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Title: **Consumer perceptions of smart grid development: Results of a Hong Kong Survey and policy implications**

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Consumer perceptions of smart grid development:

Results of a Hong Kong Survey and policy implications

Abstract

Consumers have a major role to play in smart grid technologies which can be instrumental in addressing climate change and energy challenges. However, little is known about how consumers perceive, and how they might respond to the opportunities that smart grid technologies offer. This paper reports the results from a Hong Kong survey (n=505). It contributes to the literature by providing a better understanding of the perceptions and behaviour of electricity consumers about the possible deployment of smart grids.

Our results indicate that Hong Kong consumers generally welcomed smart grid technologies and had a preference for energy saving, energy efficiency and renewable energy while they showed a high level of opposition to nuclear power. They displayed an interest in playing a much more informed and active role in energy decision-making, but they were sensitive to tariff increases. Motivations and barriers for consumers to support smart grid developments are also discussed. We conclude with a discussion of policy implications for effective consumer engagement. More

policy attention is needed on demand-side measures, introducing institutional and regulatory changes, and modifying relationships between consumers, the government and utilities.

INTRODUCTION

Impacts of climate change, gas price spikes and the renewed concerns about nuclear risks following the Fukushima accident have heightened the need to move away from current unsustainable energy systems. Smart grids, as a major innovative energy alternative, have received growing attention from policy makers and scholars. Smart grids are electricity networks that can integrate information technology into the grid (SGA, 2011; ETP, 2006). Smart grids can be instrumental in reducing carbon emissions, improving energy saving and efficiency, and integrating a broad range of generation and storage options including renewable energy. Smart grids therefore have been regarded as a key to both demand-side and supply-side management of energy systems (Executive Office, 2011; IEA, 2011).

Electricity consumers have the potential to play an important role in addressing climate change problems through the development of smart grid technologies. On the demand-side, well-informed and price-responsive consumers are expected to play a more active role in managing electricity consumption rather than being passive users only. Consumers could contribute to energy saving, energy efficiency and peak load shifts through using real-time electricity information and smart meters which are

linked with dynamic pricing systems (Executive Office, 2011; IEA, 2010a; Strbac, 2008). Consumers, for example, can connect smart appliances to the grid and respond to pricing signals and information, and alter their electricity consumption pattern by delaying consumption until off-peak periods when electricity is cheaper (Haney et al., 2009). On the supply-side, consumers could assume the role of electricity producers/ suppliers, through micro-generation technologies such as wind turbines and solar panels to generate electricity at the household and community levels (Nye et al., 2010).

The important role of consumers in sustainable energy management has been highlighted in a recent report published by the International Energy Agency (IEA) (IEA, 2009). In contrast to the overriding attention given to nuclear and other supply-side measures by the media and academics (IEA, 2010a), the IEA report argues that about half of our means for de-carbonising by 2030 would have to come from energy efficiency measures. Another quarter could be achieved through renewable and bio-fuels while nuclear and carbon capture and storage would contribute only 10% respectively.

Worldwide, a number of countries and cities have been making progress in smart

grids using different approaches and with various outcomes. The recent publication of the smart grid policy framework in the US (Executive Office, 2011) and the Smart Grid Roadmap launched by the Korean government are examples of such initiatives (MKE and KSGI, 2010; Mah et al., 2011).

Consumer participation in smart grid development is emerging. Japan's Smart Grid Community and Korea's Jeju Testbed Demonstration Project are some of the examples of this emerging movement (Ogawa, 2010; KSGI, 2011). In Hong Kong, about 400 households have participated in a smart grid pilot in a private housing estate (Cheung, 2011).

The potential benefits of smart grids can be considerable in terms of energy savings and the creation of new global and domestic markets (IEA, 2009). However, current electricity systems are characterised by the dominance of fossil fuels, the presence of centralised grid systems, and linear supplier-end user relationships in which consumers play a passive role in energy decision-making. The real issue is how the potential contribution of consumers in smart grid technologies can be realised and contributes to the transition towards a more sustainable energy future.

Smart grids look different from the current electricity systems in important ways. They require a transition of current electricity systems that are characterised by centralised, fossil-fuel based facilities to one that can incorporate decentralised system using more diverse energy sources as well as more price-sensitive and well-informed consumers (Nye et al., 2010). The transition would create electricity systems which enable consumers to make informed and empowered energy-related choices and make personal behavioural changes (DeWaters & Powers, 2011; ECME Consortium, 2010). Such systems also alter the provider-consumer relationships from the current one way to a two-way relationship in which consumers could assume the role of co-provider or "prosumer" in a more decentralised electricity system (Devine, 2007; Potter et al., 2009).

Such a transition therefore requires significant socio-institutional change, with implications for institutions and actors involved in market formation (Brown, 2009). Beyond studies on the technical aspects of smart grids (see for example Depuru et al., 2011), an emerging body of studies has discussed and examined a broad range of policy and governance issues concerning consumers in the context of smart grid-related technologies. Such issues include consumer perceptions (Devine, 2007), motivations (Leenheer et al., 2011; Vasconcelos, 2008), concerns (Gan, 2009;

Blumstein et al., 1980; Wiser, 2000), policy preferences (Curry et al., 2005), market impacts of different incentives schemes (Leenheer et al., 201)), and other governance issues such as empowering (Executive Office, 2011), power relationships, information sharing, loyalty, trust and accountability (Parag, 2009; Zio, 2011) and the attitude-behaviour gap (Litvine, 2011; Parag, 2009).

Amidst the growing body of smart grid studies, public opinion surveys on smart grid-related issues have been increasing. Those surveys on smart grids have focused on consumer awareness, knowledge levels, degree of concern (Business Wire, 2010; GE Energy, 2010; Wimberly, 2011), perceived motivations (OECD, 2011; Deloitte, 2011; Oracle, 2010), perceived barriers and risks (Oracle, 2010; Deloitte, 2011; Gan, 2009; Wiser, 2000) and willingness to pay (Deloitte, 2011; Oxfam, 2010). Some surveys focus on specific technologies or specific stakeholder groups. Surveys conducted by for example Leenheer et al. (2011) have examined consumer attitudes towards micro-generation while surveys conducted by for example Wimberly (2011) focus on households.

However, two major gaps in existing knowledge remain. First, the literature on the interactions between consumers and demand-side and supple-side-management has

remained relatively limited, and this is particularly so in the context of smart grid technologies and Asia. Second, public opinion surveys on smart grid-related issues have been growing but few are able to draw instructive policy implications from survey data. To partly fill this knowledge gap, this paper draws on a survey of Hong Kong's electricity consumers and assesses their perception and behaviour, and how they would respond to the possible deployment of smart grids in the future.

Hong Kong merits study for a number of reasons. Hong Kong is an atypical urban city that differs from other cities in many important ways. Hong Kong has no indigenous fossil-fuel resources. It does not have strong energy policies and tend to emphasise a policy of laissez faire in relation to energy-related environmental issues. The disincentive created by the Scheme of Control Agreements, the regulatory framework for the electricity sector which links the rates of return with fixed asset investment, to energy efficiency has also set Hong Kong apart from other urbanised cities. However, Hong Kong may serve as a policy laboratory for future cities where high-rise buildings have substantial potential for energy efficiency. The focus on consumer perceptions of smart grids in this study has relevance beyond Hong Kong as the involvement of households in energy efficiency has become a growing trend in many western and Asian cities such as New York, Seoul, Singapore where green growth and

green tech are underpinning new pathways of developments (Chua, 2012; City of New York, 2010; MKE and KSGI, 2010). Hong Kong's experience in smart grid development could therefore contribute to our understanding of how cities transit towards more sustainable future.

Hong Kong also merits scholarly and policy attention in the broader Chinese context. Hong Kong and its neighbouring Pearl River Delta have been given an important role by the central government to pioneer and act as a role model for low-carbon development in the country (NDRC, 2008; NDRC, 2010). China has occupied a central role in global climate change impacts and responses. The IEA has estimated that over 80% of the growth of world electricity demand will take place in China and other non-OECD countries by 2030 (IEA, 2009). China alone will be responsible for three-quarters of energy-related CO_2 emissions by 2030 (IEA, 2009). The experience learnt in Hong Kong can be useful for deriving policy recommendations for China and the global community.

In the rest of this paper, we will first highlight global trends in the involvement of consumers in smart grids and the latest developments in Hong Kong. We will then discuss some key theoretical issues relating to consumers in the context of smart grid

technologies. This is followed by a detailed discussion of our survey results. The final section discusses the policy implications of the findings.

CONSUMERS AND SMART GRIDS: GLOBAL TRENDS and HONG KONG CONTEXT

Global trends

Major initiatives on smart grids are emerging around the world as we noted in our earlier discussion. Consumer involvement and responses vary in these emerging smart grid initiatives. In the US, the emphasis is on smart metering and dynamic pricing (Executive Office, 2011). In Ontario, Canada, almost every home and small business has been equipped with a smart meter. More than 4.5 million smart meters have been installed and approximately 1.6 million customers have switched to time-of-use billing in Ontario (end 2010) (OSGF, 2011). In contrast, Europe places emphasis on decentralised electricity systems in which consumers have become “prosumers” who both produce and consume electricity (Potter et al., 2009). Those “prosumers” can sell electricity that they generate from micro-generation technologies such as wind and solar power at household and community levels (Klein, 2010; Ragwitz, 2010).

Consumer responses to smart grid developments also vary in a rapidly changing stakeholder landscape. While consumers in places such as Ontario are highly positive, some smart grids developments provoked public outcries, project delays and even withdrawal of policy support. Anecdotal evidence suggests that negative consumer responses have occurred in many places, in various forms and with different impacts (Table 1). While some local people blocked the development (Baker, 2011; Smart Grid News, 2011a), some required opt-out arrangements (Smart Grid News, 2011b) or even moratoria (Baker 2011; Smart Grid News, 2011a; Parkhurst, 2010). Consumers are concerned about a broad range of issues that span from costs, health and safety (Cassidy, 2011; Smart Grid News, 2010a; Smart Grid News, 2010b), data-sharing, privacy, fairness, involuntary remote disconnection, uneven distributional effects and the impacts on vulnerable groups such as the elderly or people who are less familiar with IT (Executive Office, 2011; Smart Grid Today, 2010a). Most reported smart-grid backslash took place in the US while similar trends of mistrust are emerging elsewhere such as in Korea (Mah et al., 2011) and Australia (DTF, 2011).

Table 1: Consumers' negative responses to smart grids

Place	Year	Consumers' responses and outcomes	Concerns
Bakersfield, California, US	2009	The "Bakersfield effect": smart meters blamed for dramatic increase in electricity bills (Gohn. B., 2010).	Alleged inaccuracies of smart meters
Texas, US	2010	Smart meters blamed for dramatic increase in electricity bills (Smart Grid Today, 2010a).	
Marin County, California, US	2010	Smart meter backlash continued with alleged health issues including headache and cancer. After public blocked the roads to meter installation, the County Board of Supervisors of Marin County approved a one-year moratorium on smart meter installation, joining smart meter bans in Fairfax and Santa Cruz Counties (Baker, D. R., 2011; Smart Grid News, 2011a).	Alleged health problems
Scarborough, Cape Elizabeth and Sanford, Maine, US	2011	In the state of Maine, the towns of Scarborough, Cape Elizabeth and Sanford passed moratoriums on smart meters due to health concerns (Parkhurst, 2010). Provisions for an opt-out of the smart meter were offered in Maine (Smart Grid News, 2011b).	
Maryland, US	2011	Maryland Public Utilities Commission rejected initial smart meter plan on a number of consumer related issues including the risk burden for consumers. An alternative plan was only accepted with strict new conditions (PSC, 2011).	Unfair distribution of costs, benefits and risks between consumers and utilities
Illinois, US	2011	Governor indicated to use veto against smart meter legislation under pressure of consumer groups as the proposal would shift the risk to customers, guarantee utilities double-digit profits, bypass regulatory processes and did not provide adequate protection for consumers (Sauer, 2011; Yeagle, 2011; Yount, 2011a; 2011b).	
Ontario, Canada	2010	Privacy Commissioner urges a halt to smart grid as for fear of backlash due to data breach; "Privacy by Design" principles were adopted (Smart Grid Today, 2010b).	Privacy
Victoria, Australia	2010-1	Indefinite moratorium on the roll-out of smart meters was announced in 2010 because of concerns that pensioners and the poor would be hardest hit by higher electricity prices (Austin, P., 2010). Smart meter installation has resumed while a review and public consultation is still ongoing (DTF, 2011).	Concerns for vulnerable groups
Victoria, Australia	2011	Following a spate of consumer complaints blaming smart meter for electric shocks, a research found that only one of the reported cases was linked to incorrect smart meter installation while 3,500 others were due to faults in existing wiring (Fyfe, 2011a; 2011b).	Safety

Hong Kong Context

Located on the southeast coast of China, Hong Kong has a population of 7 million people and an area of about 1,104 km^2 (CSD, 2010; HKTDC, 2010). Since it's handover from British to Chinese sovereignty under the "one country, two systems" model in 1997 (Holliday et al., 2002), it has been a Special Administrative Region of China which enjoys a relatively high degree of autonomy in executive, legislative, and judicial matters under the authority of China's central government (Conney, 1997).

The issues of climate impacts, energy security and nuclear risks have heightened the concerns among Hong Kong government and other stakeholders about how Hong Kong's fossil fuel-based electricity system can become more sustainable (Environment Bureau, 2010). The electricity system in Hong Kong is dominated by fossil fuels. In 2009, 54% of electricity in Hong Kong was generated by burning coal, while about 23% from burning natural gas and about 23% imported from the Mainland (Environment Bureau, 2010). Electricity consumption has experienced a gradual growth over the past decade as it increased approximately 14% from 131,000 Terajoule in 2000 to 149,000 Terajoule in 2009 (EMSD, 2011). Electricity consumption profile has also been stable over the past years. Commercial sector has

been the largest sector, accounted for about 65% of the total electricity consumed in this city in 2009. Residential sector is the second largest consumer, accounted for about 26% whilst industrial and transport sectors accounted for the remaining 9% in 2009 (EMSD, 2011). The modest growth in electricity consumption has been driven mostly by the commercial sector. Between 2000 and 2009, industrial consumption recorded a 26% increased whilst residential consumption remained relatively stable and industrial consumption experienced a 37% decrease (EMSD, 2011). Hong Kong's GHG emissions increased by 19% from 39.2 millions tonnes in 1990 to 46.7 million tonnes in 2005 (EPD, 2010) while the city's energy consumption grew by an average of 1.3% annually between 1995 and 2005 (Yau, 2008) and emitted about 42 million tonnes of CO_2 in 2008 (Environment Bureau, 2010).

It is in these climate change and energy contexts, Hong Kong has made limited progresses in the development of smart grids. Hong Kong has not formulated specific policy framework, plans and programmes for smart grid technologies. There are some R&D projects and small-scale community pilots conducted by universities and utilities (Cheung, 2011; Li & Yang, 2011). A smart meter pilot conducted in Lohas in Tseung Kwan O by China Light & Power Company is one of these initiatives (Cheung, 2011). There are also quite a number of smart grid companies providing IT

services and smart grid appliances in this city (Tsang, 2011). These initiatives however are relatively small in scale and limited in scope. Studies examining economic benefits and costs of the potential deployment of smart grids in Hong Kong have been lacking, although such studies could have generated important data upon which policy makers and other stakeholders can assess technological and policy options.

Although smart grid initiatives are minimal, several characteristics of Hong Kong people's perceptions of energy/ climate-related issues and recent trends in policy initiatives are noteworthy as they are key contextual factors which have created opportunities and barriers for smart grid developments.

First, there is a contrast between a high level of public concern of climate change issues and an energy policy-making system which is seen by many stakeholders as ineffective. A number of public opinion surveys have shown that climate change is a major concern for Hong Kong's public (HSBC, 2010; Oxfam, 2010; POP, 2008). In a major global study in 2010, climate change, for the first time, tops the list of Hong Kong people's concerns even ahead of economic stability (HSBC, 2010). However, the government's initiatives on combating climate change problems has been

criticised by NGOs and academics as inadequate and ineffective (see for example Leverett et al., 2007; Oxfam, 2010).

Second, although demand-side initiatives have taken place to reduce GHG emissions, advocacy for demand-side management has become more intensive, and it is particularly so in the wake of the Fukushima accident in Japan in March 2011. A comprehensive review of those demand-side initiatives is available elsewhere (see for example EPD, 2008). In opposition to the Hong Kong government's recent proposal to increase the use of nuclear power from the present 23% to 50% by 2020 as a key strategy to meet the carbon intensity reduction target of 50-60% by 2020 (Environment Bureau, 2010), major local green groups including WWF and Greenpeace China have actively lobbied for much more aggressive policies for demand-side measures as an alternative to using more nuclear (Greenpeace, 2010a; Legco, 2011). For instance, based on a study conducted jointly with Ove Arup & Partners Hong Kong, WWF argued that Hong Kong could achieve a 37% reduction in carbon emissions (using 2005 as base year) by 2020 without using more nuclear power, in which 60% of the carbon reductions could come from demand side management (Legco, 2011).

Third, on the supply side, although some progress have also been made (EPD, 2008), Hong Kong's electricity system has not moved away from the status quo in significant ways. The electricity sector has remained fossil fuel-based, dominating by two monopolies while the development of renewable energy is minimal. The Scheme of Control Agreements (SCA) are regulatory agreements signed between the government and the two local monopolized utilities, China Light and Power (CLP) and Hongkong Electric (HKE). SCAs, which were revised in 2008 and will expire in 2018, provide incentives for renewable energy investment but those incentives are relatively minimal – the permitted rate of return of investment for renewable energy facilities is set at 11%, which is modestly higher than that for other fixed assets which is set at 9.99% (Environment Bureau, 2008).

At present, renewables amounted to 0.12 TWh in 2008, representing a minute 0.4% of Hong Kong's total primary energy supply (IEA, 2010b). The government's proposed renewable target of 3-4% of the city's electricity supply by 2020 has been seen by some green groups as too modest (Greenpeace, 2010a). The two local power companies have committed to setting up their own pilot commercial-scale offshore wind farms with a planned total installed capacity of 300 MW (Environment Bureau, 2010). However, small-scale renewable energy facilitates at household and

community levels which has a potential to contribute to the decentralised aspect of smart grids have negligible developments. A few small-scale renewable energy projects have been undertaken by the utilities, the government, private developers and schools (Close & Chan, 2010; EMSD, 2010). However most of them are not connected to grids with a few exceptions such as the Ma Wan Primary School (EMSD, 2010).

Fourth, in terms of consumer engagement, residential consumers generally have a negligible role in informed participation in consumption decision-making. Two major energy management programmes introduced in recent years, a three-year rebate programme implemented by the two utilities back in the early 2000s (between 2000 and 2003) (Legco, 2002) and the energy audit programme introduced more recently in the revised 2008 SCAs, all excluded residential customers in the programmes, covering only industrial and commercial customers (Environment Bureau, 2008).

Furthermore, some critical issues relating to consumer engagement and smart grid developments were raised in public debate in recent years but the discussion has failed to bring major changes to the existing electricity regime. Those issues include the role of consumers, tariff reforms (see for example (Luk, 2005), and the broader

issue of regulatory reforms (Lo, 2008b; Luk, 2007). For example, a proposal to introduce a time-of-use pricing system – a kind of dynamic pricing system that can facilitate consumers to respond to price signals and subsequently facilitate peak load shift (Lo, 2008a) – was raised in a 3-year DSM programme implemented by the two utilities between 2000 and 2003 (Legco, 1999), but this was abandoned in the final programme mainly because of the opposition from the Legislative Council (LegCo) (Legco, 2002). Incentive earnings were also once proposed to be provided to the two utilities for energy saving, but this proposal failed to gain support from LegCo. LegCo was skeptical about legitimising extra profits for the utilities (Lo, 2008b).

To sum up, the opportunities and barriers for smart grid deployment in Hong Kong have been shaped by a dynamic stakeholder landscape in which the government, business, consumers and NGOs interact. It is important to note that the contrast between a high level of public concern of climate issues and an energy policy-making system which is seen as ineffective, in combination with the criticism on the current energy initiatives have driven Hong Kong towards a general consensus that changes in energy policies are needed. While smart grids may present opportunities for Hong Kong to address climate change issues, the negligible role played by consumers and the political sensitivity relating to regulatory reforms and tariff changes in Hong

Kong are the major political and institutional barriers for smart grid development.

OBJECTIVES AND METHODOLOGY

Based on the theoretical insights and our understanding on the contextual characteristics of Hong Kong, the objective of our survey is to understand the perceptions and behaviour of Hong Kong's electricity consumers regarding the possible deployment of smart grids in the future. We also aim to generate data about public attitudes to inform policy makers, the business community and other stakeholders for decision-making.

A telephone survey was conducted between 17 May and 24 May, 2011, using a random sample of 505 respondents drawn from Hong Kong residents of age 18 or above who speak Cantonese. The overall response rate is 69.0%. The standard sampling error for percentages based on this sample was less than 2.2 percentage points. The sampling error for percentages was less than plus/ minus 4.4 percentage points at 95% confidence level.

This study has adopted several measures to minimize sampling bias. Firstly, telephone numbers were drawn randomly from the residential telephone directories published by

the Hong Kong government as “seed numbers”. Based on this set of telephone numbers, another set of numbers was generated using the “plus/minus one/two” method to capture the unlisted numbers. Duplicated numbers from the two sets were filtered, and the remaining numbers were mixed in random to derive the final telephone sample for this study. Secondly, to enhance the representativeness of the findings, the raw data collected have been adjusted accordingly to provisional data (end 2010) obtained from the Census and Statistics Department in relation to the gender-age distribution of the Hong Kong population. Our analysis is based on the weighted sample. Details of the sampling method is reported in Chung et al., 2011.

The questionnaire was developed by the authors based on a review of the academic literature and surveys in the areas of energy, climate change, environment and smart grids in the global and Hong Kong contexts. There are five sections in the questionnaire. The questions covered respondents’ view on the important aspects of electricity supply, respondents’ assessment of the performance of the existing electricity supply system, respondents’ acceptance of smart grid technologies, respondents’ behaviour relating to smart grid technologies, and socio-demographic characteristics.

Since the development of smart grids in Hong Kong has been very limited, we expect most Hong Kong people are unfamiliar with the term “smart grid” and have no direct involvement in such developments. We therefore deliberately avoided the use of the term “smart grid” in constructing the questions. Rather, we asked for views on different key components and aspects of smart grid development. The combined data from this survey can be interpreted as an indication of the respondents’ perception of smart grid technologies.

To ensure valid and reliable samples we commissioned the Public Opinion Programme at The University of Hong Kong, a research institute which has substantial experience of survey research in Hong Kong, to administer the telephone survey and conduct data analysis. Pilot testing was conducted and no major changes were required.

SURVEY RESULTS

1. What are electricity consumer perceptions of the performance of the electricity suppliers in Hong Kong

Previous studies conducted by for example Lo (2008a, b) have suggested that the dominant concerns of electricity policy in Hong Kong are reliability and affordability while environmental aspects have been given less priority. A public opinion survey conducted by the Hong Kong Census and Statistics Department (CSD) in 2004 produced similar findings. In the CSD survey, some 49.7% and 34.5% of the respondents considered a "reliable and stable electricity supply" and "low electricity tariff" as "the most important aspect of electricity supply" respectively while only a small number of respondents stated that "availability of choice of electricity suppliers" (6.8%) and "more environmentally sustainable energy sources" (3.7%) as "the most important aspect of electricity supply" (CSD, 2004).

Our results complement the existing data by showing that while most Hong Kong people considered reliability of supply and tariff as important, they also considered broader environmental and social issues (including risk and safety and impacts on community) as important. 93.5%, 96.0% and 83.2% respectively of the respondents consider "impacts on the environment", "risk and safety such as health risks related to nuclear explosion" and "impacts on community such as community discontent to new nuclear power plants" as important (Figure 1).

A possible explanation for the contrasting results between this present survey and the CSD survey in 2004 is because of the way how the questions were constructed. By asking which aspects are "important" rather than "most important", our results complement the previous studies that although environmental and social concerns are not the "most" important aspects of electricity supply perceived by respondents, but these are still perceived as "important".

Another notable finding is that the respondents also regarded the choice of electricity suppliers (76.6%) and electricity sources such as renewable electricity (81.4%) as being important, although these options are not currently available (Figure 1).

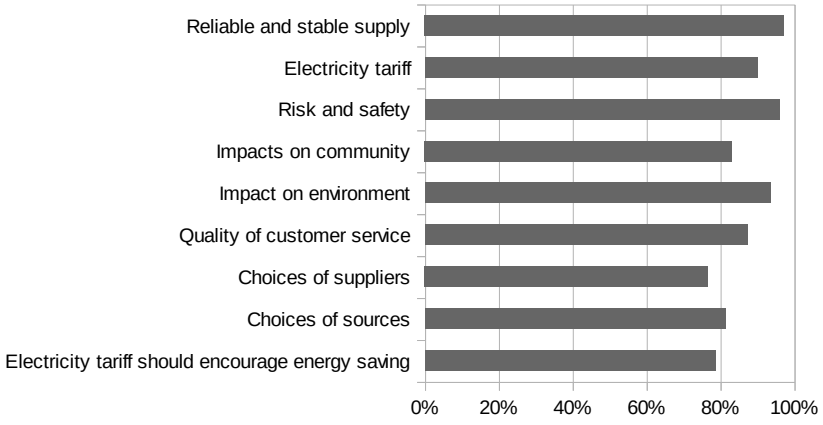

Figure 1. Summary of responses to the question "To what extent do you agree the following features of electricity supply are important?" (Expressed as aggregate percentage of 'strongly agree' and 'agree' responses).

When asked to assess the performance of their electricity suppliers, our respondents

agreed that their electricity suppliers provide reliable (95.1%) and affordable (79.5%) electricity, but they were less satisfied with their environmental performance. Only 48.0% and 42.9% of the respondents agreed that their electricity suppliers were committed to energy efficiency and environmental improvement respectively (Figure 2).

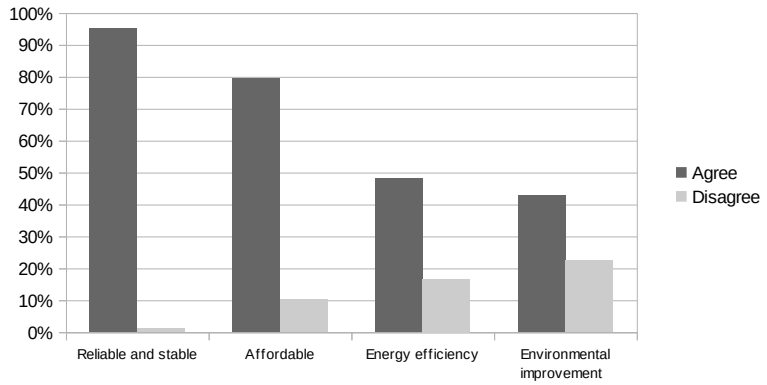

Figure 2. Summary of responses to the question “To what extent do you agree with the following statements?” a) My electricity supplier provides a reliable and stable supply of electricity. b) My electricity supplier provides affordable electricity. c) My electricity supplier is committed to energy efficiency. d) My electricity supplier is committed to environmental improvement. (Expressed as aggregate percentage of 'strongly agree', 'agree', and 'disagree', 'strongly disagree' responses).

2. What are Hong Kong consumer preference on energy approaches to addressing climate change impacts

This survey asked the respondents their preferences concerning energy choices. Our respondents showed a preference for energy saving, energy efficiency and renewable

energy while indicating a high level of opposition to nuclear power. Among major energy choices, our respondents were most supportive of "reduce energy consumption or improve energy efficiency" (93.2%) and "use more renewable energy" (92.6%). In contrast, some 62.1% of the respondents opposed using more nuclear energy while only 12.4% of our respondents supported its expanded use (Figure 3).

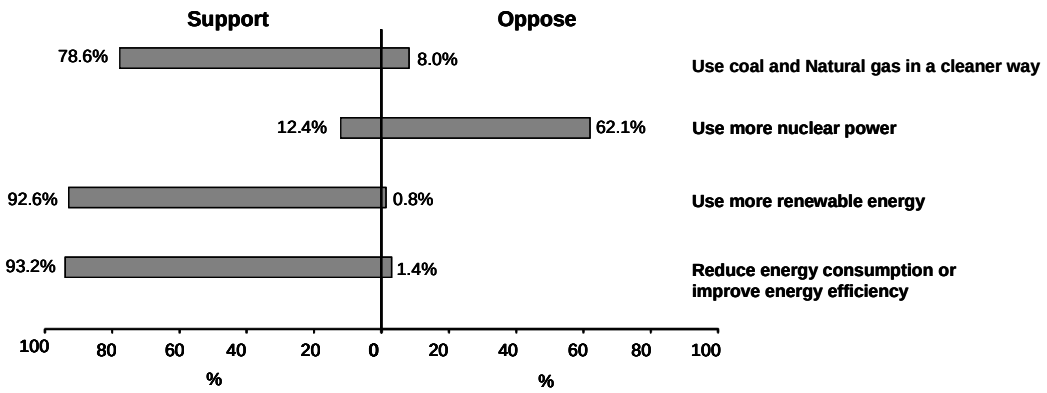

Figure 3. Summary of responses to the question "To reduce GHG emissions in Hong Kong a number of energy options are available. Which of the following options would you support?" (Expressed as aggregate percentage of 'strongly agree', "agree", and 'disagree', 'strongly disagree' responses).

Our results should be interpreted in consideration of several contextual factors. First, this survey was conducted in May 2011 - about two months after the Fukushima incident happened in Japan. Our findings relating to the high level of opposition to nuclear power may reflect the impacts of the nuclear incident on the perception of Hong Kong people. Our findings appear to be in line with those conducted with Greenpeace months before and after the Fukushima incident. Greenpeace conducted

two polls on Hong Kong people's perception on nuclear power – one in November 2010 and one in April 2011 (Greenpeace, 2010b, 2011). The findings of the two Greenpeace surveys suggest that a substantial proportion of Hong Kong people who were undecided to support or oppose nuclear energy have shifted into the opposition group following the incident. In relation to the government's proposal to use more nuclear by 2020, whereas 27% of the respondents opposed the proposal and up to 38% undecided in the November 2010 survey, the April 2011 survey showed a decline in the acceptance of nuclear energy, with up to 53% of the respondents opposing the proposal and only 22% said they had no opinion.

Another contextual factor to be considered is that according to a global survey conducted in 2008, Hong Kong people were less supportive of nuclear power than their peers in other economies including China and Taiwan (WPO, 2008a). That survey reported that 35% of Hong Kong respondents preferred less emphasis on building more nuclear power plants while 22% thought it should be more. This puts Hong Kong on the conservative side to nuclear as the average of 21 economies showed a number of 30% and 40% of the corresponding options. The public perception of nuclear power in Hong Kong should also be interpreted in the consideration of the context of the Daya Bay anti-nuclear movement in Hong Kong

back in the 1980s (Hsiao et al., 1999).

3. What is the acceptability of smart grid technologies or techniques of Hong Kong consumers?

To explore the acceptability of smart grid technologies in Hong Kong, the survey asked about three key smart grid technologies and techniques: modifying electricity consumption patterns, generating renewable energy at home and buying green electricity.

Our results suggest that many respondents welcomed the possibilities smart grid technologies may offer. If such smart grid technologies and techniques become available in Hong Kong, respondents were interested to take part in demand-side management, being a “prosumer” by generating renewable electricity at home, and buying green electricity. 84.1% of the respondents said they would change their daily pattern of electricity use, for example by washing clothes during the night rather than in daytime if electricity is cheaper. 67.3% would fit their homes with solar panels or other renewable energy-generating devices if they can sell surplus renewable electricity back to power companies. 81.5% would buy green electricity (Figure 4).

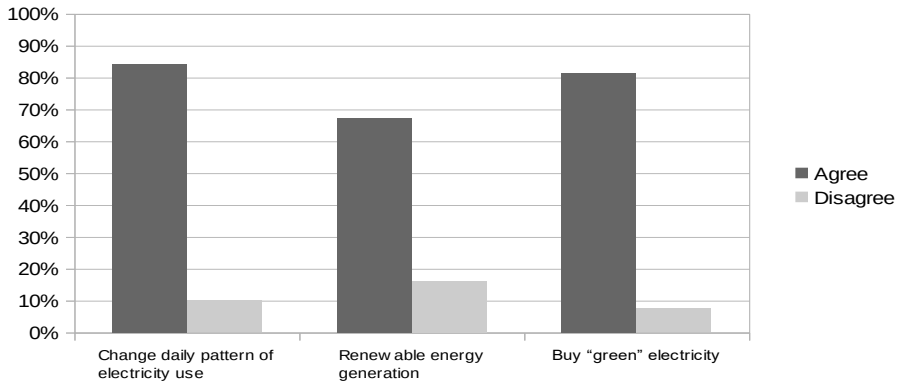

Figure 4. Summary of responses to the question “If these options are available in Hong Kong, to what extent do you agree with the following statements?” a) I woud change my daily pattern of electricity use if that would save me money. For example by washing my clothes during the night rather than the daytime if electricity is cheaper at night. b) I would fit my home with renewable energy-generating devices such as solar panels if I can sell my surplus renewable electricity back to my electricity supplier. c) I would like to buy “green” electricity (e.g. electricity generated from renewable energy). (Expressed as aggregate percentage of 'strongly agree', 'agree', and 'disagree', 'strongly disagree' responses).

While our results are in line with many consumer surveys which show very positive attitudes towards renewable energy and green electricity (see for example WPO, 2008a, b), our results however should be interpreted with caution. It is noteworthy that renewable energy in urban settings such as in the form of building-integrated solar power has been emerging (see for example Seng et al., 2008), but most of these initiatives are in the R&D stage and are small in scale. In the context of Hong Kong,

the deployment of renewable would need to overcome major problems of physical and cost constraints, and that would also require major institutional changes (CDM, 2002).

Regarding our result relating to purchasing green electricity, the result should be interpreted in a context in which the "attitude–behaviour" gaps commonly exist (Litvine, 2011). It is noteworthy that the share of consumers actually purchasing green electricity is still in the single-digit percent range in most countries (Litvine, 2011), with a notable exception in the Netherlands where about 13% of residential electricity consumers purchased green power (Bird et al., 2002; Diaz-Rainey & Tzavara, 2009). It is also important to note that even though green electricity is cheaper than "grey" energy sources at a range of 1.4 to 5.0% less in some countries including the UK, Belgium, Luxembourg and Portugal, those lower rates did not stimulate high uptake of green electricity (ECME Consortium, 2010).

These observations suggest to what extent Hong Kong consumers would realize the options of being "prosumers" and purchasing green electricity would depend on factors that extend beyond physical, economic and technological constraints. Other factors that would also be critical include market failures, institutional barriers, social

norms, perceived personal responsibility for the issue, and the felt ability to affect the outcome in a positive way (Ek, 2008; Litvine, 2011; Sovacool, 2009).

4. How Hong Kong consumers perceive tariff changes and their preferences regarding dynamic pricing options?

The survey also explored perceptions of dynamic pricing systems, which is a key regulatory and pricing element commonly adopted elsewhere to stimulate demand-responses (Faruqui et al., 2010). Currently, Hong Kong has progressive tariff systems (CLP, 2010; HEC, 2011). It is in these contexts that our results show that the respondents are sensitive to possible tariff increases but they tend to support a more dynamic tariff structure.

A number of observations relating to electricity prices should be noted. Our results show that generally Hong Kong people considered that electricity is affordable (79.5% agreed that their electricity suppliers provide affordable electricity). They also considered that the present electricity prices are high enough to deter wastage of electricity. 53.8% of the respondents disagreed that it was because electricity was not expensive that they would not explore ways or take action to reduce electricity use

while only 30.0% agreed so. It is important to note that the respondents were sensitive to tariff increase. A majority of the respondents (71.0%) disagreed that electricity prices should be raised to promote energy saving.

However, the respondents appeared to be open-minded about the options to differentiate heavy and low users, and peak-times and off peak-times users. 81.6% of the respondents agreed that heavy electricity-users should pay higher prices than low users to promote energy saving while 60.0% of the respondents agreed that higher tariffs should be charged to peak-times users. Among these two dynamic pricing options, it is noteworthy that the suggestion of differentiating peak/ off-peak users received less support from the respondents. In fact, quite a substantial number of respondents (26.3%) opposed a tariff system that charges peak-times users more (Figure 5). A possible explanation for this may be some respondents are themselves peak-times users and they are more sensitive to this change in tariff system.

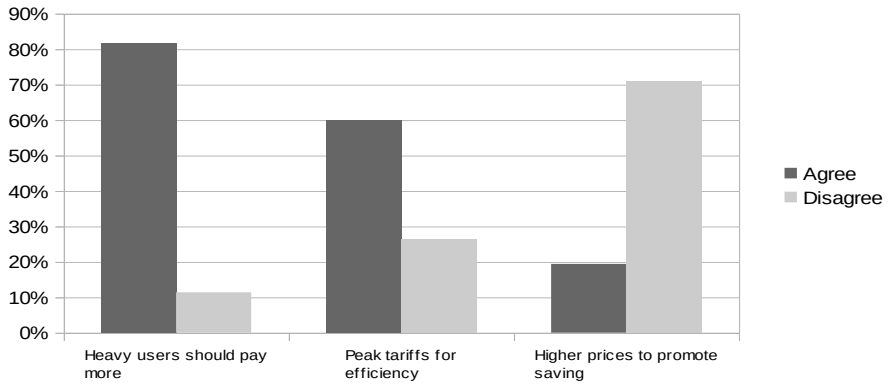

Figure 5. Summary of responses to the question "To what extent do you agree with the following statements?" a) Heavy electricity-users should pay higher prices than low users to promote energy saving. b) Higher tariffs should be charged to peak-times users and lower tariff to off peak-times users, if this can make our electrical systems operate more efficiently. c) Electricity prices should be raised to promote energy savings. (Expressed as aggregate percentage of 'strongly agree', 'agree', and 'disagree', 'strongly disagree' responses).

5. What are the factors that Hong Kong consumers think are important to provide incentives to support or take part in smart grid developments?

Demand-side management is a key component of smart grid technologies. The survey therefore asked respondents about their motivation for reducing electricity use as a way to better understand why Hong Kong consumers may support smart grid developments.

Our results show that environmental benefits (97.4% of respondents perceived this as an important motivation), the availability of energy efficiency labels (94.6%), money

saving (93.4%), the availability of energy efficient appliance in the market (81.9%), and social norms (52.7%) were some of the key motivating factors for Hong Kong people to reduce energy use (Figure 6). Our results are generally in line with those reported in other studies (OECD, 2011; Farhar et al., 1980; Blumstein et al., 1980).

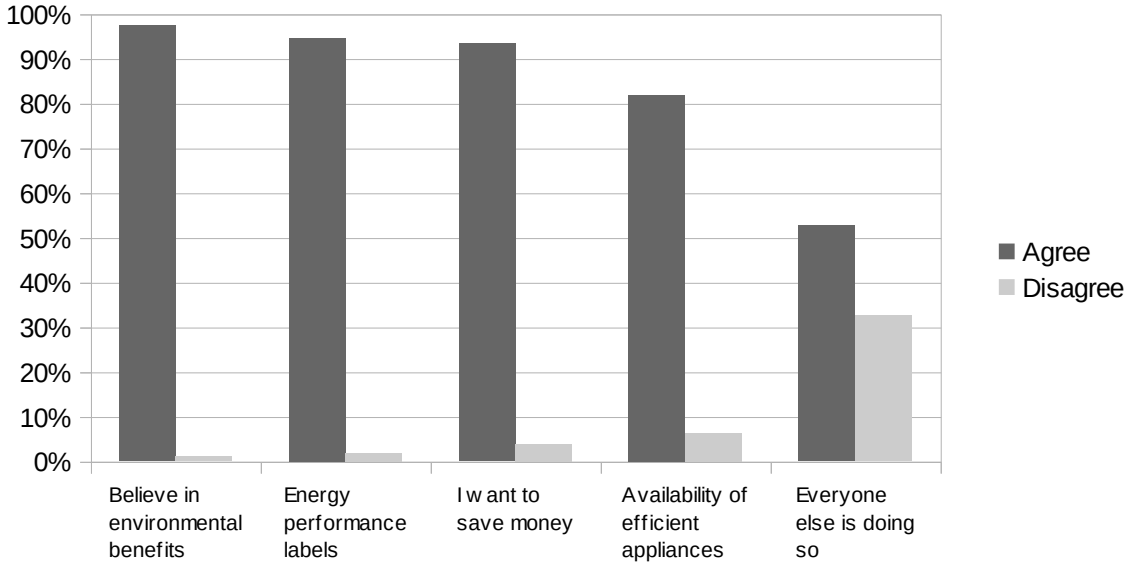

Figure 6. Summary of responses to the question "To what extent do you agree with the following factors are important in motivating you to reduce electricity use?" a) I believe this can bring environmental benefits. b) Energy performance of appliances is now indicated on specific labels and helped me to choose which one has the best energy performance. c) I want to save money. d) Energy-efficient appliances such as fridges are available. e) Everyone else is doing so and I do not like to be old fashioned or look bad. (Expressed as aggregate percentage of 'strongly agree', 'agree', and 'disagree', 'strongly disagree' responses).

6. What are the barriers that Hong Kong consumers think are important to discourage them to support smart grid developments?

Our respondents did not believe that major barriers to reduce electricity use exist. The

three main factors that respondents agreed as reasons for them not to take action to reduce electricity use are the belief that personal action will not make a difference to global climate change (43.9%), lack of information (30.8%) and electricity prices are not expensive (30.0%) (Figure 7).

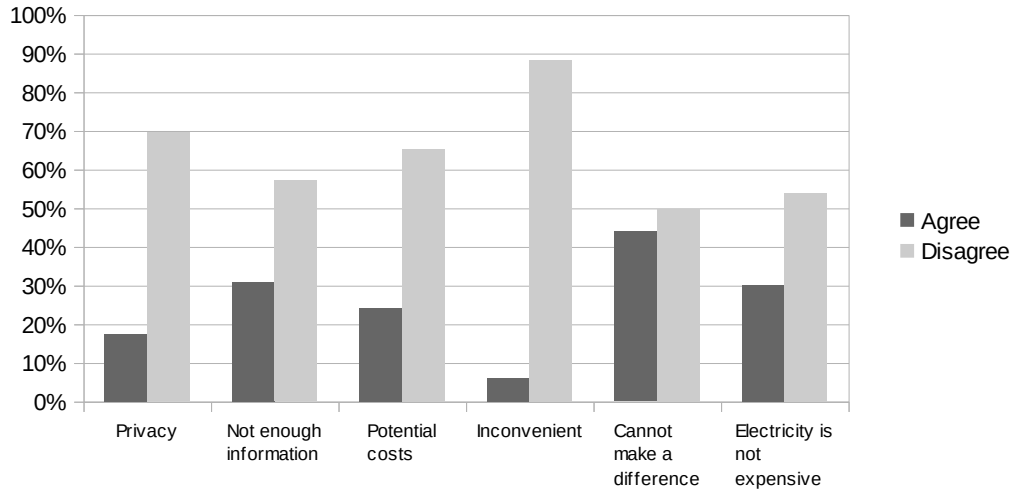

Figure 7. Summary of responses to the statement "I would *not* like to explore ways or take action to reduce my electricity use because: a) Electricity is not expensive. b) I don't think my personal action will make a difference to global climate change. c) I think it will be inconvenient and/or time consuming. d) I think it will cost me money. e) I don't have enough information to do it effectively. f) I am concerned that my electricity supplier would threaten personal privacy." (Expressed as aggregate percentage of 'strongly agree', 'agree', and 'disagree', 'strongly disagree' responses).

It is noteworthy that barriers which have been identified in a number of studies conducted elsewhere (Farhar et al., 1980; Gan, 2009; Wiser, 2000) were not perceived as barriers by our respondents. Inconvenience (88.2% of the respondents disagree this not as a barrier), privacy (69.5%), cost (65.2%) and lack of information (57.1%) were

not regarded by most respondents as barriers to energy saving in Hong Kong (Figure 7).

A notable finding is that in contrast with the more reluctant attitudes on smart grids because of privacy issues found in the western studies (see for example SGCC, 2011), our respondents did not express the same kind of concern about privacy. However, one possible explanation for this difference is that Hong Kong respondents are not aware of the privacy issues involved if detailed data of their daily electricity use are collected and utilised by or beyond their electricity supplier.

7. How Hong Kong consumers perceive changes that could be made for smart grids? Who should take action?

To understand the changes that need to be made to facilitate the introduction of smart grid technologies, this survey asked the respondents their perceived personal responsibility for the issue and their perceived ability to affect the outcome in a positive way.

Our results show two main patterns. The first is that Hong Kong respondents appear to be strong believers in their own ability to combat global climate change compared to respondents surveyed in other economies. About half (49.8%) of our respondents stated that they disagreed that their personal action will not make a difference to global climate change. This result appears to contradict other studies in the west which found a perception of low individual efficacy that people believe climate change is too complex and large a problem for individuals alone to address (Bickerstaff et al., 2008; Lorenzoni and Pidgeon, 2006; Pidgeon et al., 2008). Our finding is also in line with a study conducted by Oxfam (Hong Kong) in 2010 which found that most Hong Kong people stated that they have taken action to help combat climate change (Oxfam, 2010).

Another pattern evident in our results is that the respondents welcomed opportunities to play a more active role in managing their electricity consumption. Our results show that the respondents would like to be better informed. 91.3%, 74.7% and 67.5% of the respondents stated that they think their electricity bills should show their monthly electricity use over the past year (so that they can check if they have used more or less electricity), how much of their electricity is generated by different energy sources, and whether they have used more or less electricity when compared with the average user

(Figure 8).

In addition to being better informed, the respondents were also interested in taking personal action. As we noted in earlier discussion, they would welcome opportunities to try smart grid technologies or techniques if these options become available in Hong Kong. Furthermore, most respondents reported that they have practised some forms of residential energy conservation. However, it is noteworthy that most respondents did not practise energy conservation behaviour on a daily basis. Less than two-fifth (37.2%) of respondents "always" choose energy saving models for more efficient use of electricity. On the other hand, only 34.1% and 26.4% of the respondents "always" switch off electrical appliances and use air-conditioners in more energy efficient ways (Figure 9).

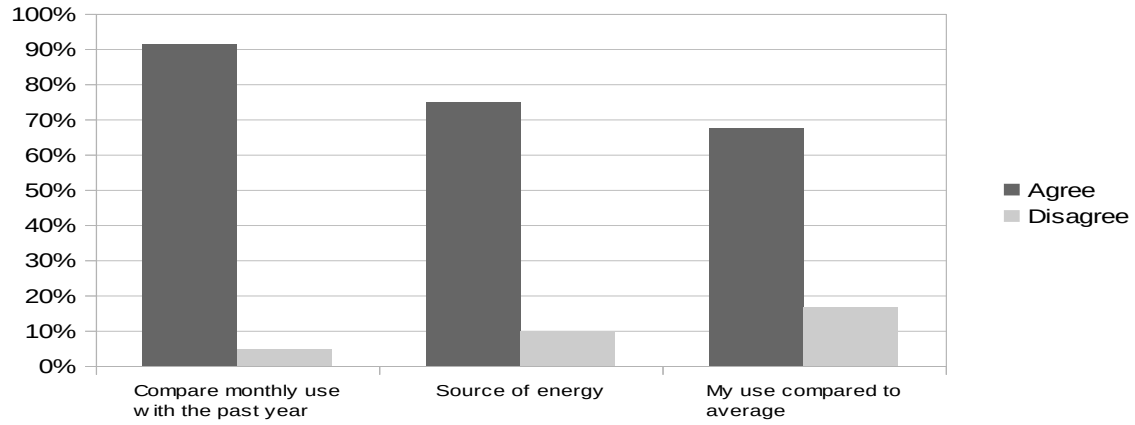

Figure 8. Summary of responses to the question "To which extent do you agree that the following information should be provided in your electricity bills?" a) My monthly electricity use in the past year so that I can check whether I have used more or less electricity. b) How much of my electricity is generated by nuclear/coal or other energy sources. c) Whether I have used more or less electricity when

compared with an average user. (Expressed as aggregate percentage of 'strongly agree', 'agree', and 'disagree', 'strongly disagree' responses).

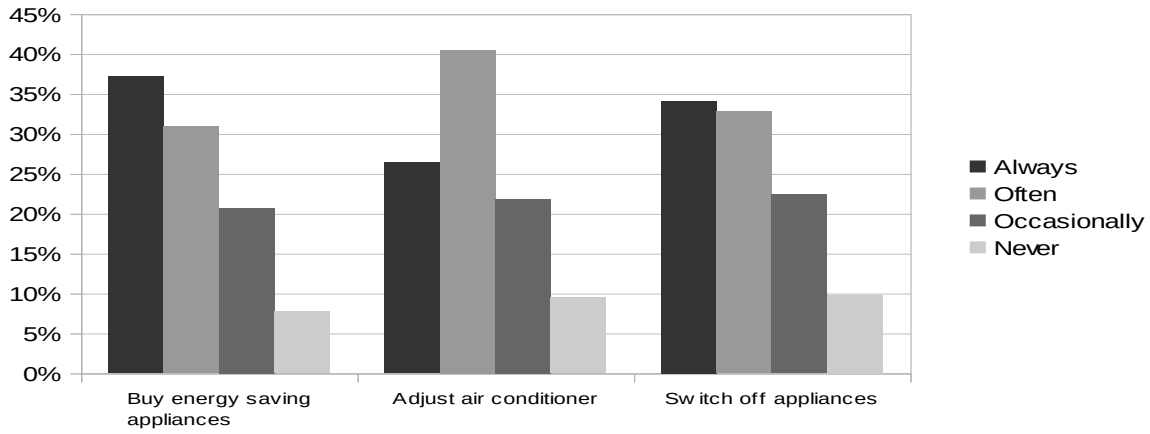

Figure 9. Summary of responses to the question "Which of the following actions have you done in the past one year?" a) When buying electrical appliances, I chose energy saving models. b) I switch off my electrical appliances e.g. TV and computers instead of keeping them in stand-by mode. c) I use my air-conditioner less often or set the temperature higher.

8. Relationships between respondents' socio-economic characteristics and their acceptability of smart grid technologies and policies

Cross-table analysis was conducted for some of the questions asked in this survey to provide insights into differences in acceptance of smart grid technologies and pricing policies and their relationship with socio-economic characteristics of the respondents. The cross-table analysis was conducted between three socio-economic characteristics (income, residence ownership - whether they own or rent their house, and their residence type – e.g. public or private housing) and two themes with a total of six

questions. The first theme is related to their perception of some key elements of smart grid technologies, and includes three specific questions concerning their perception on changing their pattern of electricity use, fitting their home with renewable energy-generating devices and buying "green" electricity. The second theme is related to their perception on tariff changes, and includes three specific questions about whether electricity prices should be raised to promote energy saving, whether heavy users and low-users should pay different tariffs, and whether peak users and off peak-user tariff should have differentiated tariff.

The results of a Chi-Square analysis suggests that there is no significant relationship between specific socio-economic characteristics and the responses of all of the six questions but one – which ask their perception on electricity tariff – "electricity prices should be raised to promote energy saving".[1]

These results highlight two main aspects of the acceptability of smart grid technologies and pricing policies. First, our results suggest that Hong Kong consumers with different socio-economic characteristics, specifically in terms of their income groups, residence ownership and residence type, hold similar perceptions on

[1] Chi-Square value <.05 indicates there is relationship.

changing pattern of electricity use, fitting their home with renewable energy-generating devices and buying "green" electricity. They also hold similar views on whether differentiated tariffs should be provided to heavy and low-users, and to peak and off-peak users.

Second, the results suggest that differences in the perception on "whether electricity prices should be raised to promote energy saving" *is* related to socio-economic characteristics. High-income groups (HK$40,001 or above) (Table 2), respondents who own their home (Table 3), and respondents who live in private housing are likely to disagree that electricity prices should be raised to promote energy saving (Table 4).

Table 2: Responses of different income groups to the question "whether electricity pricings should be raised to promote energy saving?"

Income Groups	**HK$10,000 or below**	**HK$10,001-40,000**	**HK$40,001 or above**	Total
Disagree	31.8%	36.7%	44.3%	37.3%
Strongly disagree	38.1%	35.1%	24.3%	33.4%

Pearson Chi-Square: 0.041 (P<.05)

Table 3: Responses of respondents with different resident ownership to the question "whether electricity pricings should be raised to promote energy saving?"

Residence Ownership	**Owned Flat**	**Rented Flat**	Total
Disagree	40.6%	35.4%	38.4%
Strongly disagree	29.9%	37.0%	32.9%

Pearson Chi-Square: 0.031 (P<.05)

Table 4: Responses of respondents with different residence type to the question "whether electricity pricings should be raised to promote energy saving?"

Residence Type	**Public housing**	**Private**	**Others**	Total
Disagree	30.2%	41.6%	42.7%	37.9%
Strongly disagree	40.4%	32.5%	22.6%	33.1%

Pearson Chi-Square: 0.030 (P<.05)

CONCLUSION AND POLICY IMPLICATIONS FOR CONSUMER ENGAGEMENT

Smart grid technologies may be one mechanism to facilitate fundamental changes in current energy systems which are not sustainable. This study, to our knowledge, is the first public opinion survey carried out in Hong Kong focusing on smart grid technologies. Our findings supplement the emerging but limited body of smart grid literature by highlighting the socio-political and institutional aspects of smart grid technologies. We partly filled the gap about the perception, motivations, concerns, and policy preferences relating to smart grid technologies. Specifically, this survey has provided an improved understanding of how consumers perceive, and how they may respond to the opportunities that smart grid technologies may offer. We situated the analysis of Hong Kong data in the broader global context in which consumer concerns and outcry have affected the scale and pathway of smart grid deployment (as shown in

Table 1). By providing new empirical data from an important Asian city, our analysis therefore contributes to identifying patterns and trends of those key issues in the context of a rapidly changing stakeholder landscape. Our contribution is particularly instructive because the literature on smart grid tends to focus on the technical aspects and in the western context, and the literature on non-technical aspects and in the Asian context is still lacking.

Our results have shown that respondents were supportive of smart grid technologies as a solution to climate change and energy problems. They tended to prefer energy saving/ efficiency and renewable energy to address climate change problems. They also showed a high level of opposition to nuclear energy, which may reflect a heightened concern on nuclear risks following the Fukushima incident in Japan. The respondents generally welcomed and were interested to try smart grid technologies and techniques including changing their electricity consumption pattern in respond to pricing signals, being a “prosumer” and buying green electricity.

In relation to the issue of tariff changes, our results highlighted the complexity and sensitivity of the issues involved. The respondents were sensitive to tariff increases. Most respondents disagreed with tariff increases to encourage electricity saving. But

most of them tended to support a more dynamic tariff system to encourage electricity saving. Most of them agreed that tariffs should be differentiated among heavy/ low-users, and also among peak/ off-peak times users. They also welcome the opportunities to be better informed.

Our results also showed that environmental benefits, money saving and the availability of energy efficiency labels and appliances were some of the key motivations for Hong Kong consumers to support smart grid technologies. On the other hand, it is interesting to note that the respondents perceived that there was no major barrier for them to support smart grids. Barriers commonly identified in the western literature, including privacy and inconvenience appeared to be a non-issue in the Hong Kong context, although a possible explanation for this is that Hong Kong consumers are not aware at present of the potential problems that may emerge when smart grid technologies develop in Hong Kong.

A number of policy recommendations for consumer engagement can be derived from these findings. First, this survey suggests that attention should be placed on demand-side measures in which well-informed, price-sensitive and empowered electricity consumers have the potential to play a much more active role through

smart grid technologies and techniques. Our findings suggest that consumers seem to welcome opportunities to actively engage with their electricity suppliers. They are looking for more information from their electricity bills, more choice on energy sources, and would like to try new technologies and demand-side management strategies that smart grids may offer.

Second, in order to facilitate consumer engagement, the government and the utilities will have an important role to play in developing new pricing mechanisms. Dynamic pricing would require new institutional arrangements so that adequate market signals are given to consumer to stimulate demand responses and to shift peak load. Our findings have highlighted the complexity and sensitivity of the pricing issue in the context of smart grids. It is noteworthy that although a majority of the respondents support dynamic pricing options such as those which differentiates heavy and low-users, and peak-time and off peak-time users, they are sensitive to tariff increase in general. Policy-makers need to take into account the sensitivity of the tariff issue when they design new tariff systems in order to avoid smart-grid backslash as experienced in the US. In particular, effective communication should be in place to ensure that the public will be well informed about the two sides of dynamic pricing – while dynamic pricing sets higher price for peak-time consumption, it sets lower

prices for off peak-time consumption and therefore has the potential benefit of price reduction (Albadi and El-Saadany, 2008).

For the utilities, engaging consumers may represent a new area for business growth and as a strategy to meet regulatory and environmental targets and expectations. This may be particularly so as our results show that although the respondents were satisfied with the two electricity suppliers as far as supply reliability and affordability are concerned, they were less satisfied with the suppliers' performance on energy efficiency and environmental improvement. Our respondents also indicated that choices of electricity suppliers and electricity sources such as renewable energy are important, although currently those options are not available in Hong Kong. These findings highlight the opportunities for Hong Kong consumers to catalyse changes in utilities for smart grid development.

However, to capitalise on this potential opportunity, utilities may need to play an important role in socio-institutional changes and market formation (Brown, 2009). An issue of concern is the potential problem of a low level of understanding and knowledge of the complexity of smart grid technologies and the implications to issues such as privacy. The two monopolised utilities in Hong Kong would need to be more

innovative in developing educational, billing, and marketing programmes in order to more effectively educate, empower and engage consumers through better information provision and with infrastructural support. Our findings showed that Hong Kong consumers would like to be better informed, and they welcomed opportunities to take personal action and try some smart grid technologies. Experiences of consumer engagement as reported elsewhere (see for example Hargreaves et al., 2010; and Pidgeon et al., 2008) have shown that how to visualise the potential costs of not taking action to address global climate issues and the potential benefits of energy saving is a key element of successful consumer engagement programmes.

The findings of this study are city- (Hong Kong) and technology-(smart grids) specific. However, Hong Kong shares with Singapore, Tokyo, New York and many other compact cities some general characteristics such as high energy consumption, a physical built environment dominated by high-rise buildings, high residential densities and a high degree of information technology applications (Kamal-Chaoui et al., 2009). We therefore expect that the findings can be generalised at least to some extent to other compact cities.

Our findings have a number of limitations. Because the sample size is relatively small,

the findings are indicative rather than conclusive. In addition, because the design of our survey is different from those adopted by other surveys that we have cited in this paper, it is important to note that the results of our survey cannot be strictly comparable to those of other surveys. Observations that we drew here therefore should be regarded as indicative rather than conclusive, although this approach can still generate useful observations on the trends, similarities and differences of people's perceptions and responses as demonstrated in other studies (see for example Brewer, 2005; Pidgeon et al., 2008). Furthermore, this survey focuses on only one stakeholder group – consumers, and did not involve other stakeholder groups. However, other stakeholder groups particularly the government, utilities, NGOs, experts and academics are also key players whose perceptions and behavioural responses are also important information that decision-makers for smart grids need to be informed.

Future research may generate useful data by extending this survey to other key stakeholder groups, and in other global cities. Moreover, while this survey uncovered the consumer perception of the performance of the existing electricity supply system and their acceptability of smart grid technologies, future research may focus on their acceptability of specific regulatory and institutional policies for smart grid developments. Another area that could be explored is consumer perception of the

trade-offs that would have to be made, including the trade-offs between environment and cost, and between the benefits of information technology and privacy, and the survey findings could be of high policy relevance.

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