy data would be processed carefully, safely, and reasonably.

In this thesis, the privacy protection is selected as a KPI to reflect the capability of SHET product in protecting user's personal data. Such capability is assessed by two dimensions; one is technical aspect, including the information security techniques owned by product developer to prevent consumer data leakage, and the extent of the personal data that will be utilized by SHET applications, as the users may prefer those privacy friendly products better. The other is regulatory aspect; the technology company with a good reputation of strict information safety management would be more likely to win user's trust.

2.2.13 Summary

In this section, twelve key performance indicators have been investigated from the literature to represent the various functions, attributes and performances of SHET. As the aim of this study is to understand the perceptions of the residents towards SHET and explore the influential factors of resident's adoption behavior. The KPIs are reviewed from the resident's perspective, considering user's requirements, experience and also their subjective feelings, but not totally at technical aspects. The twelve KPIs are expected to be categorized into three groups: the group of technical performance, associating with indicators of like automation, controllability, feedback, improving living comfort, convenient operation, system interoperability; the group of economic performance, associating with saving energy expense, inexpensive maintenance, cost effectiveness; and the group of capability of risk resistance, involved with indicators of system reliability, safety, and privacy protection. The three groups KPIs will become the foundation to analyze resident's attitude towards the comprehensive performances of SHET and the KPIs will also be regarded as the measurement indicator and also be developed into survey item to measure the respondent's attitude towards the SHET performance.

2.3 Theory of Attitude, Norm and Behavior

In the field of social psychology, some theories have been developed relating to human attitude, personal or social norms, and the behavior, such as theory of reasoned action (TRA) (Fishbein 1979), theory of planned behavior (Ajzen 1985), norm activation model (Schwartz 1973), value-belief-norm (VBN) theory (Stern, Dietz et al. 1999), social comparison theory (1991), technology acceptance model (TAM) (Davis 1989), etc. and these theories have been widely employed to build the theoretical base to study many kinds of behaviors, among which, TPB and NAM have been the most popular two theories to explain the pro-environmental behaviors, such as waste recycling behavior (Bratt 1999, Botetzagias, Dima et al. 2015), purchasing green products (Maichum, Parichatnon et al. 2016), purchasing green house (Tan 2013), energy saving behaviors(Wang, Zhang et al. 2014, van der Werff and Steg 2015, Tan, Ooi et al. 2017, Lopes, Kalid et al. 2019) . As the adoption of smart home energy technology is defined as purchasing related energy saving behavior essentially, in this research, the TPB and NAM will also be adopted as the foundation theories to build the theoretical framework, and reviewed in detail.

2.3.1 Theory of planned behavior (TPB)

Among the lots of behavioral theories, theory of planned behavior (TPB) has become one of the most widely used theories to construct theoretical framework for the investigation of human behaviors (Ajzen 2002). TPB was developed by (Ajzen 1985, Ajzen 1991), which has pointed out that human's actual behavior is affected by one's behavioral intention, and behavior intention is led by the behavioral attitudes (BA), subjective norms (SN) and perceived behavior control (PBC) in combination, as Figure 2.1 showing, the detail explanation is as below.

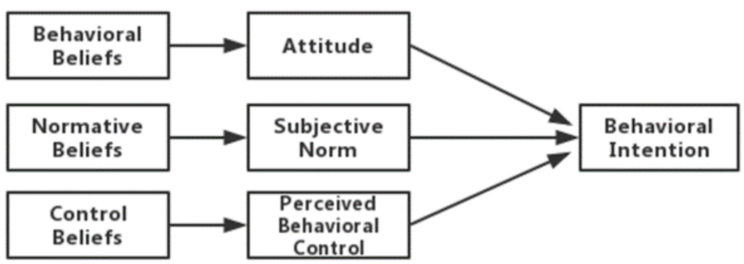

Figure 2.1 Diagram of Theory of Planned Behavior, Adapted from (Ajzen 1991)

(1) Behavioral Intention (BI)

According to the (Ajzen 2019), BI refers to one person's readiness to perform a given behavior, and is deemed as an immediate antecedent of one behavior. It will be predicted by the aggregated power of people's attitude toward the behavior, subjective norm, and perceived behavioral control; each predictor has a weighting reflecting the importance related with the behavior and population of interest. The formula of Behavioral Intention is expressed as:

$$BI = w_{BA}BA + w_{SN}SN + w_{PBC}PBC$$

Here BI is behavioral intention, BA means behavioral attitude, SN refers to subjective norm, PBC means perceived behavioral control; and w_{BA}, w_{SN}, w_{PBC} represents the weighting of BA,SN,PBC respectively.

(2) Behavioral Attitude (BA)

As the explanation of (Ajzen 2019), behavioral attitude is the degree to which performance of the behavior is positively or negatively valued, and is decided by a set of behavioral beliefs, which reflect the one person's subjective evaluation of the probable result of the performed behavior, according to one's interest and experience (Ajzen 1991). Considering the probable consequence of the behavior, the behavioral beliefs would produce positive, negative, or neutral attitude (Fishbein 1976). In formula expression, behavioral attitude (BA) equals to the aggregation value of the strength of each behavioral belief (bb) multiplied by the evaluation (e) of the outcome or experience, as shown in the following equation.

$$\sum_{i=1}^{n} \mathrm{BA} = bb_i \times e_i$$

Here BA is behavioral attitude, bb_i means the strength of behavioral belief, and e_i means the evaluation of the probable outcome of the behavior.

(3) Subjective Norm

According to the explanation of (Ajzen 2019), the subjective norm refers to the perceived social pressure to engage or not to engage in a behavior. The subjective norm is expected to be decided by a series of normative beliefs, which refers to the expectations that one person could perceive from the important referents or group, such as family, friends, teammates, company colleague, etc. (Ajzen 1991). The subjective norm can be expressed by the multiplication of the strength of each normative belief (nb) and person's motivation to comply one behavior (m), as shown by the equation below:

$$\text{SN} = \sum_{i=1}^{n} nb_i \times m_i$$

Here SN is subjective norm, nb_i means the strength of normative belief i, and m refers to the motivation to comply with the referent.

(4) Perceived Behavioral Control (PBC)

Perceived behavioral control refers to people's perceptions of their ability to perform a given behavior under the influence of a set of control beliefs (Ajzen 2019); in other words, it is the perception of one person that he/she could execute the behavior easily or with difficulty (Ajzen 2002). The perceived behavioral control (PBC) is determined by a set of control beliefs, relating with the factors that may expedite or hinder the performance of the behavior. When considering the actual behavior, the perceived behavioral control (PBC) can be deemed as a proxy for actual behavioral control, which refers to the extent that a person owns the skills, knowledge, financial capability, resources, and other prerequisites for performing one behavior (Ajzen 2002). The formulation of PBC is the weighted multiplication of the strength of control belief (cb) and the perceived power (pp) of the control factor, as shown below:

$$\text{PBC} = \sum_{i=1}^{n} cb_i \times pp_i$$

Here PBC means perceived behavioral control; cb_i refers to the strength of the ith control belief, and pp_i is the perceived power of the ith control factor.

Since the development of TPB, it has been applied in numerous of research to study human behavior, such as the health related behavior, e.g. loss weight, smoking cessation, health eating, etc. (Godin and Kok 1996, Conner, Norman et al. 2002) as well as some technology adoption behavior like the internet banking or electronic commerce (Mathieson 1991, George 2004, Shih and Fang 2004). Additionally, the behavior relevant with the sustainability and environmental protection is also a hot research topic to utilize theory of planned behavior, including the purchase behavior of green consumer goods (Vermeir and Verbeke 2008, Hsu, Chang et al. 2017, Wang, Wang et al. 2017, Taufique and Vaithianathan 2018), the daily behaviors involved with low carbon and energy saving (Masud, Al-Amin et al. 2016); investment of green property (East 1993, Tan 2013, Judge, Warren-Myers et al. 2019).

Some limitations of TPB also have been discussed. The first is some factors like personality, volitional, and demographic are not considered in the model; and the second is that TPB focus on much emphasis on the logical thinking of human being but lacking the emotional thinking; and it does not include the moral dimensions either (Barber 2011).

2.3.2 Norm Activation Model (NAM)

Except theory of planned behavior, the theory of norm activation model (NAM) is also a popular theory to study human behavior which has been applied by many studies, especially for the altruistic behavior and pro-environmental behaviors, such as the household energy saving (van der Werff and Steg 2015), reducing the burning of yard and garden waste (Van Liere and Dunlap 1978), daily energy saving (De Groot and Steg 2009) or reducing clothing consumption (Joanes 2019), etc.

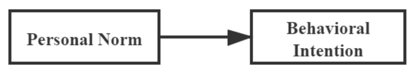

Figure 2.2 Diagram of Norm Activation Model, adapted from (Schwartz 1973, Schwartz 1977)

The theory of Norm Activation Model (NAM) (shown by Figure 2.2) was proposed by Schwartz (Schwartz 1973, Schwartz 1977), specifically for the explanation of the altruistic and pro-environment behavior (Onwezen, Antonides et al. 2013). Some altruistic behaviors are less pleasurable, like reducing the usage of air conditioner, and that is the personal values motivating one person to pursue such behavior. In the NAM, the solely antecedent of human's altruistic behavior is personal norm (Schwartz 1977), a term which is defined as the self-expectations or commitments under one's internal values and reflect one's feelings about the obligations to engage in a specific behavior (Schwartz 1973, Onwezen, Antonides et al. 2013). Personal norms will have direct influence on the behavior intention or when someone aware of the consequence (AC) of its behavior for the benefit of others or one's ascription of the responsibility (AR) for those consequences to oneself (Schwartz 1977, Han 2014).

The limitation of NAM is that NAM can explain some easy and low cost behaviors; however, for some complex and high cost behaviors, NAM lacks explaining power. The application field of NAM is very limited, only focusing on the altruistic, pro-social, and pro-environmental behaviors(van der Werff and Steg 2015).

There is no definite criterion to determine which theory can better explain the pro-environment behaviors. In those research that have applied TPB, the influences of attitude, subjective norm, and perceived behavioral control on the behavioral intention have been confirmed; however, there have been some arguments that TPB is a logical and rational cognition process (Barber 2011), that human will evaluate the benefit and cost of the outcome first before the formation of attitude; to the contrary, the pro-social or pro-environment behavior is only the activation of personal norms, deriving from the values, as long as the individual has recognized the benefits for others or the responsibility for any negative consequence, the behavior will be implemented (Wang, Wang et al. 2018).

2.3.3 The application of TPB and NAM

Each of the two theories has its own advantages, therefore, many studies have considered to integrate the TPB and NAM together or to extend the TPB with personal moral norm to explain human's pro-environment behavior. Some studies have found out that the integration of NAM and TPB model could increase the explained variance of behavioral intentions, compared to the original single model (Harland, Staats et al. 1999, Bamberg and Möser 2007). Specific to the purchasing behavior of energy efficiency technology, a list of previous studies that have been applied the integration of TPB and NAM and the associated model constructs is shown in Table 2.1.

Table 2.1 A list of previous research about purchase related energy saving behavior with application of TPB and NAM

Source	Region	Context	Theory	Factor
(Tan, Ooi et al. 2017)	Malaysia	Purchase intention for energy-efficient household	Moral extension of TPB	Attitude, subjective norm, perceived behavioral control, environmental concern, environmental knowledge, moral norm,
(Washizu, Nakano et al. 2019)	Japan & USA	Resident's willingness to pay for HEMS	Combination of TPB, NAM, and technology acceptance model(TAM)	Attitude, social norm, personal norm, perceived behavioral control, perceived usefulness, perceived ease of use
(Ji and Chan 2019)	China	Resident's adoption of SHET	Combination of TPB and NAM	Attitude towards technology performance, attitude towards economic performance, subjective norm, personal norm, perceived behavioral control
(Broman Toft, Schuitema et al. 2014)	Europe	Adoption of smart grid technology	Combination of TPB and NAM	Attitude, personal norm, perceived usefulness, perceived ease of use
(Yang, Lee et al. 2017)	South Korea	Acceptance of smart home services	Extended TPB	Attitude, subjective norm, perceived behavioral control, automation, mobility, trust, privacy risk, interoperability,
(Fornara, Pattitoni et al. 2016)	Italy	Intention to improve household energy efficiency	Extended NAM	Attitude, Moral norm, Subjective norm
(Yadav and Pathak 2016)	India	Intention to buy green products	Extended TPB	Attitude, subjective norm, perceived behavioral control, environmental concern, knowledge

2.3.4 Summary

This section reviews two predominant behavioral theories, the theory of planned behavior(TPB) and theory of norm activation model. In TPB theory, human is regarded as rational player, and the human behavior is logical, that people behavioral intention is predicted by behavioral attitude, perceived behavioral control, and subjective norm. And in theory of norm activation model, for the altruistic behavior, like energy saving, environmental protection, recycling, is deemed as only to be triggered by the personal norms, reflected the internal values of people's heart but not with the evaluation of the behavior outcome. In the context of NAM, the awareness of the responsibility or the consequence will lead people to have the personal norm to engage some altruistic behaviors. Considering the topic of this study, that the adoption behavior of SHET, on one hand, it is a purchase related rational behavior, as the consumers will evaluate the product price, the installation cost, and the expected benefit they demand; it is also a technology adoption behavior, that people need to evaluate the complicated technical attributes and functions; on the other hand, the energy saving capability of SHET also make the adoption behavior to be altruistic, because it is beneficial to the environment and society. Therefore, considering the advantages of TPB and NAM respectively, this study will integrate the personal norm with TPB to compose the theoretical backbone to investigate the influential factors for the adoption intention of SHET. On the basis of the theoretical backbone, the adoption intention of SHET is expected to be affected by attitude, subjective norm, perceived behavioral control, and personal norm.

2.4 Incentive Measures to Promote the Adoption of Energy Efficiency

2.4.1 Energy efficiency gap

The energy efficiency gap is the gap between the current and optimal level of energy efficiency achieved by a society as a result of the failure to adopt energy efficiency technology by households, industry or government institutions (Hirst and Brown 1990). (Hirst and Brown 1990) also described the two main types of barrier that are slowing down the diffusion of energy efficiency technology: structural barriers, including the distortion fuel price, availability of capital, government policy, industry standards, as well as the limitation of infrastructure; and behavioral barriers, relating to the decision making behaviors of customers, such as their attitudes towards energy efficiency, risk perception, problem of information opacity with the energy consumption, and lacking incentives (Hirst and Brown 1990). (Jaffe and Stavins 1994) pointed out policy interventions should be provided to overcome the market failures of energy efficiency technology.

After the concept of the “energy efficiency gap” was identified, many studies began to discuss the barriers to the adoption of energy efficiency comprehensively from multi-dimensional viewpoints. Many publications focused on the behavioral barriers resulting in the failure of adoption. For example, (Frederiks, Stenner et al. 2015) found that that, although many energy efficiency technologies had been demonstrated to be cost effective, consumers were not rational players, because of the existence of behavioral and psychological barriers such as loss aversion, risk aversion, sunk cost effect, inertia, satisficing, or social comparison; he also suggested that the industry practitioners and policy makers should utilize motivational measures to help consumers to overcome the cognitive bias and promote energy efficiency. (Faiers, Cook et al. 2007) suggested that government should consider policies targeting the behavioral barriers such as the consumer’s attitude, norms or beliefs. After a quantitative analysis by Monte-Carlo simulation, (Hackel, Pfosser et al. 2017) concluded that the Prospect Theory in behavior economics could explain many of the behavior barriers. (Ji and Chan 2019) explained why a resident’s positive perception of the economic performance of smart home energy technology still failed to lead to an intention to adopt the technology, from the viewpoint of behavior economics.

In addition to behavioral factors, the product price, or the upfront cost have also been regarded as accounting for slow technology adoption. (Faiers, Cook et al. 2007) stated that the lower adoption of energy efficiency technology in the UK was influenced by product pricing, and the higher requirement of capital cost made those technologies unattractive. (Reddy 2003) indicated that affordability was a main barrier for consumers, preventing the diffusion of energy efficiency technology in the residential sector of India.

Additionally, the impact of demographic factors, such as gender, level of education, household income, etc. on the adoption of energy efficiency technology was also discussed in the research, with their effects seen as varying across different regions or contexts (Mills and Schleich 2010, Pelenur and Cruickshank 2012, Chen and Sintov 2016).

2.4.2 Incentive measures

The incentive policy instrument is the crucial approach for governments to promote the adoption of efficiency technologies by residential sector. According to the summary of (Mundaca, Neij et al. 2010), the policy instruments can be classified into three main categories: economic instruments, including fiscal/financial incentives, grants or subsidy; regulatory instruments, including building codes and energy performance standards, mandatory or voluntary energy labeling; information and education schemes, including environmental awareness campaign, environmental protection education, voluntary agreement. Additionally, the demand side management (DSM) is also a measure initiated by the utility department to promote energy efficiency, through changing the electricity consumption behaviors of end users, enabled by the smart grid technology of high resolution smart meter, and smart home energy appliances. The power of subjective norms in promoting energy saving has attracted many research interests, and many social experiments have been conducted to confirm the effectiveness of subjective norms, with social comparison with information feedback being the most used.

2.4.2.1 Economic instrument

According to the policy database built by the International Energy Agency (IEA) (IEA 2020), a total of 252 economic instruments have been implemented by governments around the world targeting to improve the energy efficiency in residential sector, including in the US, Canada, China, Australia, Japan etc.. For example, the “Home energy assessment program” in Canada is aimed for reducing cost for home owners to carry out home energy retrofit. The Belgium government established a subsidy scheme in 2015 to support households to install energy saving technology and home refurbishment.

Of all the economic instruments, price subsidy for energy efficiency technology is a very dominant one used by many country governments. In China, a subsidy program called “Promoting energy-efficient appliance for the benefit of people” was launched in 2009 aimed at accelerating the penetration rate of energy efficient domestic appliances (Zeng, Yu et al. 2014). This subsidy program provided price subsidies to consumers who purchased the energy-saving household appliances such as energy saving air conditioner, refrigerators, flat panel TV, etc. In May, 2013, this program ended with a remarkable achievement of reimbursing a total of around

4.3 billion US dollars to Chinese customers, and securing a growth of 35% in the market share of energy-efficient air conditioners (Jiayang LI 2013).

In the USA, the federal government implemented a tax rebate policy known as ‘home improvement and residential energy tax credits’ (Star 2017), through which homeowners could claim tax credits from federal government for their installing the appliances to improve the energy efficiency of their house. Additionally, the utility companies in several states of the US also had utility rebate programs to promote the energy saving appliances. (Datta and Gulati 2014) asserted that the regions with utility rebate programs had a larger penetration rate for energy-efficient clothes washers and that each dollar increase in the utility rebate could increase the share of qualifying clothes washers by 0.4%. The rebate program was cost effective for the utility company in reducing the demand for electricity.

Given the price subsidy policy implemented in China, a scenario of a price subsidy scheme is proposed for this research, in the hope of improving positive attitudes towards the economic benefits of SHET adoption and decreasing the upfront cost for residents. The detail design of price subsidy scenario is shown in Chapter 7.

2.4.2.2 Demand Side Management

DSM refers to a series of actions designed to affect the customer side, which is planned and implemented by the electric power department, aiming at modifying the customers’ electricity usage behaviors so as to reduce the overall energy consumption or to reduce the grid demand during peak hours with loading management (Gellings 1985, Torriti, Hassan et al. 2010). DSM could achieve many benefits, such as reducing the generation cost of electricity for utility department, and cutting down the electricity bill for end users (Faruqui and George 2005). It can also be adopted as a tool to facilitate the connection of renewable energy (Torriti, Hassan et al. 2010).

One typical measure of DSM is the time-of-use pricing plan. TOU is an electricity rate plan in which the electricity rate varies depending on the time of day it is used, the season and whether it is a weekday, weekend or holiday (Wang and Li 2015). According to the load on the power grid, the utility company divides the day into the peak demand periods (e.g. 7:00~11:00, 19:00~23:00), flat period (11:00 ~ 19:00) and low demand period (23:00 ~ next day 7:00), and sets a higher rate for the peak period and a lower rate for the low-demand period, in order to encourage customers to make reasonable use of electricity time and shift their energy consumption from peak hours to off-peak hours. This reduces the load at peak periods and improves the utilization efficiency of power resources.

In recent years, because of the rapid development of the smart grid, TOU pricing has been deemed an effective DSM measure, relying on automation and feedback technology to change the consumption patterns of power grid end users (Gottwalt, Ketter et al. 2011, Yang, Tang et al. 2013, Wang and Li 2015). In an exploratory analysis of resident response to TOU pricing in California, (Herter, McAuliffe et al. 2007) found that participants both with and without smart appliances had significant load reductions. Participants with smart thermostats used 25% less, while participants without smart control technology used 13% less. (Chen and Hong 1996) have demonstrated the energy saving capability of TOU pricing plans through the Newton algorithm. (Rastegar, Fotuhi-Firuzabad et al. 2012) developed a framework for smart home dwellers to minimize their energy payments through a TOU pricing plan.

Considering about China, since 2012, the National Development and Reform Commission (NDRC) has guided 29 provinces to implement Increasing Block Tariffs (also known as Tired Electricity Pricing, TEP), and in 2013, the NDRC again issued a notification to each province, encouraging them to try out TOU pricing to integrate with TEP in households (Wang, Zhou et al. 2017). At present, a number of provinces have launched voluntary TOU pricing plans for residents, including Shanghai, Guangdong, Jiangsu, Zhejiang, Anhui, etc. (Zhao, Yang et al. 2017, Li, Yao et al. 2018), with residents being able to join TOU plans voluntarily.

In this study, compulsory TOU pricing plans are proposed as incentives for promoting the adoption of SHET by urban residents. According to the CSPG, by the end of 2020, complete smart grid system coverage will have been achieved in Guangdong province (CSPG 2017). In 2018, the CSPG also announced that more than 30 million smart meters had been installed free of charge, which had resulted in the full penetration of smart meters in Guangdong. The actions taken by the CSPG will be sufficient to provide an infrastructure environment that will promote SHET to the residents in Guangdong province, and a voluntary TOU plan has already been provided by the utility department in Guangdong, meaning that TOU is familiar to local residents. Against this background, a TOU scenario is proposed with the expectation of encouraging residents to utilize the smart functions of SHET, such as remote control, scheduling, automation, feedback, etc., and the different electricity rates at different hours to achieve maximum savings in their electricity bills.

2.4.2.3 Influence of subjective norm

In Theory of Planned behavior, (Ajzen 1991) stated that people's behavioral intention would be influenced by the subjective norms, which are perceived social pressures from important referents or group, such as family, friends, teammates, company colleague, etc. (Cialdini, Reno et al. 1990) suggested the subjective norms are of two types: injunctive norm and descriptive norm. Injunctive norms are perceptions that a behavior would be supported by the majority of a social group - what ought to be - while descriptive norms are perceptions that a behavior is performed by most of society (Cialdini, Reno et al. 1990, Hamann, Reese et al. 2015). The power of subjective norm in affecting one's behavior can also be supported by another psychological theory called Social Comparison (Festinger 1954), which is that people's behavior will be influenced by information about the behavior of others, through the observation of the behaviors engaged in by relevant peers (Bartke, Friedl et al. 2017).

Although the strength of subjective norms in affecting human behavior has not been utilized to formulate official policy by governments to stimulate energy efficiency, it has attracted a lot of interests in academia, and many social experiments have been carried out to examine the effectiveness of subjective norms in encouraging of energy-saving behavior. (McMichael and Shipworth 2013) carried out a case study in a British community to explore the impact of social networks on the adoption of energy efficiency measures. Their findings indicated that communication through social networks could account for one third of information seeking behavior, and such behavior was found to be associated with the behavior of energy efficiency adoption, implying the feasibility of social networks as channels to inform energy-saving programs. (Ekpenyong, Zhang et al. 2014) defined the energy savings people obtained through information transmitted through their social networks as indirect savings. They took a 56-member community as a case study, and quantified their indirect energy savings, with the conclusion that people with more social connections had more chances to promote indirect savings. A network synergy effect leading to neighborhood-wide energy efficiency was also discovered by a previous study of residents' social networks (Xu, Taylor et al. 2014). (Kandul, Lang et al. 2020) organized a field experiment to study the impact of a social comparison based information feedback on a decreasing indoor temperature, and reported an estimated average effect of 1.2% temperature reduction, they also stated that, triggered by social comparisons, people were willing to save energy at the sacrifice of partial comfort, even without direct financial benefits. Through a social experiment held in a residential building in New York City, (Jain, Gulbinas et al. 2013) captured data of occupants' energy consumption and social network interaction and successfully confirmed the impacts of social influence on energy consumption behavior through an algorithmic developed by themselves.

Beyond the field of energy saving, the Theory of Innovation Diffusion (Rogers 2010), also pointed out the information transmitted through social systems could encourage the diffusion of innovation. These predominant theories of behavior, psychology and communication, as well as the successful results of the social experiments mentioned above, provide a solid theoretical foundation to take subjective norms as tools to facilitate energy-saving behavior, both habitual and purchasing. In this study, subjective norms are also expected to be effective in the promotion of SHET in urban residents. Therefore, based on the literature review, one of the incentive scheme scenarios proposed for this study is that of a community energy-saving campaign. In this scenario, the residents of a community will voluntarily register for an energy-saving campaign, in the form of an energy-saving contest. The top one hundred participating households will be publicized on the community bulletin board, and prizes will be awarded. The design of this scenario is aimed at applying the strength of subjective norms to motivate people to adopt SHET.

2.4.2.4 Information and education

As well as economic and regulatory instruments, information, education and voluntary schemes have also been adopted by governments or private institutions to increase people's energy-saving awareness and encourage them to actively take up energy efficiency technologies. A typical example of an information and education program is the National Energy Efficiency Data-Framework (NEED) in Britain (Bricknell 2019). This framework collects domestic energy consumption data in Britain from various sources, considers the energy efficiency measures installed, property attributes and household characteristics, and analyzes the data to provide better understanding of their energy consumption to the public. It also offers reliable information for academia and industry to use. An example of a voluntary program is the Home Energy Assessment in Canada, through which a home energy evaluator will go into a resident's home, conduct a free energy audit and give advice on how to improve the home's efficiency.

The effect of the provision of information on the adoption of energy efficiency technology has attracted the attention of academia. For example, (Hafner, Elmes et al. 2019) confirmed the effectiveness of information feedback on the promotion of energy efficiency technologies, including norm-based information and environmental/financial information, but also noted that the power of normative information was stronger.

2.4.2.5 Regulatory instrument

As many as 625 regulation-orientated polices for residential energy efficiency are listed in the IEA database (IEA 2020), most of which are codes and minimum energy standards for various kinds of domestic appliances. For example, the minimum energy performance standard (MEPS) in Singapore will require all light bulbs sold in Singapore to be as energy efficient as LED bulbs from 2023, with the objective of saving $3.5 million energy costs annually for households.

Another type of regulatory instrument is the energy performance label, which can be mandatory or voluntary. In China, a mandatory energy label program has been carried out since 2005, which classified appliances into five tiers in line with their energy consumption level, from Tier 1 as most efficient to Tier 5 as least. Tier 5 is also the minimum requirement for energy efficiency for appliances to enter the Chinese market (Zeng, Yu et al. 2014).

The energy star program is a US government-backed voluntary energy performance labeling program initiated in 1992 and now adopted by many other countries, including Canada, New

Zealand, and European Union countries. Manufacturers volunteer to be certified by independent third parties and get an Energy Star label on their products, representing their capability of achieving energy efficiency. In this way, consumers receive information and make their purchase decisions. The data on the official website of Energy Star shows that, in 2017, Energy Star label products helped consumers to save 170 billion kwh of electricity and $18 billion in energy costs (Star 2020).

Additionally, many regions have formulated building codes to improve the energy efficiency of residential buildings, such as the Building Energy Code in Hong Kong (EMSD 2018), which stipulates the adoption of some energy saving products.

2.4.3 Summary

The incentive measures to promote energy efficiency technology are reviewed in this section. The measures are divided into five main categories. The first category is economic instruments including fiscal/financial incentives, tax rebates, grants or subsidy. The focus of the review is on the price subsidy schemes that have been adopted by many governments to promote energy efficiency technologies. The second category is DSM, which is a series of actions implemented by electric departments to encourage end users to change their energy-using behaviors, with the aim of reducing energy consumption and the load on the power grid. One typical DSM measure is TOU, a pricing plan with the electricity rate varying with the different periods of a day. Households that have installed smart meters and smart appliances in their homes could get better economic benefits from the differences in electricity rates at different periods, assisted by the smart functions of SHET. The third category involves using the strength of subjective norms to affect people's behaviors. Underpinned by theories of behavior, psychology and communication, this category is based on the evidence that people will be motivated by the opinion of important referents or be stimulated through comparison with referent peers to engage in some behaviors. The fourth category is information instruments, such as the energy star program, energy information disclosure for public buildings and education programs, all of which aim to enhance the energy-saving awareness and social responsibility of residents. Information and education schemes are often implemented together with other schemes, such as price subsidy or social comparison. Last is the regulatory instrument, which are the regulations governments require to be execute, most of which are industry orientated.

After this review of incentive measures, three scenarios for incentive scheme are proposed for this study – price subsidy, TOU, and a community energy saving campaign (CESC) – with the expectation of promoting the adoption of SHET by urban residents. Coherent with findings from the previous review, the scenario of price subsidy targets enhancing people's ATEP and increasing the perceived controllability of behavior by reducing the upfront cost. The scenario of TOU targets driving ATTP and ATEP, in the hope that the comprehensive smart functions of SHET will generate higher economic benefits. The scenario of a community energy saving campaign targets strengthening subjective norms, expecting the participants to be motivated to have a higher intention of adopting SHET through social comparison with other participants. As for the reasons of dropping incentive measures of education and information, as well as regulatory instrument, that is because that in this study, incentive measure of information and education will be integrated into the three proposed scenarios. In the scenario of price subsidy, the retailers will take the responsibility of educating customers about the smart functions of SHET products and also tell all the information to customers; in the scenario of DSM, the utility department will educate users and do the job of electricity rate information disclosure, and in the scenario of CESC, the jobs of community management officers are organizing, publicity, education. The regulatory instrument is government's duty which needs the cooperation of industry, and the regulatories are industry orientation, but this study is residents orientation-providing a discussion of incentive schemes targeting to improving the willingness to pay for SHEY by residents, therefore, only three scenarios are proposed here and discussed in later chapters.

2.5 Theoretical Framework

Based on the above literature reviews of behavioral models, this article introduces the construct personal norm from NAM into the TPB, with the purpose to enhance the explaining power of TPB at moral dimension. Additionally, considering the sophisticated technical attributes of smart technology, and the potential monetary gains or cost incurred during the usage of SHET, it is hard to directly use the original construct "attitude" in TPB to reflect the comprehensive evaluations of the performance of SHET. Therefore, with the purpose to better understand residents' perceptions about the technical and economic performance of SHET, as well as the capability of risk resistance, three new attitudinal constructs are developed in this study: attitude towards technical performance (ATTP), attitude towards economic performance (ATEP), and attitude towards risk resistance (ATRR). The indicators related with ATTP include: automation, controllability, feedback, improving living comfort, convenient operation, and system interoperability. The indicator involved with ATEP include: save energy expense, inexpensive maintenance cost, and cost effectiveness. The indicators of safety, privacy protection and system reliability are connecting with ATRR. PBC is reflected by the availability of some constraint resources, including knowledge & skill, financial capability and system compatibility. The subjective norm is affected by the external voice from important referents, containing public opinion, media opinion, and support from family and friends; while personal norm is reflected by the internal values of one person itself, including the environmental awareness, social responsibility, and innovativeness. (The detail description of the indicators of PBC, SN, PN are shown by section 4.3). It is also expected that some demographic factors like gender, age, education, household income, ownership of property also have influence onto the adoption intention. Hence, the theoretical framework of this study is proposed by Figure 2.3, and the detail description of the formation of the theoretical framework and research hypotheses are presented by Chapter 4.

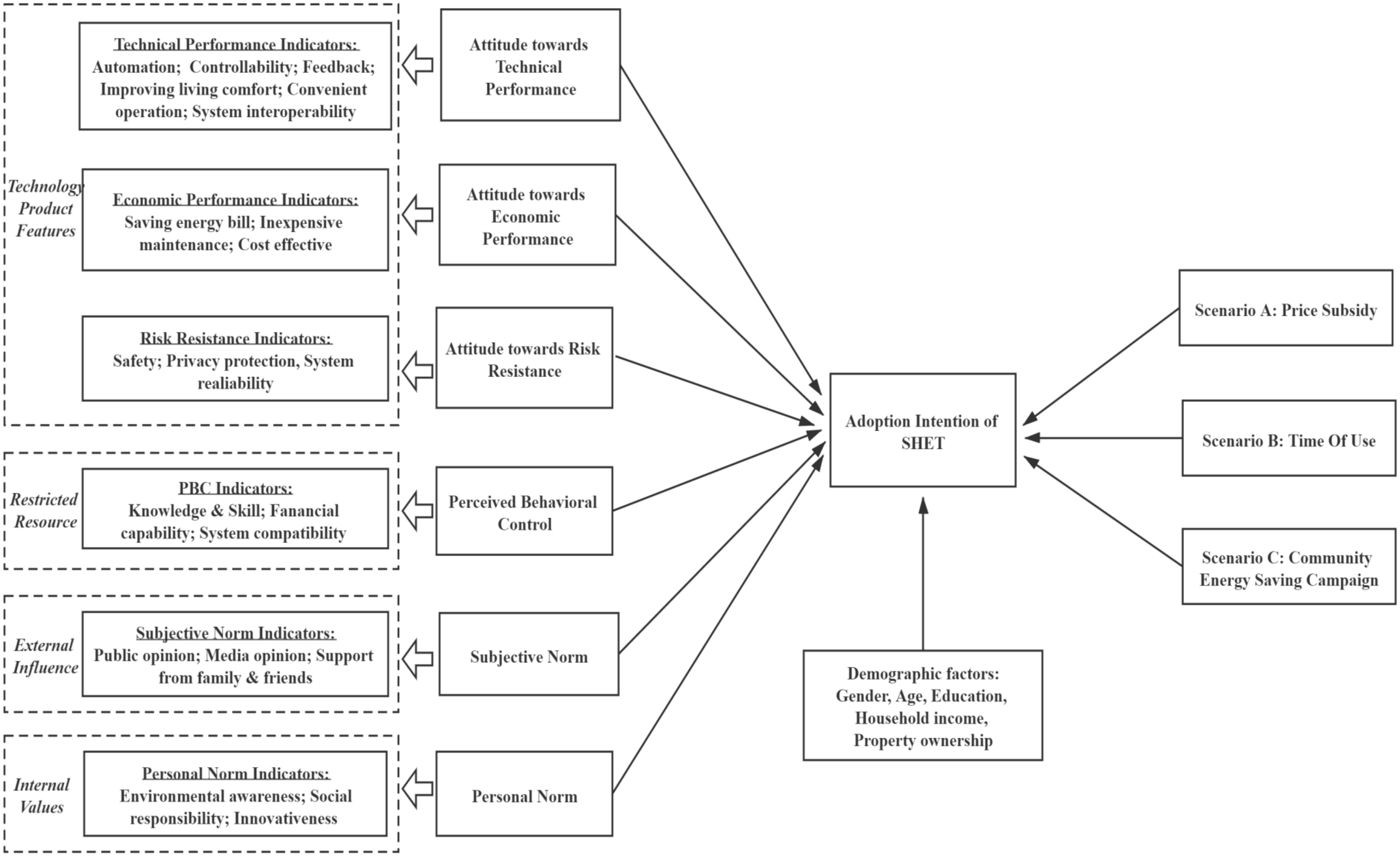

Figure 2.3 The theoretical framework for the study

Chapter 3 Research Design and Methodology

3.1 Introduction

The methodology plays a significant role in the whole research process, relating with the smooth of the research process and the validity of research findings. Chapter 3 includes two sections: firstly, the overall design of the whole research will be presented, including the research stage and the associated methodologies; section 2 will introduce each methodology in detail.

3.2 Research Design and Methodology

At the starting point of the research, a comprehensive research design should be made, in order to make the whole research process going ahead along the smooth and logical route and ensure the research problem could be addressed efficiently. The development of the research design is based on the research objectives, to breakdown the whole research into several sub-tasks, pointing out the problems to be solved in each task, as well as the feasible methodologies to be adopted. According to Chapter1, the objective of this study is to investigate the critical factors influencing urban resident's adoption intention of smart home energy technology, and to provide policy suggestions to the government and industry. Therefore, based on the goal need to be achieved, the design of the whole research process has been shown by Figure 1.4.

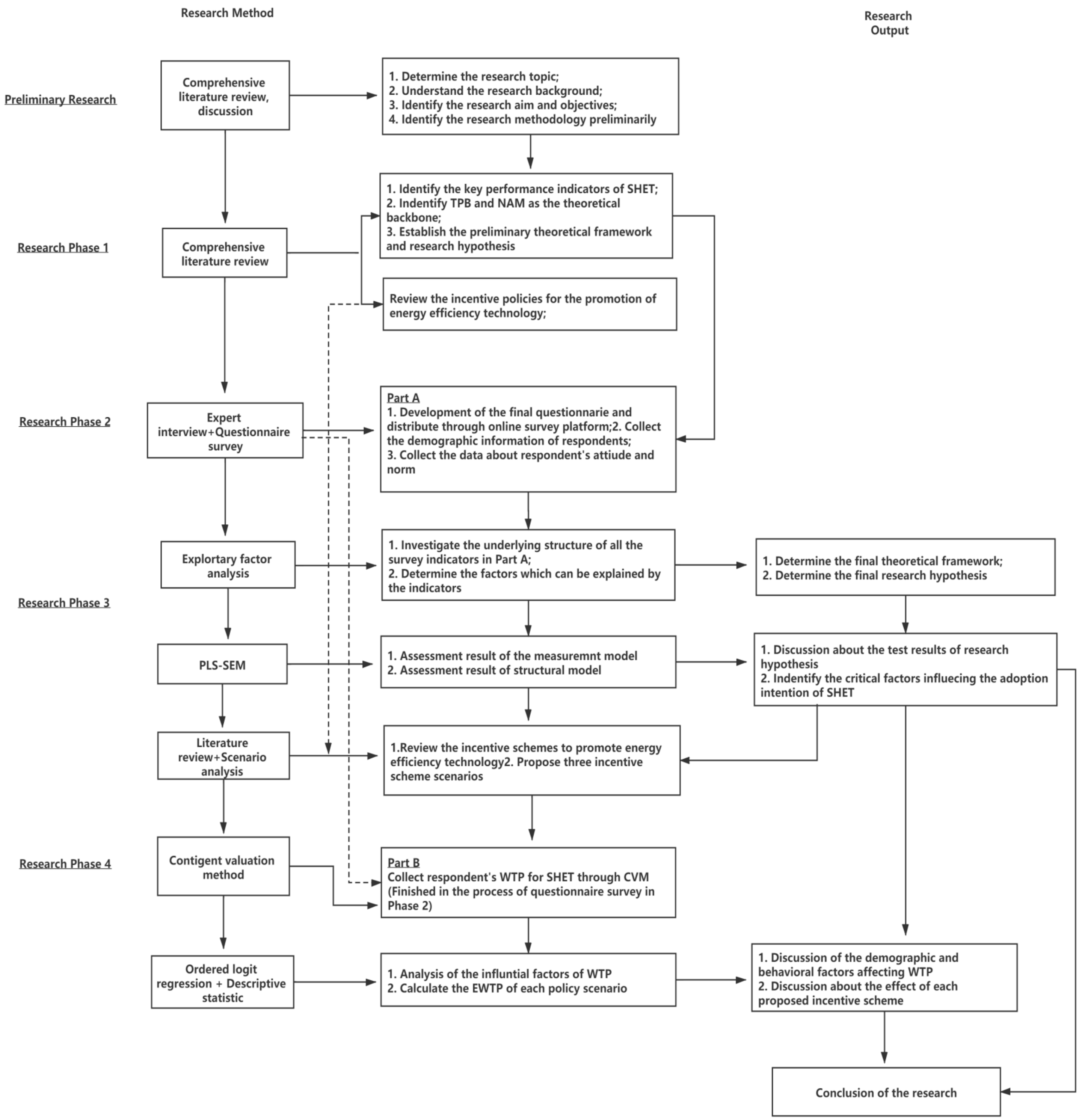

Figure 1.4 The overall research process of this study

3.3 Literature Analysis

The comprehensive literature analysis is to find out what has been achieved before for a specific research topic, to discover the significant variables relating with the topic, to identify the main methodologies for research and data collection, so as to build the knowledge and theoretical foundation for research of the topic (Hart 2018).

In this thesis, a comprehensive literature analysis will be conducted with the following objectives: (1) to understand the background of the technical issues relating to the smart home energy technology; (2) to review the formation of theory of planned behavior and norm activation model so as to construct the theoretical foundation for this research; (3) to review the key performance indicators of smart home energy technology that will influence resident's perception and attitude towards; (4) to review the behavioral and phonological factors influencing the urban residents to adopt the smart home energy technology: (5) to identify the methodologies for data collection and data analysis; (6) to review the policies that have been adopted by the governments to promote the diffusion of energy efficiency technologies.

This thesis reviewed the previous documents under the topics that mentioned above. The documents were retrieved from the databases Scopus, Web of Science and Google scholar, in the type of journal paper, conference paper, working paper or project report. In order to cover the full aspects of the knowledge involved with the topic of smart home energy technology, the influential factor for technology adoption as well as the incentive policies, the search key words are set as smart home, smart home energy management, smart grid, smart meter, technology adoption, theory of planned behavior, norm activation model, social norm, energy efficient technology, energy efficiency gap, behavior economics.

The comprehensive literature analysis is organized and summarized in three chapters of the thesis: Chapter 3 will review the theory of technology adoption and theory of planned behavior; Chapter 4 will review the key performance indicators of smart home energy technology and Chapter 5 will review the energy efficiency gap and the incentive polices for gap bridging.

3.4 Questionnaire Survey

The questionnaire survey is a widely used research methodology for efficient data collection and analysis when researching a sample of the population in a study (Hewitt, Hernández-Jiménez et al. 2017). In relation to the topics involved with this thesis, it has been adopted by numerous of studies relevant with people's perceptions, attitudes and behaviors, such as the household pro-environmental behavior (Abrahamse and Steg 2009, Newton and Meyer 2013, Wang, Zhang et al. 2014, Shi, Fan et al. 2017), the purchasing behavior involved with green or energy efficiency technology products (Vermeir and Verbeke 2008, Hsu, Chang et al. 2017, Ali, Ullah et al. 2019), the public perceptions towards the smart grid technologies (Mah, van der Vleuten et al. 2012, Ponce, Polasko et al. 2016, Yang, Lee et al. 2017, Washizu, Nakano et al. 2019). Although the methodology of questionnaire survey has some inherent weakness, such as the low response rate, the interpretation issues, dishonesty of respondents, because of its practicality, convenience, and scalability, etc., and so on some strengths, questionnaire survey is still a very popular data collection method, especially for social science studies (Sieber 1973, Evans and Mathur 2005).

In this thesis, based on the review of previous papers, a questionnaire survey was developed with the following objectives:

(1) To measure respondents' attitudes towards the key performances of smart home energy technology, including technical performance, economic performance, and risk resistance performance;
(2) To measure respondent's perceptions about the perceived behavior control, subjective norms and personal norm.
(3) To measure respondent's willingness to pay for SHET under different incentive scheme scenarios.

Structure of questionnaire

The questionnaire survey started with a introduction about the survey ovjectives and the general background of the smart home energy technology. And all the survey questions were devideded into three parts. The first part was to collect the demographic information of respondents, inlucing the gender, age, education degree, household income, usage experience. The second part of the questions was to solicite the respondents to indicate their attitudes and perceptions towards the technology performace, economic performance, risk resistance performance of SHET, perceived behaviroal control, subjective norm, and personal norm. The third part requested respondents to choose the appropriate number to represnet their maximum willingness to pay for SHET in various scenarios of incentive policy. The data collected in part 2 will be analyzed by

PLS-SEM, a widely used method to analyze the relationship between latent variables (Hair, Sarstedt et al. 2012) and the data collected in part 3 will be analyzed by logit regression model, to invesitgate the feasibility of the incentive policies facilitating the urban residents to purchase SHET.

Development of Likert scale

Likert scale was named after Rensis Likert, a psychologist who invented the rating scale (Likert 1932). Up till now, Likert scale has become the most widely used rating scale to measure respondent's attitude, or perceptions utilized in the questionnaire survey. A Likert scale is composed by several Likert items, which is a statement that requires the respondents to evaluate subjectively, but give a score in line with a quantitative dimension (Allen and Seaman 2007). In the previous research about the adoption behavior of energy efficiency technology, the five-point and seven-point measurement scales are the most widely used (Chen, Xu et al. 2017, Liu, Hong et al. 2018, Ali, Ullah et al. 2019, Ji and Chan 2019, Washizu, Nakano et al. 2019). In order to make the respondents to feel convenient and clear to express their opinions, the five-point Likert scale will be adopted in this thesis, and in the format of: strongly disagree =1; disagree =2; neutral/undecided =3; agree =4; strongly agree = 5.

Cronbach's alpha

Cronbach's alpha (Cronbach 1951) is the most widely used method to test the reliability of the measurement scale in questionnaire survey. In the structural equation modelling, several Likert item will be proposed to measure a latent variable, also called as "construct", and the associated

Cronbach's alpha is an index to determine the reliability of the Likert scale (Santos 1999). The range of alpha coefficient is between 0 to 1; and the higher the value is, the more reliability that the measurement scale have achieved. As recommended by (Nunnally 1994), 0.7 can be an acceptable threshold value to confirm the reliability of scale, but in some literatures, the coefficient value of lower than 0.7 were also accepted. In this research, the calculation of Cronbach's alpha will be executed by IBM SPSS Statistics 24, the function of Cronbach's alpha can be written as:

$$\alpha = \frac{N \overline{C}}{\vartheta + (N-1)\overline{C}}$$

Here N is the number of Likert items, $\overline{C}$ means the average value of the inter-item.

3.5 Exploratory Factor Analysis

Exploratory factor analysis (EFA) is a statistical technique to investigate a small number of underlying factors to explain or represent a greater number of measured variables or survey items (Henson and Roberts 2006). As suggested by (McNeish 2017), EFA can be used in the situations like "lacking strong theory to explain the relationship among the variables, or unclear about the number of the variables to represent the data". In many previous research related with the topic of smart technology adoption, such as the adoption of artificial intelligence in workspace (Brougham and Haar 2018), the acceptance of smart watch (Kim and Shin 2015), the adoption of smart board in education (Şad 2012), etc., EFA has been employed by authors to discover the underlying influential factors which can represent the survey items.

In the thesis, several indicators representing the performance of smart home energy technology have be investigated from literature (presented in Chapter 2), however, these indicators were not well structured and categorized, and the inherent relationship between these indicators was unknown either, with the purpose to discover whether there underlying factors that could be represented by the indicators and build a structural equation modelling finally, the exploratory factor analysis (EFA) was employed for further analysis. The procedures of EFA were executed by IBM SPSS 24, and are described as following:

(1) Conducting Bartlett’s test and Kaiser–Meyer–Olkin (KMO) test to examine the appropriateness of the data for EFA

KMO is to indicate the proportion of variance in all the measured variables that could be explained by underlying factors, and a value higher than 0.6 can be acceptable to EFA (Henson and Roberts 2006). Bartlett's test is to examine the relevance of the measured variables; if the associated *p* value is less than 0.05, it indicates that these variables are related and suitable for factor analysis (Landau and Everitt 2003).

(2) Factor extraction by principal component analysis (PCA) with Varimax orthogonal rotation

The goal of PCA is to reduce a large number of measured variables into a smaller set of composite variables which can represent them (Fabrigar, Wegener et al. 1999). Compared to other factor analysis methods, the advantage of PCA lies in the convenience of grouping variables, the explaining power of variance, and avoiding the hypothetical causal model might be underlying the data (Ford, Maccallum et al. 1986). The role of Varimax orthogonal rotation is to improve the PCA result into a more interpretable structure without changing the content (Ford, Maccallum et al. 1986, Reenu, Jiangang et al. 2018).

(3) Factor retention by the criteria of eigenvalues or interpretability

This research will adopt the default set of factor retention criteria in SPSS, that the factor eigenvalues should be higher than 1 (Kaiser Criterion) (Ford, Maccallum et al. 1986). Additionally, after the analysis, those indicators found to be not relevant with the extracted factor will be excluded. Although there is no uniform standard to decide which one should be excluded, this study will conform to the previous research experience that only the indicator with factor loading higher than 0.4 will be retained (Ford, Maccallum et al. 1986).

(4) Factor labeling

The extracted factors will be labeled in line with the information conveyed by associated indicators. Among all the indicators analyzed by EFA: automation, controllability, feedback, convenient operation, improving living comfort, and system interoperability, these six indicators are related with the technical features of smart home technology products; three indicators, including saving energy expense, inexpensive maintenance cost, and cost effective are revealing the economic performance of smart home energy technology; another three indicators containing system reliability, safety, privacy protection, reflecting user's concerns about the risks during the usage of smart home energy technology. And for the indicators relevant with the behavioral and norms, financial capability, knowledge & skill, system compatibility belong to the scope of perceived behavioral control; public opinion, media opinion, support from family and friends are relevant with subjective norm; and environmental concern, social responsibility, innovativeness are covered by personal norm.

3.6 Structural Equation Modelling

Structural equation modelling (SEM) was utilized by this thesis to analyse the relationship between the constructs in the model and test the hypothesis. In recent years, SEM has developed to be the most important and influential statistical method in the research of social science (Hair, Ringle et al. 2012). As the first generation of multivariate analysis technique, exploratory factor analysis and linear regression analysis could have achieved the function of measurement model assessment and structural model assessment respectively, however, SEM could combine and achieve the two powerful functions simultaneously (Fornell and Bookstein 1982, Lee, Petter et al. 2011).

The approach of SEM can be classified into two types: covariance-based SEM (CB-SEM) and variance-based partial least squares (PLS-SEM). Compared to CB-SEM, PLS-SEM has some flexibilities and advantages, including the acceptance to small sample size, no strict requirement of normality of data distribution, acceptance to both reflective and formative variable formats, accommodating to large number of variables, and high complexity of model (Hair, Ringle et al. 2013, Lowry and Gaskin 2014, Akter, Fosso Wamba et al. 2017). Additionally, PLS-SEM is suitable to the research with the goal of predicting target constructs or identifying the drivers, or based on the extention of existing theory; while CB-SEM is more approriate for the research whose goal is to test a theory, or to comfirm a theory, or to make aomparison between alternative theories (Hair, Ringle et al. 2011).Because of these benefits, PLS-SEM has gained its popularity in many research fields in business management, marketing, technology innovation, construction management, etc. (Hulland 1999, Tan 2013, Doloi 2014, Sarstedt, Ringle et al. 2014, Rigdon 2016, Hair, Hollingsworth et al. 2017, Usakli and Kucukergin 2018).

As for this thesis, a theoretical framework will be founded on the extension of existing behavioural theory- Theory of Planned Behaviour (TPB, shown by Figure 2.1), and one of the research objective is to identify the key constructs driving the adoption intention of smart home energy technology. Therefore, considering the previous examples and the benefits of PLS-SEM, this study will also employ this approach to analyse the theoretical model. PLS-SEM will be performed by software SmartPLS 3.0 (Hair Jr, Hult et al. 2016). A figure of theoretical SEM and constructs is shown by Figure 3.1: the outer model (encircled by the dashed line) is the measurement model of SEM; and the inner model (encircled by the solid line) is the structural model of SEM (Jr., Matthews et al. 2017). The measurement model is composed by latent variables and reflective indicators and the structural model is composed by latent variables. The execution of PLS-SEM contains three processes: a) assessment of measurement model, b) assessment of structure model, and c) assessment of significance of path coefficient (Hair, Ringle et al. 2011, Hair Jr, Hult et al. 2016). The detail result will be presented in the following sections.

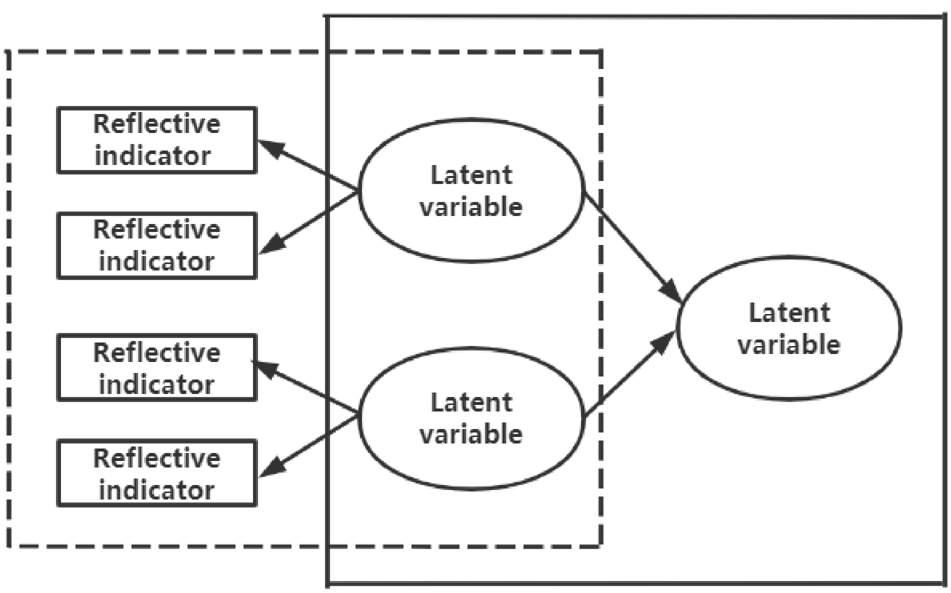

Figure 3.1 Theoretical SEM and constructs (Jr., Matthews et al. 2017)

Assessment of measurement Model

As shown by Figure 3.1, the measurement model is the outer model of SEM, representing the relationships between the latent variable construct and the associated indicator variables (Jr., Matthews et al. 2017). The measurement model will be evaluated by two types of validity:

- Convergent validity: outer loadings of indicators > 0.7; composite reliability (CR) > 0.7 and the average variance extracted (AVE) > 0.5 (Hair, Ringle et al. 2011), meaning that the indicators are reliable and more than half of the indicator variance is included in the construct (Hair Jr, Hult et al. 2016);
- Discriminant validity: to evaluate whether a construct in SEM is unique from others (Jr., Matthews et al. 2017), the criteria is square root of AVE of one construct should be higher than the correlation coefficient shared by this construct and any other constructs (Hair, Ringle et al. 2011).

Assessment of structure model

As shown by Figure 3.1, the structural model is the inner model of SEM, showing the relationships between the constructs. In the PLS-SEM, only single direction between the constructs is permitted, and the constructs are classified by two types: exogenous construct, referring to the constructs that without any path relationship pointing at them; and the endogenous constructs, referring to the constructs will be explained by other constructs through structural relationship (Hair, Ringle et al. 2011).

The primary evaluation criterion for the structural model include the significance of path coefficient, the R^2 measure, and Stone-Geisser's Q^2 value (Hair, Ringle et al. 2011). In this thesis, the test of path coefficient significance will be performed by 5000 samples of bootstrapping procedure and critical values of T test is 2.33, with the significance level of 0.05 (**p< 0.05). The R^2 measure is to test the explaining power of the latent variables in the model, with the value of R^2 the higher the better. But the judgement of R^2 value varies with the research area, for example, in the area of consumer behaviour, R^2 result of 0.20 is considered to be high, representing the model could well explain the research object (Hair, Ringle et al. 2011). Cohen suggested that in behavioural science, R^2 value of 0.35 is substantial (Aibinu and Al-Lawati 2010). In a study of consumer purchasing behaviour about the energy efficient appliances in Malaysia, the authors accepted the R^2 value of 0.496 (Tan, Ooi et al. 2017). Besides, Q^2 value is a predominant method to evaluate the model's predictive relevance, with a criterion of higher than zero.

3.7 Contingent valuation method

The contingent valuation method (CVM) was put forward by (Ciriacy-Wantrup 1947), who proposed to value the public benefits for the prevention of soil erosion by asking the individuals to state their willingness to pay for the public benefits through a survey. Since then, the CVM has gradually become a widely used survey-based technique to obtain the monetary value for some non-market goods (Hanemann 1994), such as the social welfare or public health care plans (Gertler and Glewwe 1992, Olsen and Smith 2001, Bärnighausen, Liu et al. 2007), environmental or animal protections (Wang and Jia 2012, Veronesi, Chawla et al. 2014), cultural products (Papandrea 1999), green or energy efficiency technologies (Galarraga, González-

Eguino et al. 2011, Hidrue, Parsons et al. 2011, Zhou and Bukenya 2016, Zhang, Chen et al. 2018), as well as many public infrastructure projects in developing countries (Whittington, Briscoe et al. 1990, Navrud and Mungatana 1994). Recent years, as the development of smart technologies, CVM was also applied to assess resident's willingness to pay for the smart meter, smart home energy management system, and the various functions of smart home (Gerpott and Paukert 2013, Rihar, Hrovatin et al. 2015, Washizu, Nakano et al. 2019, Yang and Lam 2019).

The implementation of CVM is based on the questionnaire survey. This part of survey usually starts with a description of the scenario that maybe a plan for social benefit such as public health care or establishment of natural conservation park, or promote renewable energy, smart gird to residents, etc. Some supplementary materials like photograph, charts or videos may also be used to assist the respondents to know of the scenarios better. The survey could be organized in the way of face to face interview, telephone survey, or through online survey platform, referring to procedures in the previous studies (Zhou and Bukenya 2016, Washizu, Nakano et al. 2019, Yang and Lam 2019).

In the survey, a value elicitation question need to be designed to obtain the respondent's maximum willingness to pay for the goods in monetary value (Carson and Hanemann 2005). The formats of the WTP elicitation question include: open-ended, bidding game, payment card, and dichotomous choice. As (Bateman, Carson et al. 2002) has recommended, the payment card format has less financial requirement and the result is more informative. In the execution of payment cards method, the respondents will be provided a series number of monetary amounts and be asked to select the amount of money representing the maximum value they are surely willing to pay. Following the value elicitation question, some much deeper questions like why you are willing or unwilling to pay can be asked (Bateman, Carson et al. 2002).

In this thesis, the value elicitation question will be based on the payment card method, but the maximum amount of money will be replaced by the number representing the maximum willingness.

The implementation of CVM for data collection is the third part of questionnaire survey, from questions 22~25 (See Appendix I), the respondents were asked to tick the appropriate number from 0~5 to show their maximum willingness to pay for SHET, which 0~ Unwillingness; 1~ Slight willingness; 2~ some willingness; 3~ High willingness; 4~ Very high willingness; 5~ Extremely high willingness. When designing the Likert scale, both 0~10 and 0~5 were considered, however, as the questionnaire survey will be translated into Chinese before handing out, and in Chinese language, the 10 point scale is quite hard to explain clearly. In order to make sure every respondent would understand the willingness scale without confusions, the scale 0~5 was adopted finally.

And the description of each question is shown by Table 3.1 below:

Table 3.1 The description of questions for WTP by CVM in the Part B of questionnaire survey

No.	Scenario	Under each scenario below, please tick the appropriate number to represent your maximum willingness to pay for SHET. The meaning of the number: 0~ Unwillingness; 1~ Slight willingness; 2~ some willingness; 3~ High willingness; 4~ Very high willingness; 5~ Extremely high willingness.	
1	Business as usual (BAU)	Everything maintain the same with your current situation, nothing will change, no incentive polices.	0 1 2 3 4 5
2	Price subsidy (PS)	Government will roll out a price subsidy policy for all the SHET products you purchase, covering all the brands, and all online or physical stores. The amount of subsidy: 10% of the product price, with a highest amount of 800 Yuan.	0 1 2 3 4 5
3	Time of use (TOU)	Government will roll out compulsory TOU electricity pricing plan in Guangdong province. The hours a day will be divided into three sections: peak period (14:00~17:00, 19:00~22:00); flat period (8:00~14:00, 17:00~19:00, 22:00~24:00) and valley period (0:00~8:00). The ratio of the electricity rate among peak, flat and valley period is 1.65:1:0.5, of which, the flat price is consistent with the electricity rate currently. The functions of SHET, like scheduling, automation, remote control, etc. will engage you to make use of the price variance across three sections, and save your electricity bill.	0 1 2 3 4 5
4	Community energy saving campaign (CESC)	The community of your residence will hold an energy saving campaign, and the arrangement of the campaign is as below: 1) The comparison criteria will be based on the amount of the household electricity consumption per month. 2) The top 10% of the households in community that consume the least electricity will be rewarded with prizes prepared by community; and their rankings and house numbers will also be listed on the bulletin board to the whole community.	0 1 2 3 4 5

3.8 Ordered Logit Regression Analysis

In the questionnaire survey, the respondents were asked to tick an appropriate choice from a string of ordinal numbers to represent their maximum willingness to pay for SHET. The number ranges from 0 to 5, with zero being no willingness to extremely high willingness, hence this string of ordinal number can be treated as ordinal categorical variables, and also the dependent variables in the model.

The ordinal logit regression will be adopted in the thesis with two purposes: 1) to analyze the influence onto the dependent variables by the independent variables, which will be executed by statistics software package IBM SPSS24; 2) to calculate the expected value of willingness to pay. The regression coefficient β stands for the increasing of one unit in the independent variable, the response dependent variable level is expected to change; the amplitude of the change equals to the value of odds ratio, which is the exponential value of the respective regression coefficient (e^{β}) ; a positive regression coefficient will lead to a positive change, and vice-versa.

In this study. when calculating the expected value of WTP, the key work is to obtain the probability of respondent's one selection. As the explanation of (Grilli and Rampichini 2014), in the ordered logit model, a respondent i's selection for one's WTP is regarded as an ordinal response Y_i with C categories alongside with a vector of covariates or factors x_i. Hence a relationship between the covariates/factors and the set of probabilities of the categories P_{ci} can be established:

$$Pci = \Pr (Y_i = y_c \mid x_i), \; c=1 \ldots C \qquad (3.1)$$

Usually, regression models for ordinal responses are expressed in the form of the cumulative probabilities, shown by Eq. (3.2), because the final cumulative probability necessarily equals to 1, the model only determines $C-1$ cumulative probabilities.

$$g_{ci} = \Pr(Y_i \leqslant y_c \mid x_i),\ c=1\cdots C \tag{3.2}$$

And the *C-1* sets of Eq. (3.2) are related to a linear predictor:

$$\beta' x_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots \beta_n x_{ni} \tag{3.3}$$

Then through logit function, Eq.(3.2) will be transformed into:

$$logit(g_{ci}) = log\,(g_{ci}/(1-g_{ci})) = \alpha_c - \beta' x_i,\ c= 1, 2\ldots C-1 \tag{3.4}$$

The parameters α_c is named as thresholds, and the cumulative probability for category c is:

$$g_{ci} = \exp(\alpha_c - \beta' x_i) / (1+ \exp(\alpha_c - \beta' x_i)) = 1/ (1+ \exp(-\alpha_c + \beta' x_i)) \tag{3.5}$$

In the thesis, the ordinal response Y_i with C categories is equivalent with respondent's selection of the ordinal number representing one's WTP. Under normal circumstance, one selection is regarded as one random event; and when a selection C_i is determined by respondent, the probability of this section $Pr(C_i)$ is the equivalent of the probability that one's willingness to pay lies between the interval of C_i and C_{i-1}. With the dependent variables lying within a given interval, the logit model is expressed as below:

$$Pr(C_i) = g_{ci-1} < WTP \leq g_{ci} = g_{ci} - g_{ci-1} \tag{3.6}$$

And the expression of expected value of WTP can be written as:

$$EWTP = \sum_{i=1}^{N} C_i \times Pr(C_i) \tag{3.7}$$

Chapter 4 Development of Theoretical Framework for Investigation of Critical Factors Influencing the Adoption Intention of SHET[3]

4.1 Introduction

This chapter will present the development of the preliminary theoretical framework. The aim of the theoretical framework is to investigate the critical factors influencing the adoption intention of smart home energy technology (SHET). The skeleton of the theoretical framework is based on the integration of two traditional behavioral theories: The Theory of Planned Behavior (TPB) and Theory of Norm Activation Model (NAM), as well as incorporating the performance of SHET. In the theoretical framework, six factors, including attitude towards the technical performance (ATTP), attitude towards the economic performance (ATEP), attitude towards risk resistance (ATRR), perceived behavioral control (PBC), subjective norm (SN), and personal norm (PN) are supposed to be positively related with the adoption intention of SHET, named as hypothesis H1~H6. Additionally, five demographic factors, including gender, age, education degree, household income, type of property (self-own/rent) are also assumed to have relationship with the adoption intention, which are named as hypothesis H7~H11.

4.2 Theoretical Framework

Based on the above literature reviews of behavioral models, this article introduces the construct personal norm from NAM into the TPB, with the purpose to enhance the explaining power of TPB at moral dimension. Additionally, considering the sophisticated technical attributes of smart

[3] This chapter has been partial published in Ji, W., & Chan, E. H. (2019). Critical Factors Influencing the Adoption of Smart Home Energy Technology in China: A Guangdong Province Case Study. Energies, 12(21), 4180

technology, and the potential monetary gains or cost incurred during the usage of SHET, it is hard to directly use the original construct "attitude" in TPB to reflect the comprehensive evaluations of the performance of SHET. Therefore, with the purpose to better understand residents' perceptions about the technical and economic performance of SHET, as well as the capability of risk resistance, three new attitudinal constructs are developed in this study: attitude towards technical performance (ATTP), attitude towards economic performance (ATEP), and attitude towards risk resistance (ATRR). According to the findings of the previous research, the demographic factors like gender, education, and income also have been found out to have relationship with people's behavior, therefore, the effects of the demographic factor will also be examined in this research. The graph of the theoretical framework is shown by Figure 4.1.

The measurement indicators to assess each model construct are obtained from the literature reviews. The specific explanations of the constructs and measurement indicators in this theoretical model are described as following.

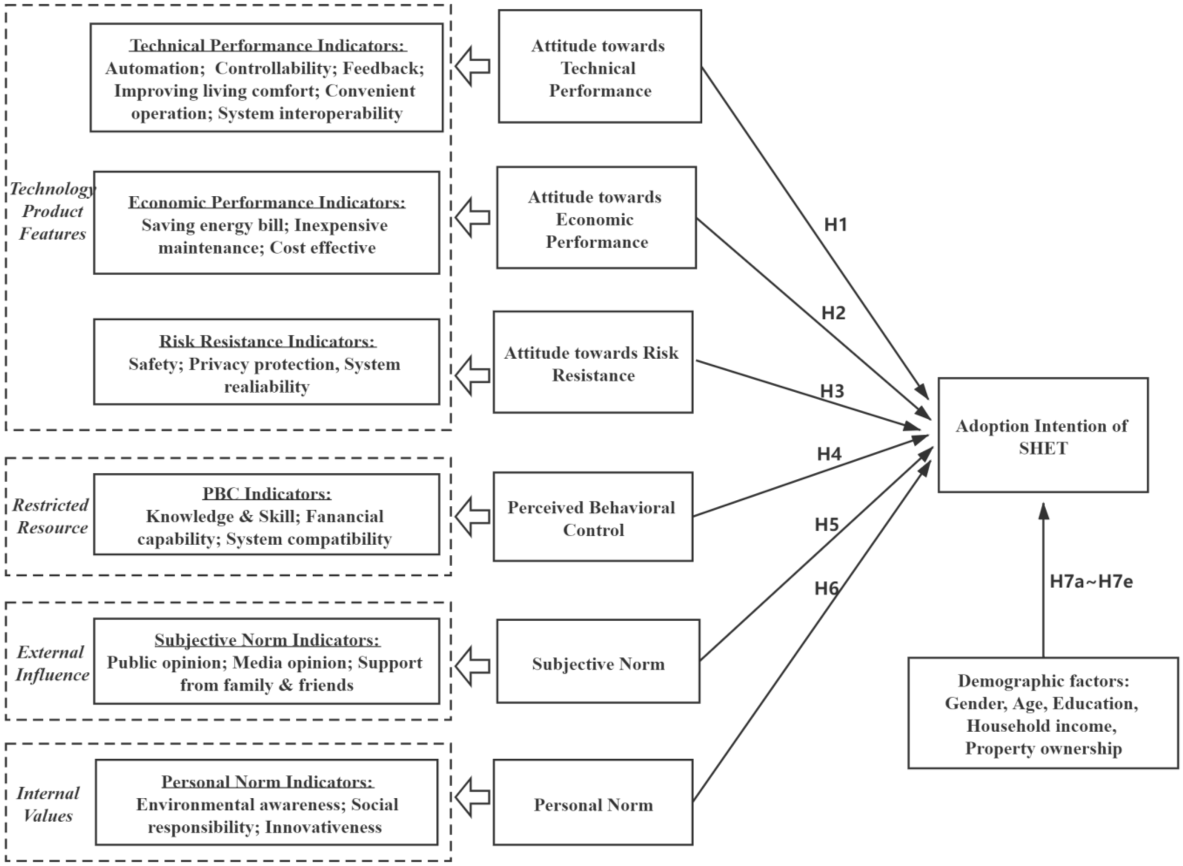

Figure 4.1 Theoretical framework for investigation of critical factors influencing the adoption of SHET

4.3 Research Hypothesis

4.3.1 Resident's attitude towards technology performance of SHET

Attitude is a mental state of readiness that person learned through experience, and exert influence on people's response (Ivancevich and Matteson 1980), which is also derived from person's subjective evaluation of the likely outcome that the behavior will produce (Ajzen 1991). In a study of household electricity behavior, (Wang, Zhang et al. 2011) defined the attitude was decided by household's evaluation of preference to electricity saving and the information availability. (Yang, Lee et al. 2017) has empirically confirmed that person's attitude toward smart home services is positively related with the adoption intention. In the context of adoption intention of smart home energy technology (SHET), attitude represents the resident's comprehensive evaluation of the performance of each function that the SHET could present.

Until to now, the smart technology is still undergoing the rapid development, with continuous new technical features and functions launched to market. As smart home technology is expected to be deep engagement into people's daily life, by sensing household occupant's daily activities, or living habits, collecting the living activity data; and making prediction (Cook 2012), it is quite crucial for smart home technology to provide a pleasant user experience. (Wong and Leung 2016) asserted that the technical (functional and operational) performance was an significant influential factor for the adoption of smart home technologies. Through a survey conducted by (Mert and Tritthart 2012), he found that consumer's perception of a mature technology would lead to one's willingness to pay for the smart appliance. Consequently, a research hypothesis can be proposed:

H1*: Resident's attitude towards technical performance (ATTP) of SHET is positively related with the adoption intention of SHET.*

ATTP is a latent variable in the theoretical model. Based on the literature review about the performance indicators of smart home energy technology in Chapter 2, it is supposed six key performance indicators of SHET that will be utilized to assess the latent variable ATTP, including: automation (Wong, Li et al. 2008, Wong, Leung et al. 2017, Parag and Butbul 2018)., controllability (Mert and Tritthart 2012, Sadrieh and Bahri 2014), information feedback (Wood and Newborough 2007, Ehrhardt-Martinez, Donnelly et al. 2010, Beth, Zinger et al. 2015), comfort (Cook 2012, Balta-Ozkan, Davidson et al. 2013, Anvari-Moghaddam, Monsef et al. 2015, Gram-Hanssen and Darby 2018), convenient operation (Cook 2012, Balta-Ozkan, Davidson et al. 2013, Gram-Hanssen and Darby 2018), system interoperability (Balta-Ozkan, Davidson et al. 2013).

4.3.2 Resident's attitude towards economic performance of SHET

(Balta-Ozkan, Amerighi et al. 2014) ever made a comparative study under the topic of public perceptions about smart home technology in the UK, Germany and Italy, and they asserted that people's perceptions of the economic performance, such as reducing energy cost, was one of the key drivers for smart home adoption in the three European countries. In the meantime, in a consumer study conducted by (Mert and Tritthart 2018) in five European countries (Austria, Germany, Italy, Slovenia and UK), they also found out that consumers' adoption intention of smart domestic appliances would depend on their perceptions about financial benefits. (Paetz, Dütschke et al. 2012) concluded that higher expected monetary gains and shorter payback period would improve consumer's evaluation of the smart home equipment. And (Wong and Leung 2016) indicated that low maintenance cost during the usage period of smart home technology is a significant indicator of good economic performance. The benefits of reducing energy expense, short payback period, and higher net present value have been demonstrated by experimental simulation for the smart energy technology solutions for single family houses in Germany and Algeria (Ringel, Laidi et al. 2019). Hence, based upon the previous research and literature reviewed, we expect that resident's attitude towards economic performance (ATEP) of SHET will have a positive impact on the adoption intention, and propose the second hypothesis:

***H2**: Residents' attitude towards economic performance of smart home energy technology is positively related with adoption intention.*

To assess the latent variable ATEP, three measurement indicators of economic performance are investigated from previous literature review, including save energy expense (Balta-Ozkan, Boteler et al. 2014, Bhati, Hansen et al. 2017, Park, Hwang et al. 2017, Strengers and Nicholls 2017, Wilson, Hargreaves et al. 2017, Parag and Butbul 2018, Sanguinetti, Karlin et al. 2018)., inexpensive maintenance cost (Balta-Ozkan, Davidson et al. 2013, Balta-Ozkan, Boteler et al. 2014), and cost effective (Mert and Tritthart 2012, Paetz, Dütschke et al. 2012, Balta-Ozkan, Davidson et al. 2013).

4.3.3 Resident's attitude towards risk resistance of SHET

The risks associated with the smart home energy technology include three types. The first type is the safety risk related with the smart grid infrastructure (Khurana, Hadley et al. 2010, Flick and Morehouse 2011), because of the highly integration of various of systems, and its vulnerable to the cyber-attack (Sridhar, Hahn et al. 2012). The second type is the privacy infringement, as in a smart home environment, the household data might be shared with utility companies, smart home service providers, governments, or some other third party institutions; and the current technology have achieved the capability to capture the household's living data and predict their occupancy and living habit (McDaniel and McLaughlin 2009, Khurana, Hadley et al. 2010), which may lead to some adverse results to house dwellers if such personal information stolen by criminal offenders (Yildiz, Bilbao et al. 2017). And the third type of risk is associated with the reliability of the smart home technology, in case the smart home technology suffer malfunction, or inaccuracy signaling, sensing, or monitoring, some unintended loss would happen to the home dwellers (Chan, Estève et al. 2008, Balta-Ozkan, Davidson et al. 2013).

Many previous surveys about public perceptions of smart technologies such as smart grid, smart meter, or smart home have showed that people are concerned with the risks introduced, and the relevant risks have been deemed as a barrier to prevent the diffusion of smart technology through residents regions (Balta-Ozkan, Boteler et al. 2014, Raimi and Carrico 2016, Bhati, Hansen et al. 2017, Parag and Butbul 2018, Sanguinetti, Karlin et al. 2018). To mitigate potential user's worries about the risks, many technology companies have engaged a lot to enhance their capabilities of risk resistance, by the way of both improving techniques and managerial regulations. Therefore, as if the residents could have positive attitude to the risk resistance of smart technology, they might be more willing to adopt. Based on this thinking, the latent variable ATRR (Attitude Towards Risk Resistance) would be added into the research model and the third hypothesis is proposed; additionally, four indicators are selected to measure ATRR, including safety, reliability, privacy protection by smart products, and privacy protection by smart service providers.

H3*: Residents' attitude towards risk resistance of smart home energy technology is positively related with adoption intention.*

4.3.4 Perceived Behavioral Control

Perceived behavioral control (PBC) is defined as people's perceptions of their ability to perform a given behavior, and determined by the capabilities or resources that can facilitate the performance of this behavior under people’s perceptions (Ajzen 1991). PBC will be reflected two dimensions of indicator: the availability of some external constraint conditions like money, time, manpower or other resources; while the other is about the internal power, like self-confidence of the capability owned to perform one specific behavior (Ajzen 1991, Wisdom, Chor et al. 2014). Additionally, as the smart technology is a kind of new emerging technology, it might be not compatible with the building system of some old buildings, therefore, the compatibility with existing building system is also a indicator of perceived behavior control of potential adopter (Balta-Ozkan, Davidson et al. 2013, Balta-Ozkan, Amerighi et al. 2014).

In the past studies about the adoption intention of energy efficiency technologies, PBC has been widely uptake into the theoretical framework, and empirically convinced as an important antecedent of behavioral intention, including (Chiou 1998, Tan, Ooi et al. 2017, Ali, Ullah et al. 2019) Therefore, based on the review of previous studies, this study has a similar expectation about PBC, and develop the below hypothesis, and three measurement indicators of PBC are chosen from past literature, including knowledge and skills, financial capability, compatibility with existing building system.

H4*: Perceived behavioral control has a positive relation with resident’s intention to adopt SHET.*

4.3.5 Subjective norm

Subjective norms refers to the social pressures that one person could perceive from one's social network, or family when he or she considers whether to engage in a behavior or not (Ajzen 1991). Cialdini et al. categorized the subjective norm into two types: injunctive norm and descriptive norm, of which, the injunctive norm refers to whether one behavior can be supported by the majority of social group; while the descriptive norm reflects a popular behavior welcomed by the society (Cialdini, Reno et al. 1990, Hamann, Reese et al. 2015). In the Theory of Diffusion of Innovation (Rogers 2010), during the decision-making process of a new technology adoption, people will be influenced by factors from the external environment, such as mass media, government policy or regulations, and their social network (Wang, Zhang et al. 2014). (Hori, Kondo et al. 2013) conducted a comparative study of household energy saving behaviors across five Asian countries, and they pointed out that the significance of social interaction factors including "favoring neighborhood" and "participating in community" were investigated through questionnaire survey. Therefore, consistent with the theory of planned behavior and the previous research, one hypothesis is developed in this thesis, and three indicators: policy environment, media publicity, and supports from social network are selected as measurement indicators to measure the factor of Subjective Norm (SN).

***H5**: Subjective norms have a positive influence on resident's intention to adopt SHET.*

4.3.6 Personal norm

Personal norm (PN) is associated with person's self-expectations or moral obligations that rooted in one's internal values (Schwartz 1977). The impact of personal norm onto the motivation of energy and environmental friendly behaviors has been empirically verified by lots of studies (Chen 2016, Ji and Chan 2019, Li, Xu et al. 2019). Additionally, except for the values of environment protection and social responsibility, particularly for some new technologies, (Agarwal and Prasad 1998) suggested that the person who had some innovative spirit in one's values would be more liable to welcome new emerging technology. (Ali, Ullah et al. 2019) has convinced the power of innovativeness as a character to affect consumers' attitude towards the adoption energy efficient appliances. In the consumer acceptance analysis of home energy management system (HEMS) for Korean market of (Park, Hwang et al. 2017), the authors concluded that the social contribution, environmental responsibility, and innovativeness were influential factors that strength people's perception of technology usefulness, and then exerted positive effect on the adoption behavior. In the thesis, referring to the previous studies, three reflective indicators of personal norm are selected, including social responsibility, environmental awareness, and innovativeness, and the sixth hypothesis for the resident's intention to adopt SHET is proposed:

H6*: Personal norm is positively related to resident's adoption intention for SHET.*

4.3.6 Demographic factors

In the previous research about people's energy saving behavior, both the habitual and the purchase related behavior included, the influences of the demographic factors such as age, income, education etc. also have been investigated by many studies, but the impacts of demographic factors were various according to the different research background. (Wang, Zhang et al. 2011) found that people's age was positively related with the willingness to save electricity through a study about Beijing residents. (Chen and Sintov 2016) reported that compared to the older, the younger generation was more likely to adopt the home energy management system in their homes after a study conducted in California of the US. (Mills and Schleich 2010) also found the significant difference existing across the age and education degree related to the purchase propensity of energy efficiency appliance. And in Europe, (Gaspar and Antunes 2011) stated that when making purchase choice, women put significant more importance on the energy efficiency, while men significantly valued the number of functions and technology innovation more.

Additionally, among these demographic factors, some are ordinal variables, like household income, and some are categorical variables, like gender, household ownership. Therefore, is hard to propose the hypothesis of the influence of demographic factors on adoption intention with direction positive, or negative, and findings in past literature could not provide enough evidence to make hypothesis with direction either.

Hence based on the previous research, we also have the same expectation in this thesis, that the demographic factors will have influence on the adoption intention of SHET by urban residents in China, and the hypothesis is:

H7*: The demographic factors will have significantly impact onto the adoption intention of SHET.*

The demographic factors include: Gender (H7a), Age (H7b), Education (H7c), Household income(H7d); Property ownership (H7e).

Chapter 5 Implementation of Questionnaire Survey in Guangdong Province

5.1 Introduction

This chapter introduces the process of the development of questionnaire, the process of data collection and the background of the survey respondents. In the previous chapter, a theoretical framework has been founded, compromising seven constructs and six hypothesizes; additionally, in order to measure the constructs, totally 22 indicators have been investigated through literature review. With the purpose to examine the hypothetical relationships proposed by the theoretical framework, as well as to discuss the incentive policies in the later chapter, a comprehensive questionnaire survey need to be organized in the targeted study area. The development of questionnaire has been based on the previous literature, and distributed in Guangdong province in 2019. After the collection of questionnaire survey was collected, an exploratory factor analysis has been conducted to investigate the underlying factors to represent those survey items and examine the compatibility with the underlying factors with the constructs proposed in the theoretical framework. After the EFA, two indicators were deleted, and a final theoretical framework including seven constructs and 19 indicators were founded.

Additionally, because the SHET is a very new type of technology, in order to make sure all the survey respondents would understand the concept of SHET. The survey starts from a introduction of SHET, proving some examples of SHET in each category, including the in home display, smart lighting, smart air-conditioner, smart washing machine.

5.2 Development of Measurement Items and Scale

The theoretical framework is composed by eight constructs, including attitude towards technical performance (ATTP), attitude towards economic performance (ATEP), attitude towards risk resistance (ATRR), perceived behavioral control(PBC), subjective norm(SN), personal norm (PN), demographic factors and adoption intention (AI). In order to examine the hypothetical relationships contained in the framework, a questionnaire survey must be developed in advance, and each construct will be measured by the survey items which is developed according to the indicators investigated though literature review in previous chapters.

5.2.1 Measurement of attitude

According to the introduction by (Francis, Eccles et al. 2004), there are two methods to measure the behavioral attitude: direct measurement and indirect measurement. The direct method is to use the bipolarized adjectives to make evaluation, (e.g. good-bad; worthless-useful); and the indirect measurement is to identify the behavioral belief first, then to develop questionnaire items to evaluate the probable performance. This study will adopt the indirect method. In this study, three types of attitudes need to be measured by survey, including ATTP, ATEP, ATRR, of which, the associated performance indicators have been found out through literature review in Chapter 2; therefore, the relevant behavioral belief will be built corresponding to the performance indicator respectively, and the development of questionnaire items are shown below in Table 5.1, Table 5.2 and Table 5.3.

Table 5.1 Measurement of attitude towards technical performance (ATTP)

Code	Indicator	Measurement item
ATTP1	Automation	I believe the SHET could execute some functions in a self-operative mode with minimum human intervention.
ATTP2	Controllability	I believe under some accidental situations, the operation of SHET can still be controllable.
ATTP3	Feedback	I believe the SHET could provide my household energy consumption information in an effective and user friendly way.
ATTP4	Convenient operation	I believe the design of the SHET is convenient for me to handle and operate.
ATTP5	Improving living comfort	I believe the SHET could improve my indoor comfort by the functions of automatically adjusting room temperature, humidity and illumination, etc.
ATTP6	System interoperability	I believe the SHET products could communicate and collaborate with the existing and also the new adopted smart products.

Table 5.2 Measurement of attitude towards economic performance (ATEP)

Code	Indicator	Measurement item
ATEP1	Saving energy expense	I believe the SHET could help me to reduce energy expense and create economic profit for my family.
ATEP2	Inexpensive maintenance	I believe the SHET would not generate costly maintenance fee.
ATEP3	Cost effectiveness	Considering the financial condition of my family, I believe the I would get a good return from SHET, compared to the money I pay for.

Table 5.3 Measurement of attitude towards risk resistance (ATRR)

Code	Indicator	Measurement item
ATRR1	System reliability	I believe the SHET could maintain smooth running and produce my desired outcomes with high accuracy.
ATRR2	Safety	I believe the SHET would not occur accidents that threaten my domestic environment and cause serious damages to my family's lives and properties, such as fire, losing control of total electricity load, etc.
ATRR3	Privacy protection	I believe the SHET and its operating agent could protect my household information, as well as utilize my privacy data legally.

5.2.2 Measurement of perceived behavioral control

As the instruction of (Francis, Eccles et al. 2004), the direct measurement of PBC is to assess one person's self-efficacy about the controllability of one specific behavior, for example, asking participants to report the extent of the confidence or difficulty they have when considering to engage one behavior; and the indirect measurement is to identify the control belief first, then to construct questionnaires to assess the power of the control factors in respondent's perceptions. This study will employ the indirect method to measure PBC. In the previous Chapter 4.3, three control beliefs involved with the adoption of SHET have been identified, including: knowledge & skill, financial capability, and system compatibility; therefore, three survey items will be developed for each of the control belief respectively, as shown by Table 5.4.

Table 5.4 Measurement of perceived behavior control (PBC)

Code	**Indicator**	**Measurement item**
PBC1	Knowledge & Skill	I believe I own the knowledge and skill to operate and handle the SHET.
PBC2	Financial capability	I believe the financial capability of my family could afford the adoption of SHET.
PBC3	Compatibility with building system	I believe the building system of my household could be compatible with SHET products.

5.2.3 Measurement of subjective norm

This study will adopt the direct method to measure the subjective norm of respondents according to the description of (Francis, Eccles et al. 2004), that to use direct questions referring to the opinions of important groups. In the Chapter 4.3, the important groups have been identified as family & friends, the public voice, and the media, therefore, the survey items are developed correspondingly, as shown by Table 5.5.

Table 5.5 Measurement of subjective norm (SN)

Code	Indicator	Measurement item
SN1	family & friends	My family member and friends would expect me to adopt the SHET.
SN2	public opinion	The public opinions expect me to adopt SHET.
SN3	media opinion	The media opinions would expect me to adopt the SHET.

5.2.4 Measurement of personal norm

The measurement of personal norm would refer to the survey item in previous research, such as (Costa 2013, Jansson and Dorrepaal 2015). In the previous chapter 4.3, social responsibility, environmental concern, and innovativeness have been identified as the moral beliefs triggered by one's internal values relevant with the energy saving behavior and adoption of innovative technology; then the survey items are developed for the beliefs respectively, as shown by Table 5.6.

Table 5.6 Measurement of personal norm (PN)

Code	Indicator	Measurement item
PN1	Social responsibility	I think it is my social responsibility to adopt SHET in my household.
PN2	Environmental concern	I believe the adoption of SHET would be beneficial to the environment.
PN3	Innovativeness	My innovative spirits make me feel I should adopt some newly emerging smart technology products.

5.2.5 Measurement of behavioral intention

There are several methods to measure people's behavioral intention. As depicted by (Francis, Eccles et al. 2004), the intention can be measured by only one item, (e.g. I intend to…), or by three or more items, like many previous TPB research did (Chou, Kim et al. 2015, Tan, Ooi et al. 2017). Additionally, many studies also have adopted willingness to pay (WTP) to measure the behavioral intention, like (Rekola 2001), who considered WTP as behavioral intention, and explained the factors influencing the forest protection program. Some researchers also stated that using WTP to measure behavioral intention could improve the prediction and prediction of actual behavior by intention (Barro, Manfredo et al. 1996, Luzar and Cosse 1998). Based on the past studies, this thesis also refer to the concept of WTP to measure people's adoption intention of SHET, and the measurement item is shown by Table 5.7.

Table 5.7 Measurement of adoption intention (AI)

Code	**Indicator**	**Measurement item**
AI	WTP	Please tick the appropriate number to represent your maximum willingness to adopt the SHET product. 0~ Unwillingness; 1~ Slight willingness; 2~ some willingness; 3~ High willingness; 4~ Very high willingness; 5~ Extremely high willingness

5.2.6 Measurement scale

As for the measurement scale, in plenty of literatures, the five-point Likert scale methodology has been widely used in questionnaire survey to measure respondent's perception, attitude, opinion, evaluation, etc. (Garland 1991, Xu, Chan et al. 2011, Wang, Wang et al. 2017). In line with the previous research method, the five-point Likert scale was also adopted here, with a scale ranging from 1= strongly disagree; 2= disagree; 3= neutral; to 4= agree; to 5= strongly agree.

5.3 Background of Respondents

A questionnaire survey was conducted in February and March of 2019 for data collection through an online survey platform WenJuanXing (WJX). The online questionnaire survey was developed on WJX first, and then the questionnaire link was distributed through various channels to urban residents in Guangdong province, including the online social media like WeChat, or Weibo, and also distributed offline in some areas like business districts, and residential areas. With a 92% respondent rate, 2391 responses returned from the total 2600 distributed questionnaires. The first part of questionnaire survey collected the demographic information about respondents, including the living area (urban area or rural area of Guangdong), gender, age, education degree, annual household income, and using experience of SHET (yes vs no). During the data screening process, firstly, the responses with missing value were deleted; because the research scope was limited within Chinese urban residents, only the respondents living in the city were retained; additionally, as the aim of this study is to measure the constructs with indicator items from the aspect of technical performance, risk resistance, economic performance, as well as some external constringent conditions, subjective norms, we expect the respondents could have basic knowledge and understanding of smart technology, and also have experience of using smart phone, smart phone applications, wireless internet, so that they could make more sensible and meaningful judgement. Consequently, the respondents aging below 18 and above 60 years old were also removed from the data sample. What is more, we also make the sex ratio of the data sample in line with the actual sex ratio of Guangdong province, which is 109.51 (Male: Female) (Luo 2019). Finally, 1490 responses were retained to compose the sample data for analysis.

The demographic information about respondents is shown by Table 5.8. The sex ratio of the data sample is 110, with 783 male respondents and 707 female respondents; the percentage of young adults (18~40 years old) and education degree of bachelor above is 75.8% and 63.8% respectively, making up the main body of respondents. As the per capita GDP of Guangdong province is forecasted to be 100,000 yuan (RMB) in 2020, in this article, according to the level of household income, respondents were divided into three subgroups: the poor, the middle class, and the affluent, whose corresponding annual household income was 0~100 thousands, 100~300 thousands and higher than 300 thousand. Table 5.8 indicates that over 70% percent of the total respondents are from middle class and the affluent, reflecting the financial capability of the sample.

Table 5.8 The demographic information of the respondents

Demographic variable		**Frequency**	**Percentage (%)**
Gender	Male	783	52.6
	Female	707	47.4
Age	Young adult(18~40)	1129	75.8
	Middle age(41~60)	361	24.2
Education	Below bachelor	540	36.2
	Bachelor and above	950	63.8
Annual household income (thousand)	Poor(< 100)	402	27.0
	Middle class(100~300)	959	64.4
	Affluent(≥300)	129	8.7
Property ownership	Self-own	1017	68.3
	Rent	473	31.7
Usage experience	Yes	1001	67.2
	No	489	32.8

5.4 Descriptive Statistics

The second part of the survey was to measure respondents' evaluations about the survey items of measurement indicators. The Cronbach's coefficient alpha of 0.96 (higher than 0.8) implied a high reliability with the five-point scale. As Table 5.9 showing, all the indicators with mean value approximate to 4.0, implying that averagely, respondents showing agreement with all the survey items of measurement indicators; and the standard deviation of each indicator is approximate to 1.1, suggesting the discreteness of data is quite close for all indicators, therefore, all the 21 indicators would be retained for the subsequent EFA.

Table 5.9 Descriptive statistics of respondent's evaluation

Measurement Indicator	Minimum	Maximum	Mean	Std. Deviation
Automation	1	5	3.99	1.122
Controllability	1	5	3.96	1.107
Feedback	1	5	4.01	1.019
Convenient	1	5	3.98	1.043
Comfort	1	5	4.06	1.074
System interoperability	1	5	3.88	1.136
System reliability	1	5	3.88	1.120
Safety	1	5	3.89	1.123
Privacy protection	1	5	3.83	1.180
Save energy expense	1	5	3.99	1.102
Inexpensive maintenance	1	5	3.85	1.158
Cost effectiveness	1	5	3.93	1.098
Public opinion	1	5	4.02	1.075
Media opinion	1	5	3.95	1.103
Support from family& friends	1	5	3.93	1.086
Knowledge & skill	1	5	3.95	1.109
Financial capability	1	5	3.86	1.133
System compatibility	1	5	3.84	1.148
Social responsibility	1	5	3.88	1.126
Environmental concern	1	5	3.91	1.087
Innovativeness	1	5	3.98	1.079

The Kruskal-Wallis test was carried out to test whether there was significant difference existing in the distribution of the measurement of the adoption intention across the subgroups under each demographical category (gender, age, education, household income). The Kruskal-Wallis test results are shown by Table 5.10: at the confidence level of 95%, the *p* value of each demographical category is higher than 0.05, which statistically confirms no significant difference between subgroups. Therefore, the sample data will be taken as a whole to be furtherly analyzed.

Table 5.10 Kruskal-Wallis test results for each demographical category

	Test statistics	D.f.	Sig.	Test result
Gender	0.123	1	0.726	The p-value of each category is higher than 0.05, therefore the null hypothesis would be retained that the distribution of WTP is the same across each demographic category.
Age	1.784	1	0.182	
Education	0.754	1	0.385	
Household Income	0.226	2	0.893	
Property ownership	0.825	1	0.364	

5.5 Exploratory Factor Analysis

In the thesis, totally 21 measurement items were subject to the EFA, the whole analysis was in line with the methodology introduced in Chapter 3.5, and the results are as below:

(1) Conducting Bartlett's test and Kaiser–Meyer–Olkin (KMO) test to examine the appropriateness of the data for EFA

As shown by Table 5.11: KMO test result is 0.988 and the Bartlett's test is 22956.468 with an associated *p* value lower than 0.05, verifying the feasibility of the sample data for exploratory factor analysis.

Table 5.11 Results of KMO and Bartlett's test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.988
Bartlett's Test of Sphericity	Approx. Chi-Square	22956.468
	df	171
	Sig.	0.000

(2) Results of exploratory factor analysis

In Table 5.12, in line with Kaiser Criterion (Ford, Maccallum et al. 1986), six extracted factors were retained with the eigenvalues of 3.455, 2.799, 2.592, 2.370, 1.900, 1.547 respectively. The cumulative percentage of the variance can be explained by the six factors together is 77.064%, indicating that almost 77% of the information inherent with the measurement indicators can be accounted by the extracted factors, and the variances explained by each factor is 18.185%, 14.627%, 13.640%, 12.472%, 10.00%, 8.140%.

Table 5.12 Result of factor extraction

Factor	Eigenvalue	Percentage of variance %	Cumulative percentage of variance %
1	3.455	18.185	18.185
2	2.779	14.627	32.812
3	2.592	13.640	46.452
4	2.370	12.472	58.924
5	1.900	10.000	68.924
6	1.547	8.140	77.064

Table 5.13 is the result of factor matrix after rotation, because the data sample in this research is as large as 1490, according to the suggestion of (Costello and Osborne 2005, Howard 2016), the cutoff value for factor loading was set at 0.3; finally, 19 indicators were retained by EFA. Based

on the research hypothesis proposed in chapter 4, Factor 1 was labeled with name Attitude to Technical Performance (ATTP), and the associated indicators included automation, controllability, feedback, convenient operation, improving living comfort, system interoperability. Factor 2 was labeled as Attitude to Risk Resistance (ATRR), with three indicators including system reliability, safety, and privacy. Factor 3 was named as Attitude to Economic Performance (ATEP), with the associated indicators of save energy expense, inexpensive maintenance, cost effectiveness. Factor 4 was labeled with Perceived Behavioral Control (PBC), and the relevant indicators contained knowledge & skill, financial capability, and system comparability. Subjective Norm (SN) was the fifth factor, with two retaining factors including public opinion and support from family & friend, the indicator media opinion was deleted because of the factor loading lower than 0.3. The sixth factor was Personal Norm (PN), with two retaining indicators environmental concern and innovativeness; the indicator social responsibility was deleted. The summary of the six factors and their associated indicators are shown by Table 5.14.

Table 5.13 Result of factor matrix after rotation

	Factor						Communalities
	ATTP	ATEP	ATRR	PBC	SN	PN	
Automation	0.651						0.727
Controllability	0.663						0.741
Feedback	0.558						0.769
Convenient operation	0.430						0.722
Improving living comfort	0.659						0.759
System interoperability	0.300						0.792
Saving energy expense		0.691					0.812
Inexpensive maintenance		0.300					0.765
Cost effectiveness		0.500					0.750
System reliability			0.602				0.750
Safety			0.589				0.741
Privacy protection			0.621				0.753
Knowledge and skill				0.351			0.803
Financial capability				0.300			0.821
System compatibility				0.636			0.765
Public opinion					0.327		0.745
Family and friends					0.403		0.704
Environmental concern						0.707	0.897
Innovativeness						0.569	0.827

Table 5.14 Summary of factors extracted and associated indicators

Factor	Indicator Code	Key performance indicator
Attitude to Technology Performance (ATTP)	ATTP1	• Automation
	ATTP2	• Controllability
	ATTP3	• Feedback
	ATTP4	• Convenient operation
	ATTP5	• Improving living comfort
	ATTP6	• System interoperability
Attitude to Risk Resistance (ATRR)	ATRR1	• System reliability
	ATRR2	• Safety
	ATRR3	• Privacy protection
Attitude to Economic Performance (ATEP)	ATEP1	• Saving energy expense
	ATEP2	• Inexpensive maintenance
	ATEP3	• Cost effectiveness
Perceived Behavioral Control (PBC)	PBC1	• Knowledge and skill
	PBC2	• Financial capability
	PBC3	• System compatibility
Subjective Norm (SN)	SN1	• Public opinion
	SN2	• Family and friends
Personal Norm (PN)	PN1	• Environmental concern
	PN2	• Innovativeness

Chapter 6 Empirical Analysis Result and Discussion: Factors influencing the adoption of SHET[4]

6.1 Introduction

This chapter will present the empirical analysis result of the structural equation modelling and conduct an in-depth discussion about the factors influencing the adoption of SHET. The data analysis includes two parts: the assessment of measurement model and the assessment of structural model. The measurement model will be evaluated by two ways: convergent validity and discriminant validity. And the structural model will be assessed by R^2 measure, and Q2 value. After the model assessment, based on the hypothesis test results, the critical factors that will affect resident's adoption intention will be discussed.

6.2 Structural equation modelling

Based on the research hypothesis, and the result of exploratory factor analysis in the previous chapters, the whole structural equation model was founded in the thesis, as shown by Figure 6.1.

[4] This chapter has been partial published in Ji, W., & Chan, E. H. (2019). Critical Factors Influencing the Adoption of Smart Home Energy Technology in China: A Guangdong Province Case Study. Energies, 12(21), 4180

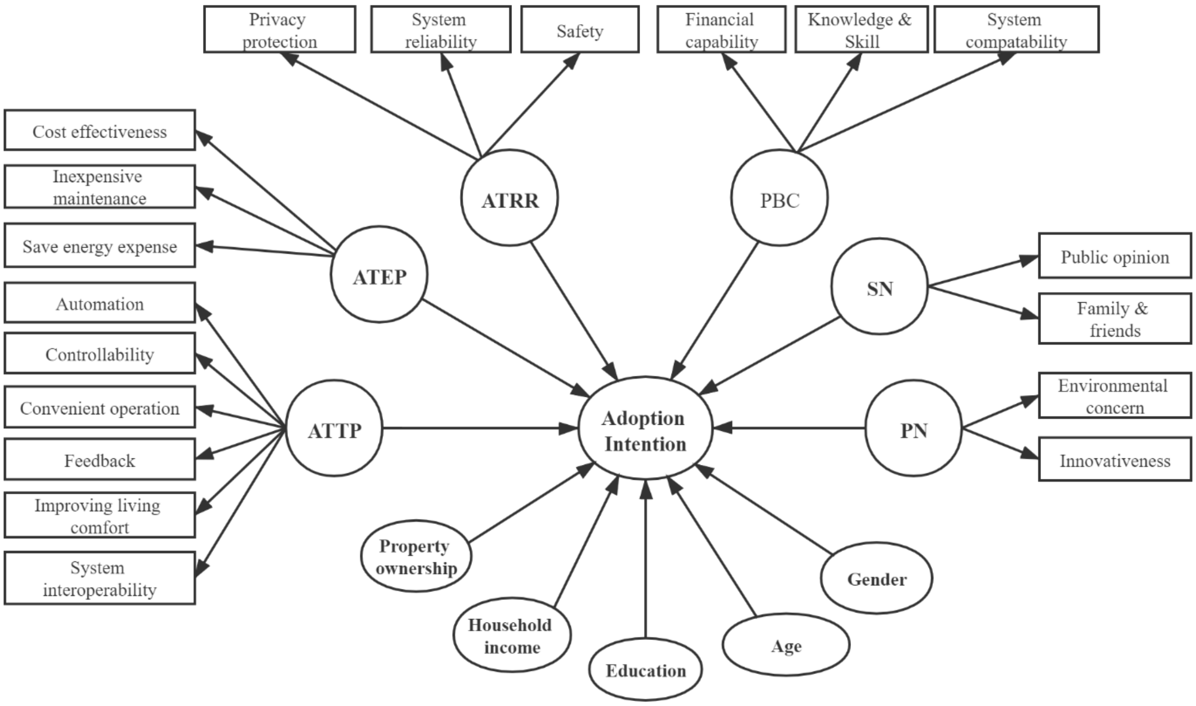

Figure 6.1 The graph of the PLS-SEM

This model contains one measurement model, compromised by the eleven factors and their associated indicators; and one structural model, composed eleven hypothetical relationships, which will be analyzed in detail in the below section.

6.3 Assessment of measurement model

Measurement model is the outer model of SEM, representing the relationships between the latent variable construct and the associated indicator variables (Jr., Matthews et al. 2017). The measurement model will be evaluated by two types of validity:

- Convergent validity: outer loadings of indicators > 0.7; composite reliability (CR) > 0.7 and the average variance extracted (AVE) > 0.5 (Hair, Ringle et al. 2011), meaning that the indicators are reliable and more than half of the indicator variance is included in the construct (Hair Jr, Hult et al. 2016);

- Discriminant validity: to evaluate whether a construct in SEM is unique from others (Jr., Matthews et al. 2017), two criterion: the square root of AVE of one construct should be higher than the correlation coefficient shared by this construct and any other constructs; or the indicator's loading should be higher than all of its cross loadings (Hair, Ringle et al. 2011).

The assessment result of convergent validity is presented by Table 6.1. All of the indicator loadings are higher than 0.7, meaning that all the measurement indicators are reliable and can be remained in the model. Both the value of Cronbach's α and Composite Reliability (CR) is more than 0.7, satisfying the requirement of internal consistency; and the value of average variance extracted (AVE) ranges from 0.662 to 0.759, indicating the constructs in model could explain at least 66% of the indicator variance, according to the recommendation by (Hair, Ringle et al. 2011, Hair Jr, Hult et al. 2016), the convergent validity of the measurement model could be convinced.

Table 6.2 and Table 6.3 introduce the assessment result of discriminant validity. As presented in Table 6.2, the square root of AVE of one construct (the numbers on the diagonal line) is almost higher than the correlation coefficient shared by this construct and any other constructs; and Table 6.3 shows that for a given construct in the model, the loading of its associated indicator is higher than all its cross loadings. Referring to (Hair, Ringle et al. 2011, Jr., Matthews et al. 2017), the measurement model has achieved satisfactory discriminant validity, implying the uniqueness of each construct compared with others.

Table 6.1 Assessment of measurement model: convergent validity

Model construct	**Indicator Code**	**Measurement indicator**	**Loading**	**Cronbach's Alpha**	**Composite Reliability**	**Average Variance Extracted (AVE)**
Attitude to Technical performance (ATTP)	ATTP1	Automation	0.833	0.915	0.934	0.703
	ATTP2	Controllability	0.839			
	ATTP3	Feedback	0.881			
	ATTP4	Convenient operation	0.830			
	ATTP5	Improving living comfort	0.855			
	ATTP6	System interoperability	0.793			
Attitude to Economic Performance (ATEP)	ATEP1	Save energy expense	0.868	0.839	0.903	0.757
	ATEP2	Inexpensive maintenance	0.861			
	ATEP3	Cost effectiveness	0.881			
Attitude to Risk Resistance (ATRR)	ATRR1	System reliability	0.873	0.838	0.903	0.755
	ATRR2	Safety	0.869			
	ATRR3	Privacy	0.865			
Perceived behavioral control (PBC)	PBC1	Knowledge & Skill	0.873	0.843	0.905	0.761
	PBC2	Financial Capability	0.876			
	PBC3	Compatibility with building system	0.867			
Subjective Norm (SN)	SN1	Support from family & friends	0.914	0.841	0.904	0.759
	SN2	Public opinion	0.902			
Personal norm (PN)	PN1	Environmental concern	0.903	0.788	0.904	0.825
	PN2	Innovativeness	0.904			
Intention	AI	Willingness to pay	1.0	1.0	1.0	1.0

Table 6.2 Assessment of measurement model: discriminant validity

	ATTP	ATEP	ATRR	PBC	SN	PN	Intention
ATTP	**0.839**						
ATEP	0.835	**0.870**					
ATRR	0.837	0.833	**0.869**				
PBC	0.843	0.820	0.808	**0.872**			
SN	0.837	0.786	0.764	0.781	**0.908**		
PN	0.818	0.774	0.765	0.763	0.758	**0.904**	
Intention	0.727	0.683	0.672	0.697	0.697	0.697	**1.0**

Note: The values on the bold diagonal line are the square root of AVE of each construct, while the other values are the inter-construct correlation coefficients.

Table 6.3 Cross loading of indicators

	ATTP	ATEP	ATRR	PBC	SN	PN	Intention
Automation	**0.833**	0.698	0.705	0.688	0.684	0.679	0.604
Controllability	**0.839**	0.7	0.701	0.68	0.693	0.677	0.606
Feedback	**0.881**	0.755	0.736	0.735	0.749	0.728	0.651
Convenient operation	**0.83**	0.711	0.689	0.696	0.701	0.678	0.592
Improving living comfort	**0.855**	0.709	0.7	0.696	0.719	0.695	0.598
System interoperability	**0.793**	0.73	0.721	0.745	0.665	0.659	0.607
Save energy expense	0.77	**0.868**	0.703	0.7	0.703	0.686	0.589
Inexpensive maintenance	0.711	**0.861**	0.75	0.718	0.656	0.663	0.588
Cost effectiveness	0.752	**0.881**	0.721	0.722	0.692	0.671	0.607
System reliability	0.741	0.717	**0.873**	0.69	0.67	0.666	0.599
Safety	0.744	0.721	**0.869**	0.703	0.676	0.671	0.585
Privacy	0.719	0.733	**0.865**	0.714	0.644	0.657	0.567
Financial capability	0.728	0.72	0.715	**0.876**	0.679	0.661	0.597
Knowledge & Skill	0.749	0.708	0.688	**0.873**	0.698	0.671	0.625
System compatibility	0.728	0.719	0.712	**0.867**	0.665	0.665	0.602
Family and Friends	0.769	0.725	0.712	0.727	**0.914**	0.69	0.652
Public opinion	0.751	0.702	0.674	0.69	**0.902**	0.687	0.613
Environmental concern	0.737	0.694	0.685	0.683	0.683	**0.903**	0.623
Innovativeness	0.742	0.704	0.697	0.696	0.687	**0.904**	0.625
Willingness to pay	0.727	0.683	0.672	0.697	0.697	0.691	**1**

Note: Bold values show that each measurement item had the highest loading on its respective construct

6.4 Assessment of structural model

The primary evaluation criteria for the structural model include the significance of path coefficient, the R^2 measure, and Stone-Geisser's Q2 value (Hair, Ringle et al. 2011). In this study, the test of path coefficient significance is performed by 5000 samples of bootstrapping procedure and critical values of T test is 1.96, with the significance level of 0.05 (*p< 0.05). Shown by Table 6.4, the hypothetical test results suggest hypothesis H1, H4, H5,H6 are supported, while H2, H3 are rejected, meaning that the positive influences of attitude towards technical performance, perceived behavioural control, subjective norm, and personal norm onto the adoption intention of SHET are empirically supported by the study, however, resident's attitude towards the risk resistance, as well as the economic performance of SHET could not be convinced to have a positive relationship with adoption intention.

The R2 measure is to test the explaining power of the latent variables in the model. In the discipline of consumer behaviour, R^2 result of 0.20 is considered to be high, representing the model could well explain the research object (Hair, Ringle et al. 2011). Cohen suggested that in behavioural science, R^2 value of 0.35 is substantial (Cohen 2013). As Table 6.4 shows, R^2 value is 0.585, representing that 58.5% of the variance in adoption intention of SHET could be explained by the eleven antecedent constructs in the proposed model. Besides, Q2 value is a predominant method to evaluate the model's predictive relevance. The constructs in the model will exhibit predictive relevance if the Q^2 value (0.565) is larger than zero (Hair, Ringle et al. 2011). Figure 6.2 below is the complete graph of PLS-SEM results of path coefficient and indicator loadings.

Table 6.4 Assessment results of structure model

Hypothesis	Relationship	Path Coefficient	SE	T value	P Values	Supported	R^2	Q^2
H1	ATTP -> Adoption intention	0.184	0.048	3.814	0.000**	Yes		
H2	ATEP-> Adoption intention	0.052	0.04	1.361	0.174	No		
H3	ATRR -> Adoption intention	0.051	0.04	1.255	0.21	No		
H4	PBC -> Adoption intention	0.172	0.039	4.417	0.000**	Yes		
H5	SN -> Adoption intention	0.187	0.034	5.539	0.000**	Yes		
H6	PN -> Adoption intention	0.187	0.033	5.737	0.000**	Yes	0.585	0.565
	H7a: Gender-> Adoption intention	0.016	0.017	0.936	0.35	No		
	H7b: Age-> Adoption intention	-0.008	0.017	0.492	0.623	No		
	H7c: Education-> Adoption intention	0.033	0.017	1.978	0.048*	Yes		
	H7d: Household income-> Adoption intention	-0.007	-0.007	0422	0.673	No		
H7	H7e: Property ownership-> Adoption intention	-0.023	-0.023	1.376	0.169	No		

Note: Bootstrap sample = 5000. * All p-values are significant at the 0.05 level.

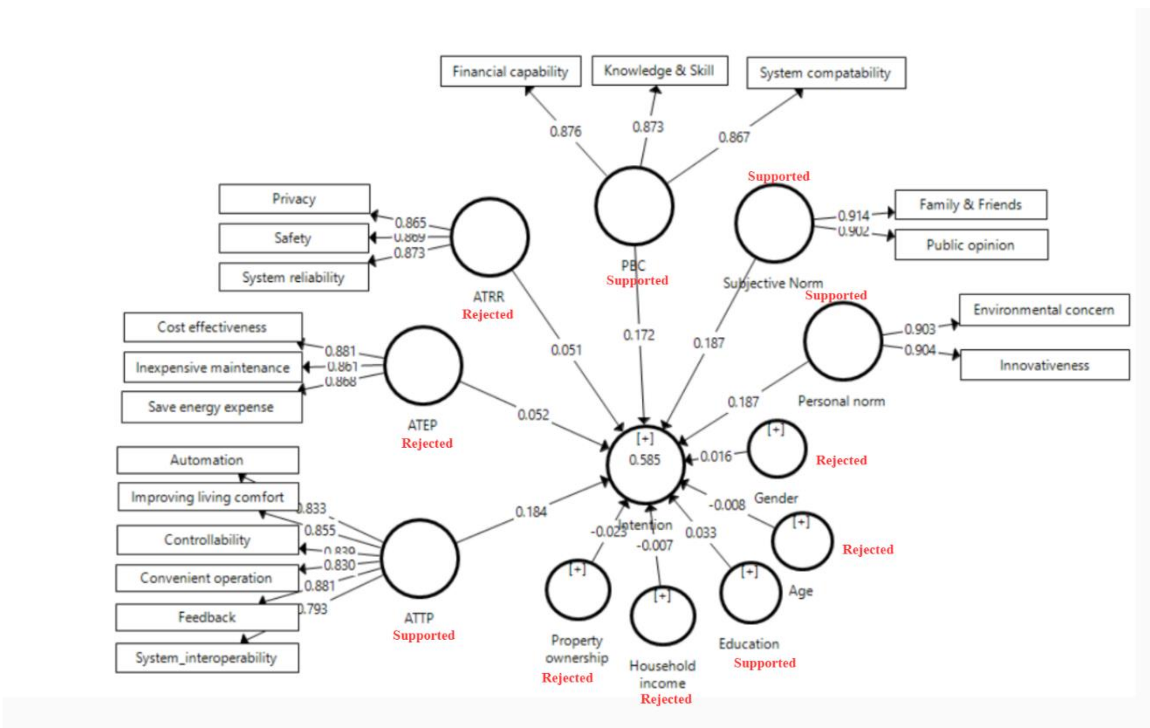

Figure 6.2 PLS-SEM results of path coefficient and indicator loadings

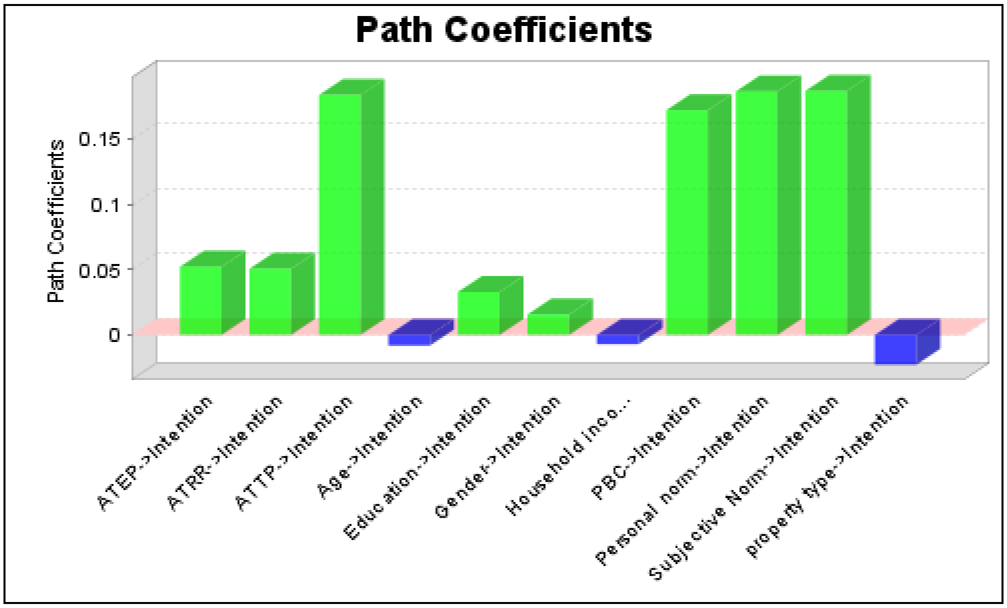

Figure 6.3 The graph of PLS-SEM path coefficient

6.5 Discussion

6.5.1 Attitude Towards Technical Performance

The measurement model confirms that attitude towards technical performance (ATTP) will have a positive relationship with residents' adoption intention of SHET. The result implies that the residents who have favorable attitude towards the technical performances or functions will be more likely to purchase SHET products. This finding is consistent with the theory of Technology Adoption Model (TAM) (Davis 1989). TAM theory is specifically designed to explain the adoption behavior of information technology, implying that the factor "perceived usefulness", defined as "the degree to which that users believe that the useful functions of information technology" is found to have a positive influence onto the adoption intention (Davis 1989, Davis, Bagozzi et al. 1989). Compared to traditional information technology such as computers, the smart technology displays more complicated technical features and is involved more deeply with people's daily life. The highest path coefficient between ATTP and adoption intention manifests that favorable perception of the complicated technical features of smart technology products (automation, controllability, feedback, convenient operation, improving comfort, system interoperability) is the strongest driver for residents' intention to use SHET. The statistics shows that 67.2% of the total respondents have the usage experience of SHET, implying that the urban residents in Guangdong primarily demonstrate positive attitudes towards the technical functions of SHET. Therefore, in an effort to improve the adoption rate of SHET, smart home industry may regard the enhancement of technical performance and user experience as their key objective.

6.5.2 Attitudes Towards Economic Performance

As shown in Table 6.4, the hypothetical positive relationship between the attitude towards economic performance (ATEP) of SHET and adoption intention is rejected, meaning that residents' perceptions of economic performance of SHET, such as financial gains through saving energy, cost effectiveness, or low maintenance cost, would not lead residents to adopt these products. This empirical result contradicts with the assumption of traditional economics that human will make rational choices after weighing the benefits and costs (Simon 1955). Not uniquely, plenty of previous research has also reported similar findings, for example, (Hobman, Frederiks et al. 2016) described that only a small minority of Australian customers participated in a cost-reflective electricity tariff program, even it was successful in reducing the peak demand and electricity expense; (Anderson and Newell 2004) analyzed the technology adoption decisions made by manufacture plants after a government-funded energy audits, and noted that half of the energy efficiency projects were rejected by plants even if the project payback period were remarkably short; (Allcott and Mullainathan 2010) pointed out that people fail to adopt those energy technologies which can help them save money, such as better insulation, or efficient domestic appliances and lighting. The positive path coefficient of ATEP to Intention shows the respondents appear a positive attitude towards the economic performance, but all these studies suggest that even people have perceived the profitable and cost effective of energy technologies, their decisions might still lead to a lower technology diffusion rate. This phenomenon is named as “Energy Efficiency Gap” (Hirst and Brown 1990, Jaffe and Stavins 1994, Gillingham and Palmer 2014), as it derives from consumer’s irrational choice that not consistent with assumptions of traditional economics, burgeoning of literature has begun to discuss this phenomenon under the theory of behavioral economics (Gillingham and Palmer 2014, Frederiks, Stenner et al. 2015).

Back to the results of this study, as shown by Table 5.8, the characteristics of the respondents, 76% young adults and 24% middle aged, well educated (63.8% have university degree or above) and 67.3% having usage experience of SHET, signifies that these urban residents in Guangdong Province exhibit some personal traits of early adopters of energy technology (Venkatesh, Morris et al. 2003, Rogers 2010, Campbell, Ryley et al. 2012). However, the favorable attitude towards the economic performance demonstrated by survey respondents could not lead to the adoption intention. In the domain of behavioral economics, the Loss Aversion concept found in Prospect Theory could provide some explanations for this consequence (Kahneman, Knetsch et al. 1991, Tversky and Kahneman 1992). Loss aversion refers to people’s tendency to weigh more loss than the equivalent gains (Tversky and Kahneman 1992). Although the residents have perceived the economic gains from usage SHET, they also have concerns about the potential loss from functional risks such as system failure, loss control, or privacy leakage; when making decision, they seem to put more value on these risks compared to the potential financial benefit. This explanation is also discussed in the study about adoption of energy efficient technology by homeowners in New Zealand (Christie, Donn et al. 2011), the author suggests homeowners have an asymmetrical perception of risk caused by social and cognitive biases, which prevents them from adopting energy efficiency technologies, regardless how great energy savings they would receive.

Additionally, sunk cost fallacy might be another reason to explain why the hypothetical relationship is not supported. Sunk cost fallacy refers to the tendency to continue a behavior or endeavor once the previously investment was made (time, money or effort) (Arkes and Blumer 1985). In the previous decision-making process of energy technology adoption, the sunk cost effect has been observed in both personal and business cases. For example, (Verstegen, Sonnemans et al. 2000) concluded that sunk cost was a significant factor affecting the adoption of energy-saving technologies by horticultural farmers based on a survey. (Kong, Feng et al. 2016) recommended that in order to facilitate the green manufacture technology diffusion through SMEs, governments should provide some financial support to SMEs for adopting the green technologies, until their savings from production could cover the substantial part of the sunk costs. In the context of this study, the residents might have purchased some non-smart or energy-inefficient household appliances before, and those products are still functioning well. Due to the psychology of not wasting resources, those residents would feel reluctant to discard them and replace them with new smart energy efficient products, even though they could perceive the economic benefits from the smart ones. To mitigate this fallacy, the smart home technology companies may consider some marketing strategies to reduce the salience of cost that consumers have already undertook, meanwhile, emphasizing those risks of retaining old household appliances, such as higher energy bill, or growing carbon emission. The industry and government might introduce some policies to reduce the switching cost for consumer from non-smart in-efficient old appliances to smart energy technology, referring to the rebate program for energy-efficient domestic appliances purchase in South Korea (Huh, Jo et al. 2019).

6.5.3 Attitudes Towards the Risk Resistance

The measurement model rejected the second hypothesis that resident's attitude towards the risk resistance capacity would be positively related with the adoption intention of SHET. The descriptive statistics show that the mean value of the three indicators associated with factor ATRR is 3.88, 3.83, 3.89 respectively, indicating a generally positive attitude towards the risk resistance capacity of SHET from respondents, however, the data analysis result shows that the effect of the factor ATRR onto the adoption intention is only 0.051, which is not high enough to empirically support the second hypothesis.

This result is consistent with the findings of those previous studies conducted in other countries that people's concern about the safety and privacy risk is the main barrier prevent the diffusion of smart home technology (Balta-Ozkan, Davidson et al. 2013, Balta-Ozkan, Boteler et al. 2014, Wilson, Hargreaves et al. 2017). (Ji and Chan 2020) also reported that Chinese users would pay high attentions to the safety and privacy protection issues related with smart technology. Because the sense of security is a basic psychological need for human being (Dupuis and Thorns 1998), users would value more for the technology presenting higher capability to assure the security of their personal lives, properties, and privacy. Beyond technology, lacking sufficient laws to protect people's smart grid data or privacy has been a global issue (Knyrim and Trieb 2011, King and Jessen 2014, Wang and Yu 2015). In China, Yang et al (Yang and Xu 2018) stated that there was legal deficiency for the personal data collection through smart city infrastructure, but due to the cultural and social difference, as well as the prevalence of surveillance camera, the Chinese customers were not as sensitive as European or American people about their privacy rights, but they still felt anxious about the possibility of their personal data to be disclosed to criminals (Huang and Wu 2019). Additionally, the users of smart home technology also feel worry about the system reliability, because the error or malfunction of complicated technology would bring trouble to their homes (Balta-Ozkan, Davidson et al. 2013). Consequently, the resident's attitude of the current risk resistance capacity of SHET could not give them motivation high enough to adopt the SHET.

6.5.4 Perceived Behavioral Control

Generally, the perceived behavioral control (PBC) derived from TPB theory is also confirmed to have a positive relationship with the adoption intention of SHET. This finding is also consistent with many discoveries of previous research of energy saving behavior or energy efficient appliance adoption (Tan, Ooi et al. 2017, Wang, Wang et al. 2018, Ali, Ullah et al. 2019). The relationship between PBC with adoption intention reflects the significance of some non-motivational factors (Li, Xu et al. 2019). In this study, the non-motivational factors refer to the residents' perceptions about the resources or conditions they own to adopt the smart products, including the knowledge, affordability, and the infrastructural conditions of their houses. The results imply that if residents believe they have more resources or more appropriate conditions to use the smart products, they are more likely to engage.

6.5.5 Subjective Norm

The positive relationship between social norms and adoption intention is confirmed by this study, which is in line with the backbone theory of planned behavior. This significant relationship implies that residents in Guangdong province would be influenced by the external environments such as public opinion, and voice from social network when they making decisions to adopt the SHET. This finding is supported by some previous studies about the energy saving or pro-environmental behavior in different regions of China, for example, both (Wang, Wang et al. 2018, Zhang, Yu et al. 2018) conducted questionnaire surveys in Shandong Province, and confirmed the significant impacts of government policies, social opinion, education onto the energy saving behavior. (Wang, Zhang et al. 2014) demonstrated the importance of policies and social norms to promote electricity saving behavior in Beijing. (Yue, Long et al. 2013) asserted the social norms were also applicable in Jiangsu Province in the household energy saving area. Outside of China, the social norm was verified to be an important factor to influence the opportunity of energy saving in American workplaces (Li, Xu et al. 2019). The social norm was also found to have a positive relation with purchase intention of energy efficient products in Korea (Ha and Janda 2012). However, some research conducted in other countries such as Pakistan (Ali, Ullah et al. 2019) and Malaysia (Tan, Ooi et al. 2017) has suggested no positive relationship between the social norm and purchase intention of energy efficient products. The difference of the results between countries might derive from the cultural difference, education level and citizen's perceptions about government enforcement.

6.5.6 Personal Norm

Meanwhile, this study presents positive impact of personal norms onto the adoption intention of SHET. Personal norm is the moral extension of TPB, reflecting the moral dimension of one's internal values. The result implies that residents owning stronger awareness of energy saving would be more possible to adopt SHET. The indicators reflecting personal norm include the social responsibility and environmental concern, which shares the similar results of some passed research of energy saving behavior (Chen 2016, Tan, Ooi et al. 2017, Wang, Wang et al. 2018, Lopes, Kalid et al. 2019). Additionally, because of the innovativeness of smart technology, one indicator reflecting one's interest about technology innovation is also employed to measure residents' internal values towards the smart technology innovation. The result confirms the reliability of this indicator. This finding echoes with the study of (Ali, Ullah et al. 2019), that the residents who have positive attitude towards the technology and innovation have higher intention to adoption energy efficient household appliances.

6.5.7 Demographic Factors

As shown by Table 6.4, among the five demographic factors examined in the study, only the slight influence of education onto the adoption intention of SHET can be empirically convinced by the data; while another four demographic factors, including the gender, age, household income, and property ownership cannot impact the urban resident's adoption intention of SHET significantly.

The positive path coefficient between education and adoption intention (0.033) implies that the education degree will affect the resident's adoption intention positively, that is the people with bachelor degree and above are more likely to adopt SHET than those who never received university education. This finding can also be supported by the results of some past literature. (Ji and Chan 2019) asserted that the people with lower education degree were harder to perceived the benefits of complicated technology than others. In a study about the residential energy efficient technology adoption across European countries, (Mills and Schleich 2012) concluded that the education level would affect family's attitude towards energy efficiency technology significantly. (Mathieson, Peacock et al. 2001) considered that the education could make people perceived more control about their behaviors. Therefore, if to promote the adoption of SHET through urban residents, both the government and industry should value the significance of education. The high school and university may hold some lectures or programs particular to teaching the knowledge of smart technology and enhancement of the environment awareness, and the industry may also hold some public seminars or social campaigns to convey the relevant knowledge and the energy conservation idea to the whole society.

Chapter 7 Scenario Analysis: Incentive Schemes for SHET Promotion

7.1 Introduction

This chapter presents the empirical analysis results for four incentive scheme scenarios: business as usual (BAU), time of use (TOU), price subsidy (PS), and the community energy saving campaign (CESC). First, section 7.2 provides a detailed description of the four incentive scheme scenarios. Section 7.3 introduces the main assumptions in the scenario design. An empirical analysis is conducted based on the OLR model, with the data collected by the method of contingent valuation by a questionnaire survey (as described in Chapter 3), and the analysis results described in section 7.4. Following that, section 7.5 is a comprehensive discussion of the scenario analysis results.

7.2 Scenario Description

7.2.1 Business as usual (BAU)

According to the Oxford dictionary (Reference), the definition of business as usual (BAU) is:

"A scenario for future patterns of activity which assumes that there will be no significant change in people's attitudes and priorities, or no major changes in technology, economics, or policies, so that normal circumstances can be expected to continue unchanged."

In this study, the BAU scenario means that under this scenario, the residents will maintain the attitudes towards the performance of SHET, and also the perceptions about subjective norms, personal norms, as same as those have been investigated in Chapter 6. And the policy background for the SHET promotion also keeps the same. Willingness to pay (WTP) will be calculated to represent resident's adoption intention quantitatively under BAU scenario.

7.2.2 Price subsidy

Price subsidy (PS) is a scheme scenario devised for this thesis, and examines the effect of a price subsidy scheme on the intention of urban residents to adopt SHET. The rationale for designing a PS scenario is that purchase and installation costs have been deemed as the main barriers preventing people's adoption of energy efficiency technology or smart technology by some previous research findings, such as (Mert and Tritthart 2012, Balta-Ozkan, Davidson et al. 2013, Hesselink and Chappin 2019); therefore a price subsidy should mitigate consumers' financial burdens and encourage purchases. Additionally, in Chapter 6, we found that the perceived economic performance of SHET did not lead residents to adopt SHET, probably because, the expected economic benefits from performance were not enough compared to the required investment in SHET to overcome the behavioral barriers. Hence, a PS policy is proposed in the hope of reducing the investment costs for consumers and raising the relative investment return, so that the perceived economic benefits would be enough to overcome the behavioral barriers from consumers' perceptions.

PS is a very common economic instrument that has been implemented by many country governments to accelerate the diffusion of energy efficiency technology products, such as energy-efficient appliance, electric vehicles, home energy retrofitting, solar PV, etc. (de la Rue du Can, Leventis et al. 2014, Sheldon and Dua 2020). China has also gained good experience from the national program named "Promoting Energy-Efficient Appliance for the Benefit of People" that has been launched in 2009. Through this program, a PS was provided to the consumers who purchased the energy saving household appliances such as energy-saving air conditioner, refrigerators, flat panel TV, etc. (Zeng, Yu et al. 2014, Wang, Wang et al. 2017). Up till 2013, a total of 4.3 billion US dollars was reimbursed to Chinese customers, and the market share of energy efficient air conditioner grew by 35% (Jiayang LI 2013).

The design of the PS scenario is based on the subsidy program for energy-saving household appliances implemented in China. The details are as follows:

1) Product eligibility: all consumers who purchase SHET products, including smart household appliances, smart lighting, smart plugs, smart home energy management system, etc.
2) Policy coverage: SHET products of all the brands, and all online or physical stores.
3) Amount of subsidy: 10% of the product price, to a maximum amount of 800 Yuan.

7.2.3 Time of use pricing plan

The TOU scenario is used in this study to examine the effect of TOU policy on urban residents' intention to adopt SHET. The rationale for the TOU scenario lies in the attributes of SHET, such as automatic control, feedback, scheduling, etc., which could enable users to utilize a TOU pricing plan fully and enjoy more economic benefit.

In this study, the TOU scenario is based on the features of the TOU pricing plan executed in Guangdong province currently, as below:

1) The residents' electricity consumption hours are divided into three sections: peak period (14:00~17:00, 19:00~22:00); flat period (8:00~14:00, 17:00~19:00, 22:00~24:00) and valley period (0:00~8:00).
2) The ratio of the electricity rate among peak, flat and valley period is 1.65:1:0.5. The flat price is consistent with the rate of the first tier in tired electricity pricing, determining by the government of each city in Guangdong province.

According to the news report published by China Southern Power Gird (CSPG 2017), the smart grid system has comprehensively covered the urban area of Guangdong province, and the smart meter has achieved 100% penetration in Guangdong residents. The power grid infrastructure system in Guangdong could therefore provide a feasible TOU pricing scenario.

7.2.4 Community energy saving campaign

The fourth scenario proposed in the thesis is named as community energy saving campaign (CESC). This scenario is orientated towards the achievement of household energy saving, targeted on motivating urban households to adopt SHET for electricity savings by the way of the incentives of material reward, acquiring honor and improving social reputation through social comparison. The rationale of CESC scenario derives from the theory of planned behavior (Ajzen 1991), which states that subjective norms are antecedents of people's behavioral intentions. The influence of subjective norms on the adoption intention of SHET has been empirically demonstrated by the survey of urban residents in Guangdong province, as shown in Chapter 6. What is more, the effectiveness of rewards in the stimulating of energy-saving behavior also has been confirmed by a number of previous research (Winett, Kagel et al. 1978, Geller 2002). Therefore, we propose scenario CESC, in the hope that the residents' intention of adopting SHET could be fostered by enhancing the subjective norms and the rewards incentive.

Taking advantage of subjective norms, and conducting social comparison activities, such as the "energy battle game" held in a student hostel (Geelen, Keyson et al. 2012), or providing the energy consumption feedback of neighborhood to the residents of multi-family apartments (Bator, Phelps et al. 2019) have been shown by the organizers to have had positive influence on energy saving, even in situations without financial incentives. The CESC scenario in this thesis is also based on such logic. The detail of the scenario is shown below:

1) The campaign is based on the residential community in urban areas of Guangdong province.
2) The campaign organizers in the community take on the responsibility of introducing the functions and benefits of SHET to the residents.
3) The comparison criteria are based on the amount of household electricity consumed per month.

4) The top 10% of the households in community that consume the least electricity will be rewarded with prizes prepared by the community, and their rankings and house numbers will also be listed on the bulletin board for the whole community.

7.3 Hypotheses for Scenario Analysis

The purpose of the scenario analysis is to observe the change in the adoption intention of urban residents after the implementation of the policies. As it is not possible to measure intention directly or quantitatively, nor to make such comparisons among different policies, this study will be based on the suggestion of (Luzar and Cosse 1998), of using WTP instead of adoption intention to measure the effects of different policies quantitatively on urban residents' adoption intention. WTP means the maximum amount that a consumer is willing to buy a product or a service, and is a very widely used method for non-market valuation. (Luzar and Cosse 1998) also suggested that the predictive ability of non-market valuation can be improved by considering WTP as behavioral intention. The following scenario analysis will calculate resident's WTP for SHET under different incentive scheme scenarios, and the quantitative results of WTP would enable us to make direct comparison between these policies. The data for calculating WTP has been acquired by contingent valuation method (CVM) through the process of questionnaire survey.

The analysis results in Chapter 6 have shown that resident's attitude towards the technology performance of SHET (ATTP), perceived behavioral control (PBC), subjective norm (SN), personal norm (PN) were the positive factors influencing the adoption intention. Here we continue to propose the hypothesis that ATTP, PBC, SN and PN would all be positively related to urban resident's willingness to pay for SHET.

Additionally, although a significant positive relationship between the ATEP and the adoption intention was rejected in Chapter 6, because the proposed scenarios will enhance economic benefits from the usage of SHET and also provide some incentive rewards, we assume that residents' positive attitude towards the economic performance of SHET will be enhanced. As a result, we hypothesize that, under the influence of the scenarios, the ATEP will affect the WTP of SHET positively.

As the results of the descriptive statistics have shown that respondents appeared very positive towards the risk resistance capability of SHET, here we also assume that under the scenarios the ATRR would be positively related to residents' WTP of SHET.

On demographic factors, (Zhao, Yang et al. 2017) concluded that family's total monthly electricity consumption would be affected by household income, house size, family members. (Washizu, Nakano et al. 2019) showed that gender, age and house size would affect people's WTP in relation to the automatic control function of a home energy management system. Hence this study will also analyze the influence of demographic factors on residents' WTP for SHET under each scenario, including gender, education level, age, household income, family members, house size, and property ownership (self-owned vs rent).

7.4 Results of Incentive Scheme Scenario Analysis

7.4.1 Descriptive statistic

The data used for scenario analysis has been collected by contingent valuation in the questionnaire survey previously from the same group of respondents. The descriptive statistic results of demographic factors, the attitude and norm variables, are presented by Table 7.1-7.2; in order to better predict the willingness to pay, some more demographic variables, including the household member, house size, property type are also introduced into for analysis. In Table 7.1, the sex ratio of male to female is very approximate to that of Guangdong province, and the profiles of the majority of the survey respondents are young adult, middle class, having received university education and even higher degree; what is more, 84.3% of the total household having 2~4 members; 68.3% of the respondents are living in the self-owned property; and 76% of the respondents living the house of size between 60~150 m^2, reflecting a satisfactory living condition for the majority of the respondents.

Table 7.2 presents the descriptive statistics of the behavioral variables, including attitude towards technology performance (ATTP), attitude towards economic performance (ATEP), attitude towards risk resistance (ATRR), subjective norm (SN) and personal norm (PN). In line with the research work shown by Chapter 5 and Chapter 6, the associated indicator to measure above five factors have been determined; the data to measure the indicator also have been acquired by questionnaire survey, and the loadings of the indicators that associated with the same factor are also quite approximate, therefore, the data for the analysis of each factor can be calculated by the mean value of its associated indicators, which can be expressed as:

Factor $_{i\,=}$ Mean value (Indicator $_i$ 1, Indicator $_i$ 2, Indicator $_i$ 3…)

Here i means the i^{th} respondent participating the survey, indicator $_i$ 1,2,3… refers to the value that the i^{th} respondent has evaluated for indicator 1,2,3…. by Likert scale.

The descriptive statistic results in Table 7.2 shows that generally, the respondents hold a very positive perception of the attitude and norm factors, with mean value approximate to 4.00 (very agree).

Table 7.1 Descriptive statistics of the demographic variables

	Description	Frequency	Percent %	Mean	Std. Deviation
Gender	Male =1	783	52.6	0.53	0.5
	Female =0	707	47.4		
Age	Young adult (18~40) =1	1129	75.80	1.24	0.429
	Middle aged (41~60)=2	361	24.20		
Education	below bachelor =1	540	36.20	1.64	0.481
	bachelor and above=2	950	63.80		
Income	Poor =1	402	27.00	1.82	0.568
	Middle class = 2	959	64.40		
	Affluent = 3	129	8.70		
Household member	Single =1	36	2.4	3.95	1.074
	Coupe =2	320	21.5		
	Three people family =3	520	34.9		
	Four people family =4	416	27.9		
	Five or above =5	198	13.3		
Property ownership	Rent =0	473	31.70	0.68	0.466
	Self-own =1	1017	68.30		
Size	0~60 m^2 =1	176	11.8	3.01	1.202
	61-90 m^2 =2	361	24.2		
	91-120 m^2 =3	407	27.3		
	121-150 m^2 =4	366	24.6		
	≥151 m^2 = 5	180	12.1		

Table 7.2 Descriptive statistics of the behavioral variables

	Description	Frequency	Percent %	Mean	Std. Deviation
ATTP	Strongly disagree =1	28	1.9	4.00	0.933
	Disagree = 2	145	9.7		
	Agree = 3	49	3.3		
	Very agree = 4	852	57.2		
	Strongly agree = 5	416	27.9		
ATEP	Strongly disagree =1	54	3.6	3.92	1.021
	Disagree = 2	133	8.9		
	Agree = 3	116	7.8		
	Very agree = 4	759	50.9		
	Strongly agree = 5	428	28.7		
ATRR	Strongly disagree =1	29	1.9	4.00	1.026
	Disagree = 2	168	11.3		
	Agree = 3	105	7.0		
	Very agree = 4	659	44.2		
	Strongly agree = 5	529	35.5		
PBC	Strongly disagree =1	63	4.2	3.89	1.042
	Disagree = 2	133	8.9		
	Agree = 3	122	8.2		
	Very agree = 4	758	50.9		
	Strongly agree = 5	414	27.8		
SN	Strongly disagree =1	51	3.4	3.97	0.995
	Disagree = 2	123	8.3		
	Agree = 3	84	5.6		
	Very agree = 4	791	53.1		
	Strongly agree = 5	441	29.6		
PN	Strongly disagree =1	46	3.1	3.93	0.99
	Disagree = 2	139	9.3		
	Agree = 3	98	6.6		
	Very agree = 4	797	53.5		
	Strongly agree = 5	410	27.5		

Table 7.3 and Figure 7.1 show the descriptive statistic results of the willingness to pay (WTP) for SHET under four scenarios of incentive schemes indicated by the respondents, including the frequency and percentage for each level of WTP, the mean value and standard deviation. The mean value of WTP can tell us generally, respondent’s WTP is high in all the scenarios.

Table 7.3 Descriptive statistic results of the willingness to pay for SHET

	Description	Frequency	Percent %	Mean	Std. Deviation
Scenario A	Unwilling = 0	77	5.2		
	Slight=1	91	6.1		
Business as usual	Some=2	187	12.6	3.03	1.153
	High=3	546	36.6		
	Very High=4	540	36.2		
	Extremely willing=5	49	3.3		
Scenario B	Unwilling = 0	58	3.9		
	Slight=1	102	6.8		
Price subsidy	Some=2	179	12.0	3.13	1.159
	High=3	476	31.9		
	Very High=4	594	39.9		
	Extremely willing=5	81	5.4		
Scenario C	Unwilling = 0	66	4.4		
	Slight=1	88	5.9		
Time of use pricing plan	Some=2	181	12.1	3.1	1.144
	High=3	525	35.2		
	Very High=4	562	37.7		
	Extremely willing=5	68	4.6		
Scenario D	Unwilling = 0	84	5.6		
	Slight=1	83	5.6		
Community energy savings campaign	Some=2	201	13.5	3.05	1.195
	High=3	498	33.4		
	Very High=4	552	37		
	Extremely willing=5	72	4.8		

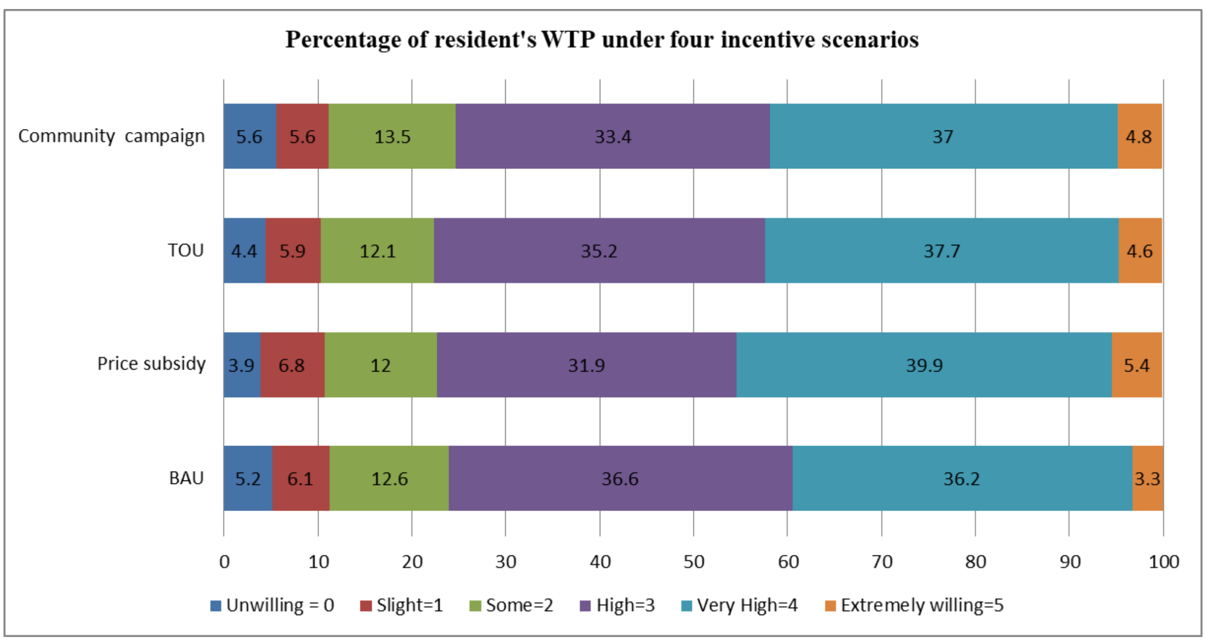

Figure 7.1 Percentage of resident's WTP under four incentive scenarios

7.4.2 Results of ordered logistic regression model

The analysis of the significant variables influencing WTP for SHET and the calculation of WTP are based on the methodology of ordered logistic regression model, of which, the detail introduction and mathematical procedures have been illustrated in Chapter 3.7 and Chapter 3.8, and the empirical analysis results are presented by Table 7.4~7.7.

Table 7.4 is the results of the ordered logit regression model for the scenario of BAU. Without the influence of any policy, totally five variables are statically significant, of which, one demographic variable is education, with a significance level of 0.05, and a regression coefficient of 0.276, indicating that education has a significant positive influence on WTP in scenario of BAU. And OR value of 1.318, means that when education degree increases from below bachelor to bachelor and above, the increasing amplitude of WTP will be 1.318 times. Besides, four behavioral variables are statistic significant, including ATTP, PBC, SN, PN (at significance level of 0.01), and the positive coefficients of the four behavioral variables reveal that they all have positive influence onto the WTP. Additionally, SN has the highest odd ratio of 1.698, meaning that the one unit increasing of SN will lead to 1.698 times of increasing of WTP and then is PBC (1.648), PN (1.647), ATTP (1.528) in turn. However, most demographic variables, including gender, age, household income, family member, property ownership, house size and two behavioral variables, ATEP and ATRR do not affect WTP in BAU scenario, which is consistent with the results modeled by PLS-SEM previously.

Table 7.5 is the results of the ordered logit regression model for the scenario of price subsidy. Two demographic variables gender and education have been empirically to be found statistic significant, at the significance level of 0.01. The negative regression coefficient of Gender (-0.448) indicates that compared to male, the female respondent's willingness to pay for SHET is lower, and OR value of 1.566 means that the WTP of the male is 1.566 times of the WTP by the female. The positive coefficient of education (0.292) shows to be a positive influential power, with OR value of 1.340, implying an increasing effect of 1.340 times onto the WTP in price subsidy scenario when the education degree changing from below bachelor to bachelor and above. The variable of property ownership also has shown statistic significant at 0.05 significance level, with positive coefficient (0.237), which presents a positive influence onto the WTP, and the OR value of 1.267, suggests that compared to the respondents who rent house, those living in the self-owned houses are more willing to pay for SHET, with an increasing willingness of 1.267 times higher. Additionally, similar to the results of BAU scenario and previous research, only four behavior variable are found to be significant positively related with the WTP under this scenario, including ATTP, PBC, SN, PN, while the ATEP or ATRR appear to be irrelevant.

Table 7.6 presents the results of the ordered logit regression model for the scenario of TOU pricing plan. Gender and education still prove to be the significant demographic variables, of which, the results show that compared to the female, and the one without bachelor degree, the male and people receiving at least university education are more willing to pay for SHET. The type of property ownership is also statistical significance at significance level of 0.05, with the result indicating a higher WTP for people who own the houses of themselves, than the people who live in the rental house. One point different from the above two results lies in the behavioral variable ATEP, that under scenario of TOU pricing plan, ATEP has become a significant influential factor of WTP at a significance level of 0.05 with the regression coefficient value of 0.185. And the OR value is 1.203, which means that if resident's attitude toward economic performance of SHET was increased by one unit, the increasing amplitude of WTP under TOU would appear to be 1.203 times. Another four behavior variables including ATTP, PBC, SN, PN are also proved to have positive influence, and the ATRR is irrelevant either.

Table 7.7 shows the analysis result of the order logit regression model under the scenario of community energy saving campaign. Gender is still found to have significant influence at significance level of 0.01, and the coefficient value (-0.380) also shows that the male has a higher WTP than the female; the OR value of 1.462 means that the WTP of male is 1.462 times than the WTP of female under this scenario. One point should be noticed that age is the first time to be proved significant influence on the WTP in CESC scenario, with the regression coefficient of -0.270, at significance level of 0.05, indicating that age has a significant negative impact on WTP under CESC scenario. The OR value is 0.763, which means that when age increases by one unit (from young adult to the middle), the reduction amplitude of WTP is 0.763 times. For the behavioral variables, except ATRR, another five variables also empirically convinced to significant affect the WTP positively. Under CESC scenario, property related variables are found to be irrelevant with WTP.

Table 7.4 The analysis results of Ordered Logit Model-Scenario of BAU

			Estimate	Odds ratio	Std.	Wald	Sig.	95% Confidence Interval	
								Lower Bound	Upper Bound
WTP in BAU	WTP = 0		3.133		.376	69.447	.000	2.396	3.870
	WTP = 1		4.926		.401	150.580	.000	4.139	5.713
	WTP = 2		7.180		.455	248.743	.000	6.288	8.072
	WTP = 3		9.412		.475	392.235	.000	8.481	10.344
	WTP = 4		12.652		.505	628.460	.000	11.662	13.641
Demo-graphic variables	Age		-0.103	0.903	0.116	0.779	0.377	-0.330	0.125
	Gender	Female	-0.152	1.164	0.100	2.334	0.127	-0.347	0.043
		Male	0[a]						
	Education		0.276	1.318	0.104	7.012	0.008**	0.072	0.480
	Income		-0.017	0.983	0.087	0.037	0.847	-0.188	0.154
	Member		-0.039	0.962	0.046	0.709	0.400	-0.130	0.052
Property variables	Size		-0.004	0.996	0.041	0.012	0.914	-0.086	0.077
	property ownership	Rent	-0.169	1.184	0.107	2.502	0.114	-0.378	0.040
		Self-owned	0[a]						
Behavioral variables	ATTP		0.424	1.528	0.100	17.823	0.000**	0.227	0.620
	ATEP		0.193	1.213	0.089	4.718	0.060	0.019	0.367
	ATRR		0.081	1.085	0.087	0.866	0.352	-0.090	0.252
	PBC		0.500	1.648	0.085	34.542	0.000***	0.333	0.666
	SN		0.529	1.698	0.091	33.517	0.000***	0.350	0.709
	PN		0.499	1.647	0.088	31.775	0.000***	0.325	0.672

Link function: Logit.

The significance level of model-fitting is lower than 0.001, suggesting that the model fits well.

** $p<0.05$;*** $p<0.01$

Table 7.5 The analysis results of Ordered Logit Model-Scenario of Price Subsidy

			Estimate	Odds ratio	Std.	Wald	Sig.	95% Confidence Interval	
								Lower Bound	Upper Bound
WTP in Scenario B: Price subsidy	WTP = 0		2.121		0.429	24.418	0.000	1.280	2.962
	WTP = 1		4.170		0.442	89.131	0.000	3.304	5.036
	WTP = 2		6.197		0.479	167.512	0.000	5.259	7.136
	WTP = 3		8.103		0.493	270.169	0.000	7.137	9.069
	WTP = 4]		11.088		0.515	463.917	0.000	10.079	12.097
Demographic variables	Age		-0.118	0.888	0.115	1.050	0.305	-0.344	0.108
	Gender	Female	-0.448	1.566	0.099	20.343	0.000***	-0.643	-0.253
		Male	0[a]						
	Education		0.292	1.340	0.103	7.984	0.005***	0.090	0.495
	Income		0.010	1.010	0.087	0.013	0.909	-0.160	0.180
	Member		-0.075	0.928	0.046	2.642	0.104	-0.166	0.015
Property variables	Size		-0.027	0.974	0.041	0.421	0.516	-0.107	0.054
	Property ownership	Rent	-0.237	1.267	0.106	4.995	0.025**	-0.445	-0.029
		Self-owned	0[a]						
Behavioral variables	ATTP		0.742	2.101	0.101	54.183	0.000***	0.545	0.940
	ATEP		0.117	1.125	0.088	1.769	0.184	-0.056	0.290
	ATRR		-0.169	0.845	0.087	3.780	0.052	-0.339	0.001
	PBC		0.277	1.319	0.084	10.904	0.000***	0.113	0.441
	SN		0.581	1.787	0.091	40.682	0.000***	0.402	0.759
	PN		0.449	1.566	0.088	26.185	0.000***	0.277	0.621

Link function: Logit.

The significance level of model-fitting is lower than 0.001, suggesting that the model fits well.

** p<0.05;***p<0.01

Table 7.6 The analysis results of Ordered Logit Model-Scenario of Time of Use

			Estimate	Odds ratio	Std. Error	Wald	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
WTP in Scenario C: Time of use pricing plan	WTP = 0		3.024		0.432	49.006	0.000	2.178	3.871
	WTP = 1		4.862		0.449	117.425	0.000	3.983	5.742
	WTP = 2		7.093		0.497	203.986	0.000	6.120	8.067
	WTP = 3		9.229		0.514	322.237	0.000	8.222	10.237
	WTP = 4		12.251		0.538	517.597	0.000	11.195	13.306
Demographic variables	Age		0.127	1.135	0.116	1.195	0.274	-0.101	0.354
	Gender	Female	-0.329	1.390	0.099	10.958	0.001**	-0.524	-0.134
		Male	0[a]						
	Education		0.208	1.232	0.104	4.033	0.045**	0.005	0.411
	Income		0.096	1.101	0.087	1.220	0.269	-0.074	0.267
	Member		-0.090	0.914	0.046	3.792	0.051	-0.181	0.001
Property variables	Size		-0.026	0.974	0.041	0.401	0.527	-0.107	0.055
	Property ownership	Rent	-0.258	1.295	0.106	5.905	0.015**	-0.467	-0.050
		Self-owned	0[a]						
Behavioral variables	ATTP		0.837	2.310	0.102	67.939	0.000***	0.638	1.036
	ATEP		0.185	1.203	0.089	4.364	0.037**	0.011	0.359
	ATRR		0.010	1.010	0.087	0.013	0.908	-0.161	0.181
	PBC		0.203	1.225	0.084	5.834	0.016**	0.038	0.368
	SN		0.519	1.680	0.091	32.398	0.000***	0.340	0.697
	PN		0.393	1.482	0.088	20.032	0.000***	0.221	0.566

Link function: Logit.

The significance level of model-fitting is lower than 0.001, suggesting that the model fits well.

** $p<0.05$;*** $p<0.01$

Table 7.7 The analysis results of Ordered Logit Model-Scenario of Community Energy Saving Campaign

			Estimate	Odds ratio	Std. Error	Wald	Sig.	95% Confidence Interval	
								Lower Bound	Upper Bound
WTP in Scenario D: Community energy saving campaign	WTP = 0		2.730		0.426	41.107	0.000	1.895	3.564
	WTP = 1		4.332		0.444	95.221	0.000	3.462	5.202
	WTP = 2		6.547		0.487	180.688	0.000	5.592	7.502
	WTP = 3		8.477		0.501	286.741	0.000	7.496	9.458
	WTP = 4		11.420		0.522	478.453	0.000	10.397	12.443
Demographic variables	Age		-0.270	0.763	0.115	5.518	0.019**	-0.495	-0.045
	Gender	Female=0	-0.380	1.462	0.099	14.772	0.000***	-0.573	-0.186
		Male=1	0[a]						
	Education		0.181	1.199	0.103	3.103	0.078	-0.020	0.383
	Income		0.027	1.027	0.086	0.096	0.757	-0.143	0.196
	Member		-0.086	0.917	0.046	3.538	0.060	-0.177	0.004
Property variables	Size		0.011	1.011	0.041	0.076	0.783	-0.069	0.091
	Property Right	Rent =0	-0.114	1.121	0.106	1.169	0.280	-0.321	0.093
		Self-own=1	0[a]						
Behavioral variables	ATTP		0.701	2.015	0.100	48.751	0.000***	0.504	0.897
	ATEP		0.243	1.275	0.088	7.616	0.006**	0.070	0.415
	ATRR		-0.025	0.975	0.086	0.086	0.769	-0.195	0.144
	PBC		0.224	1.251	0.083	7.237	0.007**	0.061	0.388
	SN		0.475	1.608	0.090	27.479	0.000***	0.297	0.651
	PN		0.474	1.606	0.088	29.446	0.000***	0.303	0.646

Link function: Logit.

The significance level of model-fitting is lower than 0.001, suggesting that the model fits well.

** p<0.05;***p<0.01

The summary and comparison of the influential factors for WTP of resident for SHET in the four various incentive scheme scenarios are shown by Table 7.8. According to the ordered logit model as demonstrated in Equation 3.1~3.7, the probability of each level of WTP and expected value of WTP of each incentive scheme scenario are shown in Table 7.9 and Figure 7.2.

Table 7.8 Summary of the influential factors for WTP in four incentive scheme scenarios

		BAU	Price subsidy	TOU	CESC
Demographic variable	Gender(M=1/F=0)	--	-0.448***	-0.33**	-0.38***
	Age	--	--	--	-0.27**
	Education degree	0.161**	0.292***	0.208**	--
	Household income	--	--	--	--
	Family member	--	--	--	--
Property variable	Property ownership (Self-own=1/Rent=0)	--	-0.24**	-0.26**	--
	House size	--	--	--	--
Behavioral variable	ATTP	0.424***	0.742***	0.837***	0.701***
	ATEP	--	--	0.185**	0.243**
	ATRR	--	--	--	--
	PBC	0.5***	0.277***	0.203**	0.224**
	SN	0.529***	0.581***	0.519***	0.475***
	PN	0.499***	0.449***	0.393***	0.474***

Table 7.9 Probability of each level of WTP and the EWTP in four scenarios

WTP	BAU	Price subsidy	TOU pricing	Community Energy Saving Campaign
Unwilling = 0	1.0%	0.2%	0.4%	0.6%
Slight=1	4.9%	1.5%	2.2%	2.3%
Some=2	31.5%	10.2%	17.7%	18.5%
High=3	47.4%	35.7%	48.0%	43.8%
Very High=4	14.5%	47.1%	29.4%	32.1%
Extremely willing=5	0.7%	5.3%	2.2%	2.7%
E*WTP*	2.72	3.44	3.10	3.13

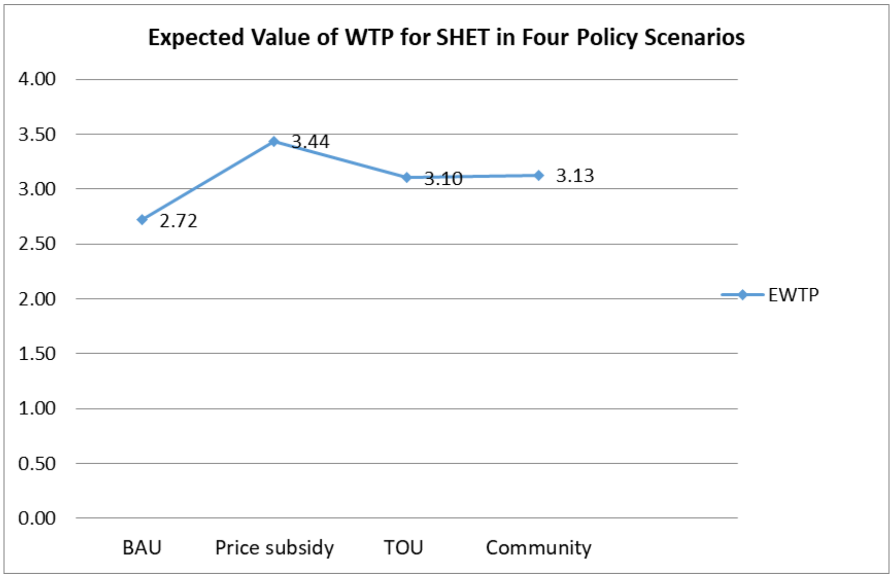

Figure 7.2 The expected value of the WTP for SHET in each scenario

7.5 Discussion

The analysis results tell us that the WTP for SHET of the respondents will be affected by a series of factors, including demographic, property related, and behavioral. The influential factors vary when people are stimulated by different types of incentive schemes.

First, of the demographic variables analyzed by this thesis - gender, age, level of education, household income and number of family members – the last two were not found to have any impact on the WTP. Gender has been shown to be a significant factor affecting WTP in all the incentive scheme scenarios including PS, TOU and CERC, with males showing higher WTP for SHET than females. This finding might be explained from the viewpoint of (Shields and Zeng 2012), which asserted “Chinese men, not women, show a greater concern about environmental problems and the seriousness of the environmental degradation in China”, because of the difference in the economic and education status of men and women in contemporary China. And (Kotzé, Anderson et al. 2016) also stated that women are less optimistic than men when facing high technology electronic products, because women appear to be higher level of risk-aversion; and women also need more time to making purchase decision than men.

Education was also found to be a significant positive influencer of WTP in three scenarios: BAU, PS and TOU. Those with university degrees and above were more likely to pay for SHET than those without. This finding is consistent with some previous research such as (Mills and Schleich 2012), whose study of residents' energy-efficient technology adoption in European countries concluded that the education level had a strong impact on family's attitude towards energy efficiency technology. (Nair, Gustavsson et al. 2010) found a positive relationship between resident's education degree and the investment of energy efficiency measure in Sweden, as was also the case with the findings of a study conducted in Canada (Das, Richman et al. 2018). Generally, the people who have received higher education degree can have better perceptions about the complicated smart technology (Ji and Chan 2019) and also have a deeper understanding of incentive policies. In order to foster the adoption of SHET by urban residents, government or industry organizations should therefore value the positive influence of education. They might offer training courses to enhance the perceptions about or understanding of smart technology by people with lower educational backgrounds and education departments could also promote the teaching of knowledge of smart technology in secondary schools and universities.

Age was found to be significant only in the CESC scenario and had a negative effect, reflecting the possibility that older people are less willing than young adults to participate in such community campaigns. This finding can also find support in some previous research, such as (Poortinga, Steg et al. 2003), which found that older people considered technical improvements for energy efficiency less acceptable than younger people. This result also implies that the willingness of older people to participate in community campaigns is lower than that of younger people. This is echoed by (Folz and Hazlett 1991) who found out that communities with lower median ages were more willing to join compulsory waste recycling programs.

On variables related to property, house size did not have any significant influence on the WTP in any of the scenarios. That is different from a research finding about the WTP of home energy management systems in the USA, which suggested that house size had a positive impact (Washizu, Nakano et al. 2019). In the PS and TOU scenarios, the rights over the property were shown to be a significant factor. Compared to respondents living in rental houses, those who owned their residence appeared to have higher WTP. One possible reason may be that people who live in rental houses have to face frequent moves. It is the homeowner's duty to purchase and install a household appliance, so, according to their perceptions; the adoption of SHET is not their business. However, as well as large smart appliances, SHET includes portable products such as smart plugs, smart table lighting, etc., which can help the users to save energy. The smart industry could therefore develop products and marketing strategies specifically to focus on renters.

On behavioral variables, consistent with the previous findings in Chapter 6, four factors –ATTP, PBC, SN, and PN – are significant positive factors impacting the WTP of residents for SHET. ATRR showed no significant influence on the WTP in any of the four scenarios. However, there were some differences with ATEP, in that in the BAU and PS scenarios the ATEP did not show any significant influence, while in the TOU and CESC scenarios ATEP had a positive impact on the WTP. These two scheme scenarios could enhance respondents' attitude towards the economic benefits gained from SHET and stimulate their adoption willingness. Comparing the four scheme scenarios, it can be found that the effect of ATTP on WTP is almost as much as 50% in all three proposed scenarios, which indicates that this policy could enhance people's perceptions about the technology performance of SHET. Comparing the three scenarios, the influence of ATTP is strongest in TOU, which corresponds with the orientation of TOU – to make full use of the smart functions of household appliances and smart grids to achieve the active management of energy consumption by households. In addition to the influence of ATTP, the influence of SN is also very important, showing the impact of social influence on people's intentions about some innovative as well as environmentally friendly behaviors. In the CESC scenario, PN exerts an even slightly higher influence than SN on respondents' willingness, which shows the importance of people's internal values.

From Table 7.9 and Figure 7.2, we can find that all the three proposed scheme scenarios successfully improved respondents' WTP for SHET to various extents. The PS policy appears to have the strongest effect, improving willingness by 26.4%. The welcome for the PS policy is unsurprising, as it is a very common economic instrument adopted by the governments of many countries (Kalish and Lilien 1983). And PS is also not unfamiliar to the Chinese people either, as the long-term implementation of PS for energy label products and electronic vehicles has made a large contribution to the acceleration of the two industries (Hao, Ou et al. 2014, Zeng, Yu et al. 2014). However, when implementing a PS policy, governments need to pay attention to the implementation period and the mode of execution. Regulation of the retailers and education of customers are also indispensable.

Improvement under the CESC scenario was 15%, making it the second most effective of the three polices. The effect of the CESC policy shows the effectiveness of social comparison or social influence in the promotion of energy-saving activities. Similar measures have been adopted by some previous experiments, such as (Geelen, Keyson et al. 2012). The residents who participated in the game in this study were provided with direct feedback, including on their energy consumption and the ranking of their competitors. The study showed that the participants were strongly motivated by this game to save energy, achieving 24% energy saving on average. Moreover, after the game, some participants asserted that, in the process of playing the game, they had developed some real habits of energy saving. Implementation of this campaign has to pay attention to the difference in the willingness of the younger age group compared to that of older people, and it is suggested that the organizer of such a campaign should design some activities specifically for middle-aged people, in order to stimulate their enthusiasm to participate.

The TOU pricing plan ranked third, with a 14% increase compared to the BAU scenario, verifying the positive influence of TOU on people’s willingness to pay for SHET. As a common measure of DSM, the effectiveness of TOU pricing in changing the energy consumption patterns of residents and saving household energy consumption have been demonstrated by much research and recognized by the industry and government. The implementation of TOU pricing in China can be traced back to 2013, when some provinces of China, such as Guangdong province, began to formulate TOU pricing plans and encourage residents to join voluntarily. However, there is some feedback that the total electricity bill under TOU plans is not much different from the original pricing plan, while the tariff calculation seems more difficult. One possible explanation for this phenomenon is that the users of TOU plans neither change their energy consumption pattern nor take full advantage of the lower rate in off-peak hours. Luckily, the technical functions of SHET could help the users to solve these problems through automation, remote control, scheduling, and feedback, as long as the users schedule the operations in advance. The development of smart grid and SHET allows residents to make the best use of TOU pricing more conveniently and efficiently, which is also why the influence of ATTP on TOU is higher than on the other scenarios. Additionally, it is suggested that the utility department could consider promoting a compulsory TOU pricing plan, and that a clear and transparent electricity bill could make this pricing plan more acceptable.

Additionally, one objective of this study is to take Guangdong as study area, in hopes of the findings about Guangdong province to be a paradigm of other regions of China. However, when considering the application of three incentive schemes in other provinces, some factors of the development environment of politics, economy, environment, and demographics of other regions must be figured out. For the incentive scheme price subsidy, which has been implemented in the whole China for several years, targeting to the energy efficient household appliance, it seems to be applicable to the smart home energy products. For the incentive scheme of TOU plan, the local infrastructure system of smart grid and smart meter must be considered, because the stated owned utility company CSPG in Guangdong province has asserted the urban area of Guangdong province has achieved fully coverage of smart grid and smart meter, which provide the objective condition to implement TOU into the urban residents, but for those province with the complete smart grid system, nor the smart meter installed for the household, the TOU plan would not be feasible. And for the incentive scheme of CESC, if to effectively implement this scheme, the role of community management is quite important, therefore it is more suitable for the areas where has built well grassroots government system and the community officers should take much responsibility.

Chapter 8 Conclusion

8.1 Introduction

The conclusions of this study will be presented in this chapter. Firstly, the research objectives will be reviewed respectively, then the major research findings will be summarized, and the significance and contributions of the study will also be introduced, following by pointing out the research limitations and the directions of future effort.

8.2 Review of the Research Objective

The aim of this thesis is to contribute to the understanding of the perceptions about the smart home energy technology by Chinese urban residents and analysis of the behavioral, social, psychological factors explaining people's adoption intention, as well as provide policy implications to the industry and government in order to promote the diffusion of smart home energy technology through urban residents. To achieve the aim, four objectives have been established: 1) to investigate the key performance indicators representing the complicated performance of SHET; 2) to develop measurement scales for investigating the urban resident's adoption intention about SHET; 3) to identify the critical factors influencing the adoption intention of SHET; 4) to propose the incentive schemes that will facilitate the urban residents to adopt SHET.

The first objective has been achieved by comprehensive review of literature in the topic of SHET and the social acceptance of smart technology, finally twelve indicators were identified, including automation, controllability, feedback, improving living comfort, convenient operation, system interoperability, saving energy expense, inexpensive maintenance, cost effectiveness, reliability, safety, and privacy protection.

The second objective has been achieved by the literature review of attitude and behavioral theories involved with the energy saving and technology acceptance. After literature review, the integration of two behavioral theories, theory of planned behavior (TPB), and theory of norm activation model (NAM), was determined to be the theoretical backbone of this study. Referring to the previous traditional questionnaire survey of TPB and NAM, also on the basis of the work in the first objective, a set of questionnaire to evaluate respondent's attitude towards technical performance, economic performance, risk resistance of SHET, and respondent's perceptions about perceived behavioral control, subjective norm, and personal norm was developed. After meeting with some industry experts, the questionnaire was finalized and distributed through the urban residents in Guangdong province.

The third objective has been achieved by two data analysis methods, exploratory factor analysis (EFA) and PLS-SEM. Through EFA, the six factors (also called latent variable) relating with the adoption intention of SHET were determined and name labeled, which were ATTP, ATEP, ATRR, PBC, SN, PN; the associated measurement indicators of each factor were also confirmed, consequently, six research hypothesis were formally established. Then the PLS-SEM was applied to examine the hypothesis, whose results indicated that four factors exhibiting significant positive influence onto the adoption intention of SHET, including ATTP, PBC, SN, PN; while two factors have not been found significance. Based on this result, a comprehensive discussion was conducted.

The fourth objective has been attained by methods of literature review, contingent valuation, and ordered logistic regression. Referring to the current energy efficiency polices that have been implemented by various governments, and some methods to encourage energy saving used by social experiments, three incentive scheme scenarios have been proposed in this study. In order to examine the effect of these polices onto the adoption intention of SHET, this study adopt contingent valuation method (CVM) to elicit respondent's willingness to pay (WTP) to represent their maximum intention to purchase SHET; then the analysis results of logit regression revealed that all the three schemes were effective, and the scheme of price subsidy appeared to be the strongest. At last, discussions about the influential factors of resident's WTP for SHET and the applicability of each scheme were conducted.

8.3 Significance and Contribution of the Study

At the theoretical aspect, this study has proposed a theoretical framework by the integration of two predominant human behavior theories, and connecting the sophisticated attributes of smart home energy technology, attempting to compromise the functions and performances of smart technology into the human attitude, norm, perceptions and behavioral intention. Based on the proposed theoretical framework, data analysis has been conducted, and some findings have been investigated, which can make contribution to the knowledge building in the area of smart technology adoption.

On the application side, reducing the energy consumption in residential section of China is still a critical problem facing by government and building industry. Although the effectiveness of SHET in energy saving has been recognized, only the widely adoption of the technology, could realize the benefits of the technology progress introduced to the human society, which is just the significance of that study matters.

Firstly, the findings of this study will provide some understanding to the practitioner of smart home industry about the potential users' attitudes towards the complicated performance of SHET, and their perceptions about the social and conditional factor related with the technology adoption.

Secondly, in order to promote the diffusion of SHET, this study has proposed three incentive schemes, and has examined the effects of schemes onto resident's WTP, which could provide some policy implications to the policy makers, in case they would formulate the industry policy in future.

Finally, selected as the targeting area of this study, Guangdong province has been standing at the frontier of the development of the economy and all kinds of advanced technologies, and its development experience has always been regarded as paradigm of other regions of China. Therefore, the findings of this study will not only benefit the smart home industry in Guangdong province, but also provide recommendations to other regions.

8.4 Limitation and Future Effort

Several limitations existing in this study should be acknowledged. The first is that the theoretical framework in this study was developed upon the integration of two predominant behavioral theories, TPB and NAM, hence the constructs of the research model, and the measurement indicators were still under the general framework of the two theories. However, as the complexity of human behavior and smart technology, the adoption intention may also be affected by some other factors, for example, the climate factors, or the policy factors, as these contextual factors are not relevant with the behavioral theories, they are not discussed by this study.

Secondly, there are some limitations associating with the data collection method- questionnaire survey. One is about the data quality: the research data was collected from self-reporting questionnaire but not from the observation of real behaviors, and the respondent's answers may be influenced by some inherent bias resulting from personal characters, society environment, or demographic factors, but not the real situations. The other limitation is related with the data source. Although the distribution areas of questionnaire have been completely within Guangdong province, it could not fully make sure all the response data coming from Guangdong, as the survey was an online form, some people out of Guangdong might fill the form.

Thirdly, the respondent data adopted by this study was confined to the groups aging between 18~ 60 years old, in order to make sure the data quality. Nevertheless, as China is gradually becoming an aging society, the requirements of the old people should also be given enough attention.

And finally, the study totally focused on the behavior on residents, however, currently, more and more people would like to buy well decorated house from real estate developers directly. It is real estate company's decision whether to install the SHET products in the new built houses, therefore, the attitude and practice of real estate company would also have influence on the social acceptance of SHET.

Based on the limitation mentioned above, the possible research directions for future are proposed below:

1) Expanding the sample of the respondents to cover the old group; and understand the old people's perceptions and attitudes towards SHET.
2) Investigate the factors influencing the adoption of smart technology beyond the framework of predominant behavioral theories.
3) Where feasible, acquiring the real observed behavioral data for the usage of smart home energy technology.
4) To investigate the attitude and practice of real estate company about SHET and the inter-effects between real estate developer and house buyers about the adoption intention of SHET.

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Appendix-Questionnaire

*Translation in English, original copy is in Chinese

A survey for the adoption intention about the smart home energy technology of urban residents in Guangdong Province

Dear respondent:

I am a PhD student in the Department of Building and Real Estate in The Hong Kong Polytechnic University. You are cordially invited to participate in a research survey, entitled: Investigation of influential factors for the adoption intention of smart home energy technology by urban residents in China.

As the rapid development of information technology, now we have stepped into the era of smart. The smart meter, smart TV, smart car, etc. are not strange to our lives. Among the various smart products, there is one important category: smart home energy technology, which specializes in offering energy management solutions to residents through its various functions. The overall SHET includes three sub-categories: user interface, containing energy portal, In Home Display, load monitor; smart hardware, including smart appliances, like smart washer/dryer, smart thermostat, smart air conditioner, smart lighting, smart plug, etc.; and plat form, like smart home energy management system (HEMS). SHET could bring many benefits to your lives, like reducing energy bill, improving indoor comfort, convenience, etc.

The purpose of our survey is to investigate the factors influencing your adoption intention of SHET, so that to provide recommendations to industry and government. The questionnaire has 3 sections, 25 questions. There are no standard answers to the questions, and it only takes you 5-10 minutes to complete the questionnaire. We promise that your personal information will not be disclosed and remain strictly confidential.

If you have any enquiries or suggestions about this research, please contact Miss. Ji Weiyu, via the email address: jiweiyu186@

Best regards!

JiWeiyu

Department of Building and Real Estate

The Hong Kong Polytechnic University

Some examples of SHET products:（image source: website）

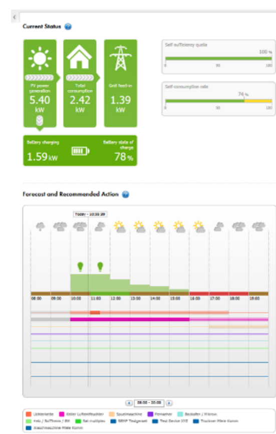
1. Smart home energy consumption monitor，Household energy management App:

2. SHET hardware products：

Smart air-conditioning **Smart washing machine**

Smart plug **Smart lighting**

3. Smart home energy management system:



Part I: Background Information

1. Your gender:

○Male ○Female

2. Your Age:

○below 18 years ○18~40 years old ○40~60 years old ○above 60 years old

3. Your living area:

○City ○Rural area

4. Education degree:

○Below bachelor

○Bachelor and above

5. Your household annual income (RMB):

○lower than 100000

○100001~300000

○ more than 300001

6. The number of your family members:

○Single

○Couple

○Three people family

○Four people family

○More than five

7. The ownership of your property:

○Self-owned

○Rent

8. The size of your house:

○ 0-60 m^2

○ 61-90 m^2

○ 91-120 m^2

○121-150 m^2

○ more than 151 m^2

9. Do you have any experience of using SHET?

○Yes

○No

<u>Part II Attitude and perceptions about the influential factors of adoption intention of SHET</u>

Below 6 questions will survey you attitude towards the technical performance of SHET, please tick the appropriate number to represent your attitude.

1= strongly disagree; 2= disagree; 3= neutral; to 4= agree; to 5= strongly agree

1. I believe the SHET could execute some functions in a self-operative mode with minimum human intervention.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

2. I believe under some accidental situations, the operation of SHET can still be controllable.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

3. I believe the SHET could provide my household energy consumption information in an effective and user friendly way.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

4. I believe the SHET products could communicate and collaborate with the existing and also the new adopted smart products.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

5. I believe the design of the SHET is convenient for me to handle and operate.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

6. I believe the SHET could improve my indoor comfort by the functions of automatically adjusting room temperature, humidity and illumination, etc.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

Below 3 questions will survey you attitude towards the economic performance of SHET, please tick the appropriate number to represent your attitude.

1= strongly disagree; 2= disagree; 3= neutral; to 4= agree; to 5= strongly agree

7. I believe the SHET could help me to reduce energy expense and create economic profit for my family.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

8. I believe the SHET would not generate costly maintenance fee.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

9. Considering the financial condition of my family, I believe the I would get a good return from SHET, compared to the money I pay for.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

Below 3 questions will survey you attitude towards the risk resistance capability of SHET, please tick the appropriate number to represent your attitude.

1= strongly disagree; 2= disagree; 3= neutral; to 4= agree; to 5= strongly agree

10. I believe the SHET and its operating agent could protect my household information, as well as utilize my privacy data legally.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

11. I believe the SHET could maintain smooth running and produce my desired outcomes with high accuracy.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

12. I believe the SHET would not occur accidents that threaten my domestic environment and cause serious damages to my family's lives and properties, such as fire, losing control of total electricity load, etc.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

Below 3 questions will survey your perceptions about the behavioral control, meaning the external restricted conditions are resources in the adoption of SHET, please tick the appropriate number to represent your perceptions.

1= strongly disagree; 2= disagree; 3= neutral; to 4= agree; to 5= strongly agree

13. I believe I own the knowledge and skill to operate and handle the SHET.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

14. I believe the financial capability of my family could afford the adoption of SHET.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

15. I believe the building system of my household could be compatible with SHET products.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

Below 3 questions will survey your perceptions about the subjective norms, meaning the social pressure you could perceive from some important person or groups, please tick the appropriate number to represent your perceptions.

1= strongly disagree; 2= disagree; 3= neutral; to 4= agree; to 5= strongly agree

16. The main public opinions expect me to adopt SHET.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

17. The media opinions would expect me to adopt the SHET.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

18. My family member and friends expect me to adopt the SHET.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

Below 3 questions will survey your perceptions about the personal norms, meaning the internal values of yourself, please tick the appropriate number to represent your perceptions.

1= strongly disagree; 2= disagree; 3= neutral; to 4= agree; to 5= strongly agree

19. I think it is my social responsibility to adopt SHET in my household.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

20. I believe the adoption of SHET would be beneficial to the environment.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

21. My innovative spirits make me feel I should adopt some newly emerging smart technology products.

strongly disagree	○1	○2	○3	○4	○5	strongly agree

Part III Adoption intention about SHET

Below 4 questions will survey your intention to adopt SHET, please read the descriptions of 4 scenarios carefully, and tick the appropriate number to show your willingness.

0~ Unwillingness; 1~ Slight willingness; 2~ some willingness; 3~ High willingness; 4~ Very high willingness; 5~ extremely high willingness

22. In the current situation, please tick the appropriate number to represent your maximum willingness to adopt the SHET product.

Unwillingness	○0	○1	○2	○3	○4	○5	Extremely high willingness

23. Government will roll out compulsory TOU electricity pricing plan in Guangdong province. The hours a day will be divided into three sections: peak period (14:00~17:00, 19:00~22:00); flat period (8:00~14:00, 17:00~19:00, 22:00~24:00) and valley period (0:00~8:00).

The ratio of the electricity rate among peak, flat and valley period is 1.65:1:0.5, of which, the flat price is consistent with the electricity rate currently.

One tip: The functions of SHET, like scheduling, automation, remote control, etc. will engage you to make use of the price variance across three sections, and save your electricity bill.

Unwillingness	○0	○1	○2	○3	○4	○5	Extremely high willingness

24. Government will roll out a price subsidy policy for all the SHET products you purchase, covering all the brands, and all online or physical stores. The amount of subsidy: 10% of the product price, with a highest amount of 800 Yuan.

Unwillingness	○0	○1	○2	○3	○4	○5	Extremely high willingness

25. The community of your residence will hold an energy saving campaign, and the arrangement of the campaign is as below:

1) The comparison criteria will be based on the amount of the household electricity consumption per month.

2) The top 10% of the households in community that consume the least electricity will be rewarded with prizes prepared by community; and their rankings and house numbers will also be listed on the bulletin board to the whole community.

Unwillingness	○0	○1	○2	○3	○4	○5	Extremely high willingness

附件-问卷调查(中文版)

尊敬的先生/女士，

您好！我是香港理工大学建筑与房地产学系的博士生。现在诚邀您参加题为“中国城市居民对智能家居节能技术产品采纳意向的关键影响因素”的调研活动。

随着信息技术的飞速发展，现在我们已经步入了智能时代。智能电表、智能电视、智能汽车等，这些智能产品在我们的生活中并不陌生。在众多的智能产品中，有一个很重要的类别:智能家居节能产品，这种类型的产品可以通过其各种功能为居民提供能源管理解决方案，并帮助用户培养节能行为。智能家居节能产品划分为三个类别: 用户操作界面（包含能源门户、家庭能源显示器、家庭电力荷载监控器等）、智能硬件（包括智能家电，如智能洗衣机/烘干机、智能恒温器、智能空调、智能照明、智能插头等）、和智能管理平台，如智能家庭能源管理系统(HEMS)。智能家居节能产品可以给您的生活带来很多益处，比如减少能源开支，提高室内舒适度，为生活带来便利等。

此次调查的目的是了解影响您对智能家居节能产品采纳意向的因素，以便为行业和政府提供建议。问卷有部分，25个问题。每个问题没有标准的答案，请您选择最符合您情况的选项。填写问卷大概需要-10分钟。我们保证您的个人信息不会被泄露，填写内容严格保密。

如果您对本次研究有任何疑问或建议，请通过电子邮件联系及女士:jiweiyu186@

智能家居节能产品示例（图片来源网络）:

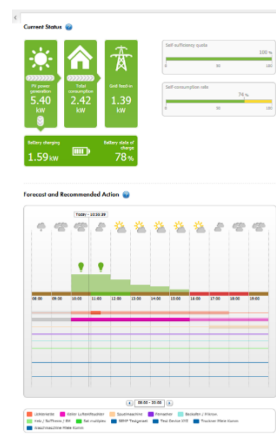
1. **智能家庭能源显示器，家庭能源管理 app：**

2. **智能家居硬件设备：**

智能空调 **智能洗衣机**

智能插座 **智能灯具**

3. 家庭能源管理系统:



Part I: 背景信息

1. 您的性别：

○男性 ○女性

2. 您的年龄：

○18 岁以下 ○18~40 岁 ○40~60 岁 ○60 岁以上

3. 您的居住区域：

○城市　　　○农村

4. 您的学历:

○高中及以下

○大学本科及以上

5. 您的家庭年收入 (RMB):

○十万元以下

○10 万~30 万

○ 高于 30 万

6. 您的家庭成员数量:

○单身

○二人

○三口之家

○四口之家

○五人以上

7. 您的房屋产权情况:

○自有产权

○租赁房屋

8. 您的居住面积:

○ 0-60 m^2

○ 61-90 m^2

○ 91-120 m^2

○121-150 m^2

○ more than 151 m^2

9. 您是否拥有使用智能家居节能产品的经验？

○有

○没有

Part II 您对智能家居节能技术产品的态度与认知

以下 6 个问题将会调查您对智能家居节能产品技术性能的态度，请在适当的数字上打勾表示您的态度。

1= 强烈不同意; 2= 不同意; 3= 中立; 4= 同意; 5= 强烈同意

1. 我相信智慧家居节能产品可以实现全自动化操作，最大化减少人为干预。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

2. 我相信智慧家居节能技术产品是可控的，可以根据我的指令转换功能和工作模式。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

3. 我相信智慧家居节能技术产品能够以高效友好的方式向我提供我的家庭能耗信息。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

4. 我相信我目前购买的智能家居节能产品可以与现有的以及未来可能会使用的智能产品实现系统兼容。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

5. 我相信智能家居节能产品的设计可以让我方便快捷地操作。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

6. 我相信智能家居节能产品可以通过自动调节室内温度、湿度、照明等功能来提高我的室内舒适度。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

以下 3 个问题将调查您对智能家居节能产品的经济表现的态度，请在适当的数字上打勾表示您的态度。

7. 我相信智能家居节能产品可以帮助我降低能源消耗，节省能源花费。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

8. 我相信智能家居节能产品不会产生昂贵的维护费.

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

9. 考虑到我家庭的经济状况，以及我在智能家居节能产品上的投资，我相信智能家居节能产品是具有成本效益的。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

以下 3 个问题将调查您对智能家居节能产品在风险抵抗能力方面的态度，请在适当的数字上打勾表示您的态度。

10. 我相信智能家居节能产品和它的运营商可以保护我的家庭信息，以及合法利用我的隐私数据。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

11. 我相信智能家居节能产品能够维持可靠的运转，并以较高的准确性提供我想要的服务。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

12. 我相信智能家居节能产品不会发生火灾、电力负荷失控等危害我的居住环境、对我家庭的生命财产造成严重损害的事故。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

以下 3 个问题将调查您对行为控制因素的看法，即来自外部的限制条件和资源等，请选择合适的数字代表您的看法。

13. 我相信我拥有操作和处理智能家居节能产品的知识和技能。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

14. 我相信我们家的经济能力可以负担得起智能家居节能产品。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

15. 我相信我的家庭建筑系统可以与智能家居节能产品兼容。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

以下三个问题将调查你对主观规范的看法，即你从一些重要的人或团体所感受到的社会压力，请选择适当的数字代表你的看法。

16. 当前社会舆论期待我使用智能家居节能产品。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

17. 当前大众媒体的舆论期待我去使用智能家居节能产品。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

18. 我的家庭成员和朋友会希望我使用智能家居节能产品。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

以下三个问题将调查你对个人规范的看法，即你自己的内在价值，请在适当的数字上打勾来代表你的看法。

19. 我认为使用智能家居节能产品是我社会责任感的体现。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

20. 我相信使用智能家居节能产品将对环境有益。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

21. 我的创新精神让我觉得我应该采用一些新兴的智能科技产品。

强烈不同意 ○1 ○2 ○3 ○4 ○5 强烈同意

Part III 智能家居的采纳意向

以下 4 个问题将调查您采用智能家居节能产品的意愿，请仔细阅读 4 种情景的描述，并勾选适当的数字来表示您的意愿。

0~ 无意愿; 1~ 轻微意愿; 2~ 有一些意愿; 3~ 高意愿; 4~ 非常高意愿; 5~ 极高意愿

22. 在目前的情况下，请勾选适当的数字以表示您对智能家居节能产品的采纳意愿。

没有意愿 ○0 ○1 ○2 ○3 ○4 ○5 极高意愿

23. 电力部门将在广东省推出强制性的分时电价方案。即将一天 24 小时分为三个时段: 高峰时段(14:00~17:00,19:00~22:00); 平稳时段 (8:00~14:00,17:00~19:00,22:00~24:00) 和低谷时段(0:00~8:00) 。峰、平、谷时段电价比例为 1.65:1:0.5，其中，平稳时段电价与当前广东省阶梯电价制度中第一梯度一致。

一个小提示:智能家居节能产品的功能，如预约、自动化、远程控制等，可以帮助用户有效利用三个电费时段的价格差异，以此节省电费。

没有意愿 ○0 ○1 ○2 ○3 ○4 ○5 极高意愿

24. 政府将对你购买的所有智能家居节能产品实行价格补贴政策，政策覆盖所有品牌、所有线上和线下实体店。

补贴金额:产品价格的 10%，最高 800 元。

没有意愿 ○0 ○1 ○2 ○3 ○4 ○5 极高意愿

25. 您居住的社区将举办一场节能活动，活动安排如下:

1)以住户每月用电量为基准进行比较。

2)对每月家庭用电消耗最低的前 10%的家庭住户，社区将给予一定物质奖励，并且获奖者的排名和门牌号将在社区公告栏公示。

没有意愿 ○0 ○1 ○2 ○3 ○4 ○5 极高意愿

Appendix-Data analysis by PLS-SEM

Appendix Figure 1: Latent Variable Correlations

	ATEP	ATRR	ATTP	Age	Education	Gender	Household income	Intention	PBC	Personal norm	Subjective Norm	property ownership
ATEP	1	0.833	0.855	-0.049	-0.06	-0.018	0.018	0.683	0.82	0.774	0.786	0.002
ATRR	0.833	1	0.845	0.001	-0.067	-0.04	-0.003	0.672	0.808	0.765	0.764	0.007
ATTP	0.855	0.845	1	-0.036	-0.008	0.018	0.024	0.727	0.843	0.818	0.837	-0.018
Age	-0.049	0.001	-0.036	1	-0.062	0.004	0.056	-0.04	-0.034	-0.027	-0.047	0.018
Education	-0.06	-0.067	-0.008	-0.062	1	0.052	0.039	0.009	-0.072	0	-0.024	-0.008
Gender	-0.018	-0.04	0.018	0.004	0.052	1	-0.015	0.015	-0.024	0.001	-0.001	-0.065
Household income	0.018	-0.003	0.024	0.056	0.039	-0.015	1	0.017	0.038	0.028	0.035	-0.024
Intention	0.683	0.672	0.727	-0.04	0.009	0.015	0.017	1	0.697	0.691	0.697	-0.028
PBC	0.82	0.808	0.843	-0.034	-0.072	-0.024	0.038	0.697	1	0.763	0.781	0.017
Personal norm	0.774	0.765	0.818	-0.027	0	0.001	0.028	0.691	0.763	1	0.758	-0.018
Subjective Norm	0.786	0.764	0.837	-0.047	-0.024	-0.001	0.035	0.697	0.781	0.758	1	-0.001
property ownership	0.002	0.007	-0.018	0.018	-0.008	-0.065	-0.024	-0.028	0.017	-0.018	-0.001	1

Appendix Figure 2: Latent Variable Covariance

	ATEP	ATRR	ATTP	Age	Education	Gender	Household income	Intention	PBC	Personal norm	Subjective Norm	property ownership
ATEP	1	0.833	0.855	-0.049	-0.06	-0.018	0.018	0.683	0.82	0.774	0.786	0.002
ATRR	0.833	1	0.845	0.001	-0.067	-0.04	-0.003	0.672	0.808	0.765	0.764	0.007
ATTP	0.855	0.845	1	-0.036	-0.008	0.018	0.024	0.727	0.843	0.818	0.837	-0.018
Age	-0.049	0.001	-0.036	1	-0.062	0.004	0.056	-0.04	-0.034	-0.027	-0.047	0.018
Education	-0.06	-0.067	-0.008	-0.062	1	0.052	0.039	0.009	-0.072	0	-0.024	-0.008
Gender	-0.018	-0.04	0.018	0.004	0.052	1	-0.015	0.015	-0.024	0.001	-0.001	-0.065
Household income	0.018	-0.003	0.024	0.056	0.039	-0.015	1	0.017	0.038	0.028	0.035	-0.024
Intention	0.683	0.672	0.727	-0.04	0.009	0.015	0.017	1	0.697	0.691	0.697	-0.028
PBC	0.82	0.808	0.843	-0.034	-0.072	-0.024	0.038	0.697	1	0.763	0.781	0.017
Personal norm	0.774	0.765	0.818	-0.027	0	0.001	0.028	0.691	0.763	1	0.758	-0.018
Subjective Norm	0.786	0.764	0.837	-0.047	-0.024	-0.001	0.035	0.697	0.781	0.758	1	-0.001
property ownership	0.002	0.007	-0.018	0.018	-0.008	-0.065	-0.024	-0.028	0.017	-0.018	-0.001	1

Appendix Figure 3: Fornell-Larcker Criterion

	ATEP	ATRR	ATTP	Age	Education	Gender	Household income	Intention	PBC	Personal norm	Subjective Norm	property ownership
ATEP	0.87											
ATRR	0.833	0.869										
ATTP	0.855	0.845	0.839									
Age	-0.049	0.001	-0.036	1								
Education	-0.06	-0.067	-0.008	-0.062	1							
Gender	-0.018	-0.04	0.018	0.004	0.052	1						
Household income	0.018	-0.003	0.024	0.056	0.039	-0.015	1					
Intention	0.683	0.672	0.727	-0.04	0.009	0.015	0.017	1				
PBC	0.82	0.808	0.843	-0.034	-0.072	-0.024	0.038	0.697	0.872			
Personal norm	0.774	0.765	0.818	-0.027	0	0.001	0.028	0.691	0.763	0.904		
Subjective Norm	0.786	0.764	0.837	-0.047	-0.024	-0.001	0.035	0.697	0.781	0.758	0.908	
property ownership	0.002	0.007	-0.018	0.018	-0.008	-0.065	-0.024	-0.028	0.017	-0.018	-0.001	1

Appendix Figure 4: Cross Loadings

	ATEP	ATRR	ATTP	Age	Education	Gender	Household income	Intention	PBC	Personal norm	Subjective Norm	property type
Age	-0.049	0.001	-0.036	1	-0.062	0.004	0.056	-0.04	-0.034	-0.027	-0.047	0.018
Automation	0.698	0.705	0.833	-0.008	0.005	0.019	0.008	0.604	0.688	0.679	0.684	-0.031
Controllability	0.7	0.701	0.839	-0.021	-0.007	0.017	0.029	0.606	0.68	0.677	0.693	-0.032
Convenient operation	0.711	0.689	0.83	-0.029	-0.004	0.035	0.036	0.592	0.696	0.678	0.701	0.002
Cost effective	0.881	0.721	0.752	-0.045	-0.048	-0.006	0.001	0.607	0.722	0.671	0.692	0.012
Education (BB=1/BA=2)	-0.06	-0.067	-0.008	-0.062	1	0.052	0.039	0.009	-0.072	0	-0.024	-0.008
Environmental concern	0.694	0.685	0.737	-0.029	0.014	-0.005	0.026	0.623	0.683	0.903	0.683	-0.023
Family and Friends	0.725	0.712	0.769	-0.045	-0.035	-0.005	0.026	0.652	0.727	0.69	0.914	-0.016
Feedback	0.755	0.736	0.881	-0.031	-0.011	0.022	0.021	0.651	0.735	0.728	0.749	-0.031
Financial capability	0.72	0.715	0.728	-0.03	-0.073	-0.046	0.048	0.597	0.876	0.661	0.679	0.039
Gender(M1/F0)	-0.018	-0.04	0.018	0.004	0.052	1	-0.015	0.015	-0.024	0.001	-0.001	-0.065
HouseholdIncome	0.018	-0.003	0.024	0.056	0.039	-0.015	1	0.017	0.038	0.028	0.035	-0.024
Improving living comfort	0.709	0.7	0.855	-0.044	0.019	0.038	0.019	0.598	0.696	0.695	0.719	-0.024
Innovativeness	0.704	0.697	0.742	-0.02	-0.014	0.008	0.024	0.625	0.696	0.904	0.687	-0.01
Knowledge&Skill	0.708	0.688	0.749	-0.007	-0.044	0.011	0.048	0.625	0.873	0.671	0.698	-0.011
Low maintenance	0.861	0.75	0.711	-0.032	-0.085	-0.048	0.03	0.588	0.718	0.663	0.656	0.014
Policy environment	0.702	0.674	0.751	-0.04	-0.007	0.003	0.038	0.613	0.69	0.687	0.902	0.016
Privacy	0.733	0.865	0.719	-0.01	-0.085	-0.059	-0.052	0.567	0.714	0.657	0.644	0.039
Property	0.002	0.007	-0.018	0.018	-0.008	-0.065	-0.024	-0.028	0.017	-0.018	-0.001	1
Safety	0.721	0.869	0.744	0.015	-0.051	-0.017	0.002	0.585	0.703	0.671	0.676	0.002
Save energy expense	0.868	0.703	0.77	-0.05	-0.024	0.009	0.016	0.589	0.7	0.686	0.703	-0.02
System compatability	0.719	0.712	0.728	-0.052	-0.071	-0.029	0.002	0.602	0.867	0.665	0.665	0.016
System interoperability	0.73	0.721	0.793	-0.047	-0.041	-0.041	0.009	0.607	0.745	0.659	0.665	0.029

System reliability	0.717	0.873	0.741	-0.003	-0.039	-0.029	0.041	0.599	0.69	0.666	0.67	-0.02
WTP	0.683	0.672	0.727	-0.04	0.009	0.015	0.017	1	0.697	0.691	0.697	-0.028

Appendix Figure 5: Bootstrapping result of path coefficients

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
ATEP -> Intention	0.052	0.052	0.039	1.358	0.175
ATRR -> Intention	0.051	0.052	0.041	1.244	0.214
ATTP -> Intention	0.184	0.185	0.048	3.864	0
Age -> Intention	-0.008	-0.008	0.017	0.492	0.623
Education -> Intention	0.033	0.033	0.017	1.978	0.048
Gender -> Intention	0.016	0.016	0.017	0.936	0.35
Household income -> Intention	-0.007	-0.007	0.017	0.422	0.673
PBC -> Intention	0.172	0.173	0.038	4.481	0
Personal norm -> Intention	0.187	0.186	0.032	5.749	0
Subjective Norm -> Intention	0.187	0.186	0.034	5.586	0
property type -> Intention	-0.023	-0.023	0.017	1.376	0.169

Appendix Figure 6: Result of Q^2 Value

	SSO	SSE	Q^2(=1-SSE/SSO)
ATEP	4,470.00	4,470.00	
ATRR	4,470.00	4,470.00	
ATTP	8,940.00	8,940.00	
Age	1,490.00	1,490.00	
Education	1,490.00	1,490.00	
Gender	1,490.00	1,490.00	
Household income	1,490.00	1,490.00	
Intention	1,490.00	648.481	0.565
PBC	4,470.00	4,470.00	
Personal norm	2,980.00	2,980.00	
Subjective Norm	2,980.00	2,980.00	
property type	1,490.00	1,490.00	