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RESEARCH ARTICLE



# Socio-economic inequalities in climate policies: unpacking energy efficiency barriers in low-income households

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## ABSTRACT

While it seems sensible for households to invest in energy-efficient appliances if for nothing else than to save money, many do not. Studying this from the perspective of Low-income Households (LIH) is of particular interest as it must be recognized that they face a different set of barriers. This paper establishes that there is an energy efficiency gap in LIH and the analysis of survey results revealed a few key reasons as to why this is the case based on an analysis of the interrelationship between the barriers. The findings of this study not only show that any single policy is unable to address the energy efficiency gap for LIH, it also sheds light on the importance of considering the interactions between different factors affecting sustainable consumption decision-making for LIH for policy-making. This paper argues that a policy toolkit must be adopted to address these different factors simultaneously.

## ARTICLE HISTORY

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## KEYWORDS

Energy policy; energy efficiency; demand-side mitigation; energy poverty; barriers to adoption

## 1. Introduction

As governments around the world announce net zero targets by 2050, it means agreeing on short and medium term targets to achieve this ultimate objective with energy efficiency regarded as low hanging fruit. The IPCC as early as 2007 had stated that the most cost-effective method for climate abatement potential in buildings was from appliance upgrades, and in warmer climates cooling equipment ranked high (Metz et al., 2007). Using Hong Kong as a proxy, in the peak summer months of 2018 and 2019 the share of residential electricity consumption was over 30% (Census and Statistics Department, 2019) with 57% attributable to the use of three appliances – air conditioners, electric water heaters and refrigerators (EMSD, 2020c).

With this said, the uptake of energy-efficient appliances is far below what would be expected, bringing individual benefits through lower annual energy costs and societal benefits from lower energy usage and hence pollution and climate change mitigation (Fuller, 2009; Gerarden et al., 2015; Gillingham & Palmer, 2014). This “Energy Efficiency Gap”, as it is commonly referred to, is the difference between the expected cost-effectiveness of energy efficiency and that which is observed in practice (O’Malley et al., 2003). Policies to overcome this must consider everyone so it is important that we remain

cognizant of the circumstances of lower-income groups and how these may differ from the wider population, not least their capacity to pay. This study focuses specifically on examining this gap amongst HK's LIH.

In the market for large household appliances, models with the highest levels of efficiency are often priced at a premium to those of a lesser efficiency (Markandya et al., 2009; Zhang et al., 2020). This "first cost" or extra cost to adoption is arguably the biggest barrier. With 30% of Hong Kong households living in public housing (Census and Statistics Department, 2021), single policies such as a blanket taxation for the less efficient goods or just raising the efficiency standards and thereby increasing the price miss the point that these households are attracted to these cheaper but less efficient models. Previous research have highlighted certain factors that are particularly relevant for people on lower incomes. For example, it is suggested that they tend to be less capable of comprehending or calculating the cost benefit of retaining/purchasing the less efficient appliances (Ordonez et al., 2017) and live in rented accommodation hindering their control over the energy efficiency of the appliances in their dwelling (Gillingham & Palmer, 2014).

The aim of this study then is to answer the questions of (i) whether there is an energy efficiency gap in LIH, and if so, (ii) what are the major barriers to account for it and (iii) whether there is an innovative combination of solutions to address these barriers. This study is based on a questionnaire survey conducted at public housing neighbourhoods and at NGOs serving poorer households. A total of 124 representatives of households were surveyed, out of which 89 met the low-income criteria of a monthly household income of HK\$30,000 or below (referencing the eligibility criteria set by the Hong Kong government's working family allowance scheme). The study's findings can inform policy makers in high-income densely populated cities around the world with inbuilt structural income disparities which share similar challenges as Hong Kong. There are various policy tools that are commonly used to control or influence pro-environmental behaviour, such as consumption behaviour (Jackson & Michaelis, 2003). Decision-making regarding the selection of the most appropriate (set of) policy tools should depend upon the characteristics of the target stakeholder group(s), and particularly, how such characteristics relate to their behaviour, in this case, their consumption behaviour regarding energy intensive household appliances.

The structure of this paper is as follows. [Section 2](#) provides some background and related literature on barriers to explain the energy efficiency gap and policy design studies. [Section 3](#) outlines the data and methodology used in our empirical analysis. In [Section 3](#), we present our findings regarding the energy efficiency gap amongst LIH and identify the factors which are likely to have contributed to this gap. [Section 4](#) offers an analysis on various ways to address the energy efficiency gap for LIH. Finally, in [Section 5](#), we draw some conclusions from the findings and analysis and provide some policy recommendations.

## 2. Literature review

The energy efficiency gap has received considerable attention across disciplines from economics to psychology (Gillingham & Palmer, 2014) and is adopted here to provide a basis for looking into the barriers for adoption. This involves examining the economic, behavioural and cognitive barriers which may help resolve this conundrum. As

moving to net zero carbon emissions requires behavioural changes from everyone not just those who can afford it, it raises the question of “what if a household cannot”? Barriers identified from previous studies will be reviewed and, where appropriate, factors particularly relevant to LIH will be further discussed. A study in Europe, for instance, found three additional barriers for LIH to increase uptake of more energy efficient appliances: higher up-front costs, lack of access to financing and being tenants rather than owner occupiers (Schleich, 2019). Increasing our understanding of all the relevant barriers is crucial to designing appropriate and complex policy solutions. Policy design studies are included here to provide the conceptual basis to interpret our findings in relation to the key factors guiding LIH consumption behaviour.

### 2.1. Rational behaviour

Rational behaviour, which is at the core of neoclassical economic theory, is succinctly described as “... that individuals act purposefully by consciously seeking the best possible method of achieving their objectives” (Nicolaidis, 1988, p. 316). There are constraints imposed upon the individual but for the most part they will act in complete self-interest. While rational behaviour would assume that a low adoption rate would be due entirely to optimizing decisions, it is questioned if the calculation to ensure optimality is done by consumers and even then, under uncertainty high discount rates are applied (Howarth & Sanstad, 1995). This uncertainty could, therefore, be leading them to making what they believe are rational optimizing decisions. Simon (1955) sought to explain this anomaly in the model of bounded rationality, proposing that consumers had only limited attention and were therefore systematically underweighting information. This suggests that when faced with complex decisions like calculating efficiency gains, they would concentrate on only a subset of the information that was available (Gillingham & Palmer, 2014). In the consumers’ pursuit of immediate gratification, longer term gains/savings are more than outweighed by the immediate benefit/cost (Gul & Pesendorfer, 2004). This theory is however premised on an assumption that consumers have the financial means to make optimizing decisions. As appliances which are more energy efficient tend to have a higher upfront cost LIH operating on a tight monthly household budget may not have the means to purchase a more expensive appliance even if it could save them money in the longer term. Rational behaviour, therefore, may not be the most reliable lens to view the actions of LIH.

### 2.2. Financial literacy

Central to the purchase decision of energy efficient durables is that, all else equal with respect to the product’s attributes, over the life of the product the savings in energy costs will more than compensate for the higher initial purchase cost. This assumes, however, that the consumer is capable of calculating the savings. The “Big Three” have recently become popular in helping to assess financial literacy (Lusardi & Mitchell, 2008; Mitchell & Lusardi, 2011) and have also been modified to analyse energy-related financial literacy (Blasch et al., 2021). What has emerged is that energy-specific financial literacy is necessary, general financial literacy by itself was not sufficient (Blasch et al., 2021).

Discount rates for energy efficient appliances are typically observed at levels much higher than what a standard payback period would suggest. As economic theory implies discount rates will fall as income rises, this suggests LIH will have even higher discount rates. In fact, Hausman (1979) estimated discount rates as high as 89% for households with income less than US\$6,000 and 39% for households earning less than US\$10,000. Conversely, higher levels of energy-related financial literacy have been shown to be associated with higher income and higher education levels (Blasch et al., 2021; Wagner, 2019). Conversely LIH by definition have low incomes and typically have lower levels of education (Ordonez et al., 2017) suggesting low levels of energy-related financial literacy. By implication a lack of income and education, LIHs may be unable to appreciate the longer term financial benefits of purchasing energy efficient appliances, regardless of the extra upfront cost.

### 2.3. Market failure

Market failure is likely to occur when the key ingredients that lead to the efficient allocation of resources are not found (O'Malley et al., 2003). A few key reasons have been identified to explain the energy efficiency gap in the context of market failure, including informational problems, a misalignment of landlord/tenant ambitions or simply principal-agent issues, access to credit and regulatory failure (Gillingham & Palmer, 2014).

#### 2.3.1. Informational problems

Reasons for imperfect information include consumers lacking the right information to make informed choices, the high implicit costs of acquiring the information or just plain difficulty in accessing accurate information (O'Malley et al., 2003). This inability to acquire accurate information is likely to see the consumer investing too little in energy efficiency, thereby making sub optimal purchasing decisions (Schleich, 2009).

Asymmetric information, i.e. when one of the parties in a transaction has different levels of information, can lead to adverse selection (O'Malley et al., 2003). When the seller for instance is able to convey information such as lifetime energy cost of appliances to the customer, energy saving behaviour is more likely to be triggered, e.g. a 3.4% increase in sales of the more energy efficient tumble driers was observed in a store where this was trialled (Kallbekken et al., 2013).

#### 2.3.2. Principal-agent

When looking at households it is important to note that those living in rented accommodation have less control over the provided appliances. This principal agent problem highlights the split incentives between the renter and the landlord. When an appliance needs to be replaced, the landlord is incentivized to provide the cheapest model while the tenant would prefer the cheapest one to operate. Hence, the landlord decides the energy efficiency but the tenant pays the price of that decision (Gillingham & Palmer, 2014). This is particularly pertinent in the context of Hong Kong where 57% of residents on incomes of HK\$20,000 – HK\$30,000, 63% of residents on incomes of HK\$10,000 – HK\$20,000, 70% of residents on incomes of HK\$4,000 – HK\$10,000 and 31%<sup>1</sup> of residents on incomes of less than HK\$4,000 live in rented accommodation against the overall average of 49% (Legislative Council Secretariat, 2021) pointing to a skew in the number of LIH living in rented accommodation.

### 2.3.3. Access to credit

More energy-efficient appliances would reduce the utility bills for LIH, but they are less likely to be able to finance the purchase. Traditional financing looks at the creditworthiness of a borrower and the ability of the borrower to make timely repayments on the loan. Traditional financiers may not have the skills to understand how financing energy efficiency will free up capital to make repayments and may therefore unintentionally discriminate against potential borrowers on purely traditional credit metrics (Fuller, 2009).

As mentioned previously, both the principal agent problem and lack of access to credit were two of the further three barriers inhibiting LIH to increase their uptake of more energy efficient appliances in a European study (Schleich, 2009) and *prima facie* appears relevant in our study.

## 2.4. Regulatory failure or deficit

### 2.4.1. Labelling scheme

Labelling schemes are seen as a cost-effective way of overcoming barriers, particularly informational issues and bounded rationality (Mills & Schleich, 2010). In order to encourage consumers to make informed decisions with respect to energy efficiency, the Hong Kong government introduced the Mandatory Energy Efficiency Labelling Scheme (MEEELS) in 2009. It covers the eight most energy intensive products and provides a grading system from least to most efficient (EMSD, 2020a). The average increase in energy efficiency across these three appliances by replacing for instance a Grade 3 model with a Grade 1 model is above 25%. Some studies in China have found that efficiency labelling significantly affected purchasing attitude (Shen & Saijo, 2009; Zhang et al., 2020). To improve labelling however, the inclusion of the annual running costs has been shown to be significant, helping to mitigate asymmetric information (Shen & Saijo, 2009). Importantly, a Willingness To Pay (WTP) study found that an indication of the economic value that can be gained from saving energy was the single most important element on an energy label (Newell & Siikamäki, 2014).

### 2.4.2. Electricity pricing

Electricity prices in most developed countries are regulated and this distortion leads some to believe that perhaps overall electricity prices are too low. There is also some evidence that consumers' expectations for the future price of electricity are biased downward (Todd et al., 2015). A corollary may be evident here with the real cost of automotive fuel in the US that we observe over the 90 years up to circa 2007, has in fact fallen (Turrentine & Kurani, 2007). If electricity prices are low and there is a belief that they will remain low, or even fall, there is less of an incentive to invest in energy saving technology because the economic benefit is perceived to be less. This cannot be ignored because if electricity prices were sufficiently low, no one regardless of income would **voluntarily** buy energy efficient appliances and suggests alternative regulatory actions such as tightening efficiency standards are required.

## 2.5. *Environmental concern*

While at first it seems incongruous that one's environmental concern would not affect the WTP, this phenomenon has been observed (Tan et al., 2017; Zhang et al., 2020). These studies found that while consumers appreciate that energy efficient appliances are effective in reducing pollution and positively impacting climate change it does not translate into purchasing behaviour. Studies have suggested that it is income rather than environmental concerns that is the driver for a higher WTP (Shen & Saijo, 20). This is important for our study as the focus is on LIH.

## 2.6. *Policy tools*

The policy design literature supports the development of findings into policy recommendations to address the energy efficiency gap amongst LIH. This study rides on newer developments in this field, in particular two key turning points in the 1990s: the study of policy targets and their behaviour which brought about newfound understanding and interests in policy designs based upon social and behavioural factors, and the shift from studying single instrument uses towards complex tool preferences, also known as policy toolkits (Howlett et al., 2015). Numerous studies have attempted to categorize policy instruments and to test their effectiveness in relation to different policy issues. Many scholars have also adopted the policy mixes concept to examine energy policies (e.g. Gawel et al., 2014; Mah et al., 2021; Matti et al., 2017; Pahle et al., 2021). Most relevant to this study is the research on ways to influence consumer behaviour where policies have been categorized into the more conventional tools of command-and-control and market-based measures, and the increasingly popular category of information and persuasion (Jackson & Michaelis, 2003).

The policy formulation process begins with an analysis of the abilities of different policy instruments to bring about the desired policy outcomes, where a mix of policy tools is often necessary. Energy consumption policy is inherently difficult because it involves multiple stakeholders with competing objectives requiring policy makers to be cognizant of all of these actors and their different objectives. This will inevitably require a number of policies designed to complement each other in influencing the behaviour of all actors with the ultimate objective of a reduction in overall energy consumption (Pahle et al., 2021). To avoid the system being gamed, verification of claimed savings by market participants and an ongoing assessments of pricing structures in subsidy like schemes are required to ensure any investment is being optimized (Eichhammer et al., 2013)

Other than the blunt instrument of taxes or financial incentives, 'nudge' is one of the more recent policy tools that has been used in attempting to elicit energy saving behaviour (Newell & Siikamäki, 2014). It refers to adjustments made to any aspect of a decision environment which could potentially change a consumer's behaviour in a predictable way without minimizing their choices or altering the economic incentives (Thaler & Sunstein, 2008). The 'nudge' school holds that by investigating expected behavioural implications of policy tools, policy makers could combine behavioural insights with conventional policy tools to maximize policy effectiveness (Ewert, 2020). While government initiatives such as the MEELS provide more information, more information just adds to existing information, potentially leading to further uncertainty (Strassheim, 2021), so complimentary policies conceived through social learning are required and will be explored later in this paper.



### 3. Methodology

This study was designed to look at the energy efficiency gap amongst LIH in Hong Kong. Saving energy or using energy more efficiently is cost effective because for every unit of energy saved by a household a reduction in costs will be observed and using energy efficient appliances is a means to achieve that end. By using a questionnaire focussed on the WTP for energy efficient appliances we can assess whether LIH do in fact perceive these purchases as cost effective. Previous studies have shown that by and large education levels amongst people living in LIH are lower (Blasch et al., 2021; Ferguson et al., 2007; Hirsch, 2007), they by definition have less disposable income and therefore less savings and often live in rented, older housing stock (Grösche, 2010). It should therefore come as no surprise that some sort of financial help may be required so it is important to understand to what extent and also what other factors may help motivate behavioural changes. It is well known that providing economic incentives to the entire population is hampered by the freerider problem and not necessary as those on higher incomes could have made the switch anyway seeing the financial benefits of saving electricity (Rivers & Shiell, 2016). This study does not include direct or indirect comparison with High Income Households as it was not deemed relevant because their WTP may be more a function of the expectation of publicly financed subsidies. In much the same way that Podgornik et al. (2016) studied the effect of feedback to LIH with regard to energy consumption and Vassileva and Campillo (2014) studied energy awareness in LIH in isolation, we too concentrate on LIH in isolation because targeted policies should be designed with their needs in mind.

To study this, a questionnaire survey was conducted testing a wide range of factors that contribute to the energy efficiency gap, as identified in the literature and assess what was applicable to LIH in the Hong Kong context. Testing these factors' correlation with the willingness to pay a premium would help to confirm what other authors have identified and inform policies not only for Hong Kong but more generally for developed cities with income disparities.

Hong Kong, at the end of 2020, had over 800,000 households in Public Housing or 30.4% of the population (Census and Statistics Department, 2021). Also, 287,000 households were defined by the government as poor households in 2019 (Census and Statistics Department, 2020). A purposive sampling method (Wolf et al., 2016) was used to try to reach out to LIH in public housing areas and through engagement with local NGOs. Three geographically diverse public housing estate locations on Hong Kong Island were identified and two NGOs on the Kowloon side were engaged. In the on-street surveys, we stood at main crossroads and randomly approached subjects offering a HK\$20 reward for completing the questionnaire. The NGO subjects were randomly selected through household visits and drop-ins to their centres. The survey period spanned March, April and May of 2021.

The surveys were conducted in Chinese. The full questionnaire (translated into English) can be found in the [Appendix](#). In total 124 questionnaires were conducted, with five immediately excluded due to incomplete information. As the study was only concerned with LIH we defined the income level where we would draw the line based on the working family allowance (WFAO, 2015). The line was drawn at a maximum income of HK\$30,000 so questionnaires only up to the HK\$20,001 - HK\$30,000 bracket were used for the study. This eliminated another 30 questionnaires and left us with 89 questionnaires which met our low-income criteria.



To offer more nuanced understanding on LIH, we split this group into what is generally accepted as above and below the poverty line to see if we could observe any statistically significant difference between the groups. Hong Kong officially defined this in 2019 as HK\$16,600 for a three person household and HK\$21,400 for a four person household (Census and Statistics Department, 2020). To remain on the side of prudence, we split the questionnaires between those below HK\$15,000 and those above giving sample sizes of 53 and 36 respectively. All statistics are presented on aggregate and when split out, they were clearly referred to as LI1 and LI2 representing household incomes up to HK\$15,000 and HK\$15,001 to HK\$30,000 respectively.

The first questions on the questionnaire were demographics and covered age, household income, sex and level of education. A summary of the demographics is presented below in Table 1.

**Table 1.** Demographic description of the survey sample.

Age group	20–30	31–40	41–50	51–60	Above 60
	16	18	16	14	25
Monthly Household Income (HK\$'000s)	<10	10–15	15–20	20–30	
	29	24	16	20	
Sex	Male	Female			
	28	61			
Education*	Secondary	Undergraduate	Postgraduate		
	62	20	5		

\*2 respondents did not provide their education level.

Using the SPSS statistical software, Chi squared tests were carried out to analyse questions that used ordinal data such as our Likert scale questions and more traditional t-tests and ANOVA were used for normal data sets, both at 0.05%. Correlations were also calculated for some areas of interest and described in more detail below.

Energy saving appliances are priced at a premium to generic models and the survey would capture what was the preparedness to pay a premium for energy saving appliances. The survey was also designed to identify a number of characteristics about personal behaviour and actions, knowledge of energy saving actions and government relief measures. By identifying the characteristics that correlated with the WTP a premium, negatively or positively, we can analyse those most relevant. It is hypothesized that as LIH are capital starved, their preparedness to spend extra money on energy saving appliances, despite the longer term savings, is low. Understanding what the barriers are provides a basis for further research into the specific areas identified as requiring a policy response. While complex and covering a lot of material, this is the first study of its kind in Hong Kong and the survey was constructed in such a way as to identify the most important barriers.

## 4. Findings

To answer the first research question – whether there is an energy efficiency gap amongst LIH, this section begins with exploring the upfront cost for more energy efficient appliances and LIH's Willingness-to-pay. The remaining sub-sections then focus on the findings regarding contributing factors to the energy efficiency gap.

#### 4.1. Energy efficiency gap

While efficiency gains from upgrading appliances are significant (Table 2), they come with a higher upfront cost. Using the air conditioner as an example, a top appliance retailer in Hong Kong set the price at HK\$12,280 for a Grade 1 air conditioner and HK\$9,280 for another model highly similar in size and attributes but rated Grade 4 making the Grade 1 model 32% more expensive.

**Table 2.** Efficiency gains.

	Grade 1 vs Grade 3	Grade 1 vs Grade 5
Room Air Conditioner	23% more	43% more
Refrigerating Appliances	41% more	97% more
Storage Type Electric Water Heaters	30% more	60% more

(EMSD, 2020d)

With this in mind, participants were asked how much extra they would pay for a Grade 1 air conditioner, refrigerator and electric water heater over a similar Grade 3 model (Table 3). Five answer options were given in all cases with the final option 30%, 50% and 40% higher respectively based on the observed market-based price differential and therefore the amount they would actually have to pay. The cost per KWh and the efficiency gain for each were disclosed to give sufficient information to make a comparison.

**Table 3.** Average score of WTP.

Air conditioner	2.56
Refrigerator	2.61
Water heater	2.56

Of the five choices provided, the average score for all appliances was between 2 and 3 implying in aggregate that the group was willing to pay somewhere between 5% and 10% more. We calculated the NPV of the air conditioner (see footnote 2 below) and found it to be a positive below 10 years proving that paying for its energy efficiency is cost effective. However, our respondents are using very high discount rates of 35% (those willing to pay 5% more) and 23% (those willing to pay 10% more), which puts the average payback period at around two and a half years.<sup>2</sup> We will now explore the reasons for this energy efficiency gap.

#### 4.2. Electricity pricing

At first, it appears to be counterintuitive that 96% of the surveyed people agreed Hong Kong electricity prices would rise in the future yet less than 20% of respondents were willing to pay more than 10% for any of the three more efficient appliances. This is partly explained by the significantly lower electricity prices in Hong Kong compared to most other developed cities (Figure 1). The cost of electricity, as a driver of the cost of using an appliance, has an impact on WTP. Regulatory failure in relation to electricity prices therefore needs to be examined as a potential reason contributing to the energy efficiency gap.

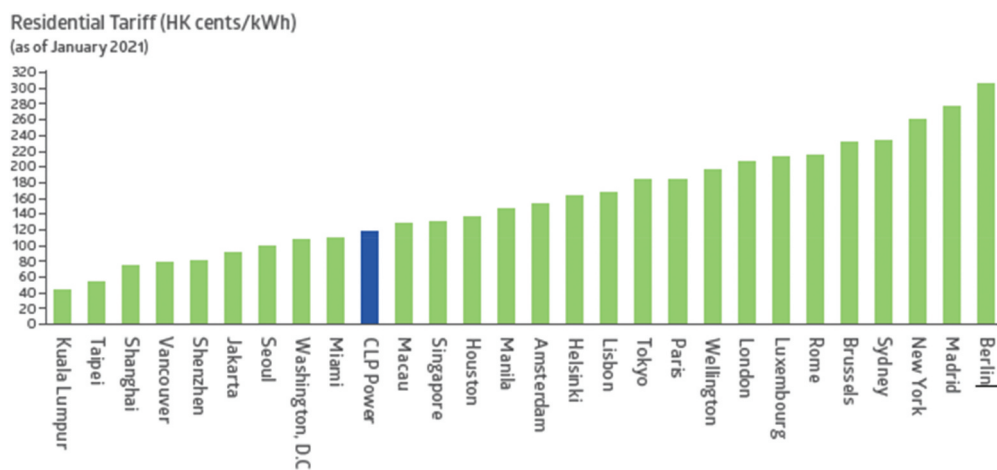


Figure 1. Residential Tariff (CLP, 2021).

#### 4.3. Subsidised financing

To address the first cost barrier, we asked respondents if they would take advantage of a scheme that subsidized the cost of upgrading their older appliance to a more efficient Grade 1 appliance. Only 16% responded that they ‘Absolutely’ would but 72% revealed they would ‘Likely’ or ‘Very Likely’ take advantage of such a scheme.

In Hong Kong, eligible persons who are served by The Hong Kong Electric Company (HEC)<sup>3</sup> are entitled to access its Energy-efficient Appliances Subsidy Programme. This allows a one-off subsidy of HK\$5,000 to either replace existing household electrical appliances with more energy efficient models, purchase new energy-efficient appliances or for the provision of improvement works for the safe use of electricity. Making reference to the eligibility criteria specified on the HKE website, respondents were asked (i) whether they fall within that category and if so, (ii) were they aware of the programme?

Out of the 54 respondents who live on Hong Kong Island, 10 were eligible to benefit from the programme but only five were aware of the programme’s existence. While our sample size is small in this aspect, if this is true of all eligible HEC customers, a significant number of households who would have access to subsidies to help overcome this initial cost barrier are not aware of the scheme.

#### 4.4. Split incentives

Amongst the respondents who rented their apartments, 48%<sup>4</sup> felt that their landlord would not replace a broken air conditioner with a more efficient and therefore more expensive model if they asked for it. This finding suggests landlords are unlikely to provide a more efficient model so the renter will be obliged to pay higher operating costs.

#### 4.5. Financial literacy/energy-related financial literacy

The last of the Big Three was used to test whether the respondent understands how to correctly discount future cashflows. This was a compound interest calculation and only 24% of the respondents arrived at the correct answer. We then looked at four variables, age, sex, income and education, and used a Wald Chi square statistic to test if there was any relationship between these and our respondent's ability to perform the calculation. SPSS was used to run the test and the Wald Chi-Square was used as the test statistic. The output is presented below:

##### 1a.

**Ho:** That there was no relationship between age and the ability to perform the calculation

**Ha:** That there was a relationship between age and the ability to perform the calculation

Chi-Square Tests (Age)			
	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.809 <sup>a</sup>	4	.432
Likelihood Ratio	3.925	4	.416
Linear-by-Linear Association	3.616	1	.057
N of Valid Cases	89		

<sup>a</sup>4 cells (40.0%) have expected count less than 5. The minimum expected count is 3.30.

##### 1b.

**Ho:** That there was no relationship between sex and the ability to perform the calculation

**Ha:** That there was a relationship between sex and the ability to perform the calculation

Chi-Square Tests (Sex)					
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.561 <sup>a</sup>	1	.454		
Continuity Correction <sup>b</sup>	.231	1	.631		
Likelihood Ratio	.549	1	.459		
Fisher's Exact Test				.591	.311
Linear-by-Linear Association	.555	1	.456		
N of Valid Cases	89				

<sup>a</sup>0 cells (.0%) have expected count less than 5. The minimum expected count is 6.61.

<sup>b</sup>Computed only for a 2 × 2 table

##### 1c.

**Ho:** That there was no relationship between income and the ability to perform the calculation

**Ha:** That there was a relationship between income and the ability to perform the calculation

Chi-Square Tests (Income)				
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.253 <sup>a</sup>	1	.022	
Continuity Correction <sup>b</sup>	4.151	1	.042	
Likelihood Ratio	5.182	1	.023	
Fisher's Exact Test				.040
Linear-by-Linear Association	5.194	1	.023	.021
N of Valid Cases	89			

<sup>a</sup>0 cells (.0%) have expected count less than 5. The minimum expected count is 8.49.

<sup>b</sup>Computed only for a 2 × 2 table.

**1d.**

**Ho:** That there was no relationship between education and and the ability to perform the calculation

**Ha:** That there was a relationship between education and and the ability to perform the calculation

Chi-Square Tests (Education)			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.432 <sup>a</sup>	2	.015
Likelihood Ratio	7.729	2	.021
Linear-by-Linear Association	8.315	1	.004
N of Valid Cases	87		

<sup>a</sup>cells (50.0%) have expected count less than 5. The minimum expected count is 1.21.

Neither age nor sex had any relationship with the ability to answer the question correctly, but income (Chi-squared test,  $\chi^2_1 = 5.25$ ,  $p = 0.02$ ) and education (Chi-squared test,  $\chi^2_2 = 8.43$ ,  $p = 0.02$ ) did. Only 15% of the LI1 respondents correctly answered the question compared with 36% of the LI2 respondents. This provides further evidence that the ability to do this calculation is positively correlated with income. There is also some evidence which suggests that education may be positively correlated with financial literacy.

With regards to the lifetime cost comparison calculation, only five respondents selected the correct answer and the explanation of how they arrived at their answer. Given the low number of correct answers, we are unable to draw any conclusions except that there is a significant cognitive deficit in this area which is central to making an informed decision.

A previous study had found that LIH had a lower level of energy related financial literacy compared to higher income groups (Blasch et al., 2021), suggesting consumers are making, perhaps subconsciously, satisfactory rather than optimum decisions using rules of thumb in their decision making (Simon, 1955). What is important here is that it is not financial literacy in isolation but energy related financial literacy that is the key to guiding behaviour (Blasch et al., 2021) and education may help to remove this barrier.

#### 4.6. Informational barriers

LIH's general knowledge about electricity usage and efficiency was tested to see if they might be aware of where significant amounts of electricity were being consumed. Respondents were asked in the local context, out of an air conditioner, a refrigerator and an electric water heater, which appliance uses the most electricity. Hong Kong experiences hot and humid weather conditions for much of the year so it should have been obvious to Hong Kong residents that the correct answer is the air conditioner. However, only 65% of respondents answered this correctly, with no differences amongst the demographics. Regarding how much more efficient a compact fluorescent globe is compared to an incandescent globe of equivalent light output, while only 11% selected the correct answer, 62% of respondents thought that the efficiency gain was no more than 25%.<sup>5</sup> This revealed that a significant number of respondents do not know where they can save electricity or which appliance is worth the investment of higher efficiency models.

#### 4.7. Energy-efficiency labelling scheme

Participants' awareness of and perceptions towards the MEELS program was tested as an indicator of its effectiveness and energy standards messaging. While awareness is high towards the label at 83% and while 70% understood the label, only 50% of respondents find that it gave them enough information. 38% said it gave them some of the information and 4% told us it did not give them the required information.<sup>6</sup> While the promotion of the program may be successful, when compared with a survey in China revealing that only 55.35% of respondents were aware of the China Energy Label (Li & Cao, 2021), it is important to note that 42% of this study's respondents were dissatisfied with the information given by the labels. Two earlier studies (Newell & Siikamäki, 2014; Shen & Saijo, 2009) had found that the most important element on the label was the economic value attached to it, i.e. the amount of money the consumer would spend each year on operating the appliance, while the amount of energy used and CO<sub>2</sub> emissions added only incremental value. As the MEELS label does not convey this information, it is likely that the 42% of respondents would find it useful to have this included in the future.

#### 4.8. Environmental concern

Finally, environmental awareness was included in the survey to test its correlation with WTP. As previous studies suggested there was no correlation (Tan et al., 2017; Zhang et al., 2020) and that socioeconomic status was the major determinant (Shen & Saijo, 2009), we were interested to test this with the target of LIH. This was in fact what we found with limited/no correlation between any of the three appliances and environmental awareness and is highly instructive for designing policy, as the motivator to increase the WTP is not a concern for the environment.

### 5. Analysis: addressing the energy efficiency gap

Based on the survey results, two major causes of concern have been revealed. Consumers are adopting discount rates as high as 30% in our earlier air conditioner example, which

puts the NPV at -HK\$1,769 in 12 years. WTP is at less than 10% extra which is not enough for energy efficient appliances. Effective means to increase uptake must be explored and considered collectively to address the needs of LIH.

### **5.1. Electricity pricing**

When the price of electricity is particularly low, where the negative externalities of electricity production are excluded, the wrong signal is sent to consumers, i.e. over-consumption is not discouraged. It creates less incentives to purchase a more expensive energy-efficient appliance. For instance, if Hong Kong's electricity prices were similar to those observed in Germany, USD339.90 per MWh (IEA, 2020), in our previous example of the air conditioner the NPV of the more efficient model would be zero in under four years and getting much closer to the two and a half year payback period required by our survey respondents. That said, as LIH are already capital constrained, higher electricity prices only increases their burden. Regardless of whether electricity prices are too low, a carefully designed combination of policy responses is appropriate.

### **5.2. Efficiency standards**

Efficiency standards bind all producers of a good in a particular market to those standards. This, however, is not without a cost because the standards forbid the sale of less efficient and cheaper goods, thus creating an implicit tax on those least able to absorb it (Hausman, 1979). But what has been shown empirically is that although prices initially increase, producers innovate driving costs back down over time (Van Buskirk et al., 2014). Therefore, targeted low cost access to finance, subsidies and/or tax incentives combined with tightening efficiency standards is an equitable way to drive the whole population towards greater energy efficiency.

### **5.3. Subsidised financing**

Lack of access to capital is the main determining factor in LIH's tendency to choose less energy efficient appliances and highlights the lack of/ineffective support from the government and the energy providers. Both energy companies in Hong Kong offer loans to non-residential customers to implement energy saving initiatives but not for residential customers. The government continues to provide subsidies<sup>7</sup> to households to address affordability issues, however, subsidizing use reduces incentives for energy saving behaviours and investing in energy saving appliances.

The financing for LIH needs to be done in innovative or creative ways such as on-bill financing (Granade et al., 2009). Using our earlier air conditioner example, we know the savings on an undiscounted basis is HK\$376 per year and therefore the extra cost is absorbed on an undiscounted basis in 6.5 years. The grants given by government would be better used by targeting consumers that are least likely to invest in energy efficient appliances and allow market forces to encourage the rest. Grants or subsidies that are seen in European countries generally take the form of incentives for appliance replacement (Ordóñez et al., 2017). In the United States, the New York State Energy Research and Development Authority (NYSERDA) provided a direct subsidy to LIH by paying 50% of



project costs up to a certain amount (Fuller, 2009). In Asia, we can cite schemes in both Korea and China that subsidize the purchase of efficient appliances to replace those regarded as obsolete (Jin, 2020). Our study found that participants would pay 5–10% more for the Grade 1 model so financing the gap may be a good first step. Analysing uptake will help inform the next step. Policy makers should concentrate on not creating equality for all residents but target where there are low costs that can provide high overall savings in GHG emissions (Ahlrichs et al., 2021).

#### 5.4. Split incentives

The issue of split incentives, which was substantiated through this survey needs to be addressed. For instance, an incentive could be provided for the landlord to purchase more energy efficient appliances, such as the low interest loans offered by the Netherlands (Vega et al., 2021). Regulation may however be required in the absence of economic incentives to motivate change (Petrov & Ryan, 2021). Further research is required to assess which policies are most suited to tackling this issue.

#### 5.5. Nudging tools: energy efficiency labelling scheme and education

As argued by more recent policy design studies, the importance of crafting a policy toolkit is increasingly recognized, where command-and-control and market-based measures are carefully combined with behavioural tools (Howlett et al., 2015). For example, studies consistently find that programs which combine an action such as a home retrofit with education derive better results than programs that give participants either the retrofit or the education (O’Callaghan et al., 2020). When developing a policy such as subsidized financing, education or targeted information must also take place. As discussed in the previous section, including estimated running costs on the MEELS label provides information that may help address some of the informational barriers. It also goes some way to addressing the bounded rationality barrier because the consumer is only required to do an easy calculation. Our survey finds that education about energy efficiency and the economic consequences is vastly inadequate and a policy response to help LIH understand these benefits is required.

### 6. Conclusion and policy implications

It is not uncommon for governments to overlook the underlying reasons for unsustainable practices or the needs of different socio-economic groups, as demonstrated by the Hong Kong Environmental Protection Department (EPD)’s general *Do’s and Don’ts* approach in dissemination of information and education to help alter energy consumption behaviour (Lo, 2008). This study reveals that the energy efficiency gap exists for LIH and points towards potential underlying factors contributing to this gap. While similar studies have been conducted before, they have only examined the energy efficiency gap in Europe and North America. This study contributes insights from an Asian context. More importantly, the findings are analysed to inform the design of an effective combination of policies which could address the combination of key factors underlying the energy efficiency gap specifically for LIH.

Two key findings emerged in the WTP section of our study which help to inform the framing of why it is important to understand LIH energy efficiency. Firstly, we found that environmental concern is not a motivating factor to pay more for more efficient appliances. Secondly, even after being told the efficiency gains available from a higher rated appliance, which in one instance was 41%, willing to pay was a mere 5–10%, which suggests both a high discount rate and a higher upfront cost presents a substantial obstacle. Relying on messages like saving the environment and even long-term savings are unlikely to be effective as standalone measures. Framing energy saving as a way to reduce energy bills and is therefore cost effective for household budgets, could be a more effective approach for LIH, especially in combination with other measures which address potential barriers preventing further uptake. The higher cost of more efficient appliances needs to be addressed in a way that emphasizes to households they will see falls in their electricity usage thereby reducing their monthly electricity bills. Low levels of energy related financial literacy, which is one of the contributing factors to the energy efficiency gap, can be overcome with better labelling.

This directs our attention to two other problems 1. The higher upfront cost and 2. the principal agent problem that exists between tenant and landlord. With regard to the upfront cost, this can be solved indirectly by raising the efficiency standards such that the price differential between the low and high efficiency products narrows. This will increase the NPV of the higher efficiency products vis a vis the less efficient products. Although an increase in efficiency standards may initially lead to a higher overall price level (pricing of the appliance), innovation has been shown to drive these prices back down (Van Buskirk et al., 2014). This can also indirectly solve the principal agent problem because the less efficient models will ultimately disappear from the market.

To help LIH overcome the higher initial cost barrier, measures are needed to incentivize them to purchase a more energy efficient appliance. Financing the differential between the less and more efficient models upfront by the government can be done at minimal cost through the issuance of a green bond/social bond and on bill financing can be utilized to fund repayments. A similar incentive scheme, possibly financed through the same mechanism can be adopted to support landlords to buy energy efficient appliances for their rental properties.

Our study has confirmed that the energy efficiency gap is evident in Hong Kong's LIH cohort. Importantly, the findings of this study show that any single policy is unable to address the energy efficiency gap for LIH. While the survey findings suggest that low energy related financial literacy has led to a lack of capacity to recognize the positive NPV of more efficient models, it cannot be considered alone. This is because there are a number of other obstacles and factors at play when considering how to address this energy efficiency gap. Even if low energy-related financial literacy can be bypassed by quantifying and informing consumers about the cost savings of a more energy efficient model through the energy labels, other measures are needed to address the obstacles of a higher upfront cost and the principal-agent problem as key barriers for the uptake of more energy efficient appliances. The electricity pricing strategies should also be reconsidered, alongside tightening efficiency standards and providing subsidized financing through the capital markets to overcome the first cost barrier. Reaching into the policy toolkit to consider the potential complementarity of several policies

can go a long way to solving this problem. Further research needs to centre around how the Green Bond financing mechanism could work in relation to other energy efficiency/retrofit policies. A second area of further research pertains to consideration of including the cost figure on energy efficiency labels.

## Notes

1. Persons aged over 60 comprise 41.2% of all homeowners. They also have little to no income as they no longer work distorting this income group.
2. The Hong Kong government uses a rate of 4% (Kong Sar Government, 2008) to assess major projects so we will use this as the base rate at which, if the government were providing these air conditioners it would use to calculate the NPV. This can also be referred to as the social rate of capital. An air conditioner has a lifespan of somewhere between 10 and 15 years, so we will use 12 years as an average and take the usage data as specified by the EMSD of 1,200 hours per year (EMSD, 2020b). Assuming electricity rates remain unchanged over this period, in less than 10 years the NPV of the more efficient air conditioner vis a vis the less efficient model is zero and at the products end of life is HK \$562 implying it is a worthwhile investment to make. Reverse engineering this NPV into a 5% more WTP implies a discount rate of about 35% and for the 10% more WTP, an implied discount rate of 23%. At these rates the payback period is just over one year for the 5% more WTP and about four years for the 10% more WTP. So, we can infer that the respondents on average require a payback period of around two and half years and have an implied discount rate of almost 30%.
3. HEC only provides electricity to residents of Hong Kong Island.
4. 20% responded that they would with the reminder responding that their landlord would likely share the cost.
5. Energy efficient globes are 75% more efficient (EMSD, 2020e)
6. Totals may not add to 100% because not all participants answered all questions.
7. The HK government provided a maximum subsidy of HK\$11,000 to all households for the provision of electricity between 2008 and 2020 and has planned a further HK\$3000 to be given to all households to offset the transition away from coal to gas over 60 months from January 2019 (HK Electric, 2015)

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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## Ethical approval

Ethical approval for this research study was granted by the Programme Director of School of Biological Sciences on behalf of the Human Research Ethics Committee of The University of Hong Kong. The approval letter was received on February 4<sup>th</sup> 2021.

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## Appendix

### Section A - Details

Section A - Details							
1	Age group (please circle)	20 – 30	31- 40	41 – 50	51 – 60	Above 60	
2	Monthly Household Income (please circle)	<HK\$10,000	10,001 - 15,000	15,001 - 20,000	20,001 - 30,000	30,001 - 50,000	> 50,001
3	Sex	Male	Female				
4	Level of Education	Secondary School		Undergraduate Degree		Postgraduate Degree	
5	Your Floor number	<20F	>20F				

### Section B - Hong Kong MEELS

- 6 The Mandatory Energy Efficiency Labelling Scheme (MEELS) is a labelling scheme set up by the Hong Government mandating that some electrical appliances will require a label affixed to them at the time of purchase showing the product's energy efficiency rating from 1 to 5. Are you aware of the scheme?

Yes No

*If you answered No to the previous Question please skip to question 10*

- 7 Do you read the label? Yes No
- 8 Do you understand the information on the label? Yes No
- 9 Does it provide you with **all** the information you require about energy efficiency to make an informed opinion of the products' suitability for you? Yes Some No



10 According to HK Electric, the average electricity tariff is HK\$1.264/kWh. Given this information please answer the following questions:

- a According to the EMSD a Grade 1 air conditioner is 23% more efficient than a comparable Grade 3 model. How much extra would you pay for a Grade 1 air conditioner?
- No more 5% more 10% more 20% more 30% more
- b According to the EMSD a Grade 1 refrigerator is 41% more efficient than a comparable Grade 3 model. How much extra would you pay for a Grade 1 refrigerator?
- No more 5% more 10% more 30% more 50% more
- c According to the EMSD a Grade 1 electric water heater is 30% more efficient than a comparable Grade 3 model. How much extra would you pay for a Grade 1 electric water heater?
- No more 5% more 10% more 25% more 40% more
- 11 Over the course of the year in Hong Kong, which of the following household appliances uses the most amount of electricity? **Choose only one.**
- Air conditioner Refrigerator Electric Water heater
- 12 Replacing an incandescent globe with a compact fluorescent globe of similar brightness can save up to how much energy?
- 0% 10% 25% 50% 75%
- 13 a Do you rent your apartment or own your apartment?
- Rent Own
- b If you rent your apartment, assume your air conditioner was no longer working and you asked your landlord to replace it with a more expensive and more efficient model. How do you think your landlord would respond?
- Would not agree Would agree but ask you to pay the difference Would agree
- 14 Will Hong Kong electricity prices rise in the future?
- Yes No

**Section C - Environmental Awareness**

- 15 *The following three household appliances contribute significantly to your overall energy consumption and because Hong Kong derives most of its electricity generation from fossil fuels, it would be better to buy more energy efficient ones to help the environment. When replacing one, on a scale of 1 - 5 how would you describe your concern about the product's impact to the environment, with 1 meaning you have no concern and 5 meaning you are very concerned.*
- |   |                 |   |   |   |   |   |
|---|-----------------|---|---|---|---|---|
| a | Air conditioner | 1 | 2 | 3 | 4 | 5 |
| b | Refrigerator    | 1 | 2 | 3 | 4 | 5 |
| c | Water heater    | 1 | 2 | 3 | 4 | 5 |
- 16 Regarding climate change, on a scale of 1 to 5 with 1 meaning you have no concern and 5 meaning you are very concerned, how concerned are you about your future?
- |  |   |   |   |   |   |
|--|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 |
|--|---|---|---|---|---|
- 17 When I leave a room I turn off the lights
- |     |    |            |
|-----|----|------------|
| Yes | No | Not always |
|-----|----|------------|
- 18 I adjust the temperature setting on the air conditioner in Spring and Autumn compared to Summer
- |     |    |            |
|-----|----|------------|
| Yes | No | Not always |
|-----|----|------------|
- 19 When a lightbulb stops working I replace it with an energy efficient compact fluorescent one
- |     |    |            |
|-----|----|------------|
| Yes | No | Not always |
|-----|----|------------|
- 20 Regarding your own efforts in energy efficiency in your home, how do you rate yourself? With 1 meaning you rate yourself as not doing anything and 5 meaning you do as much as you can
- |   |   |   |   |   |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
- 21 Compared to your neighbour, do you think you make more effort to increase energy efficiency in your home?
- |    |      |     |            |
|----|------|-----|------------|
| No | Same | Yes | Don't know |
|----|------|-----|------------|

**Section D - Financing**

- 22 Suppose you had HK\$1,000 in a savings account and the bank paid you 1% pa interest. After five years how much money would be in your account?
- |                     |                   |                     |            |
|---------------------|-------------------|---------------------|------------|
| More than HK\$1,050 | Exactly HK\$1,050 | Less than HK\$1,050 | Don't know |
|---------------------|-------------------|---------------------|------------|
- 23 *Suppose your refrigerator breaks down and you need to replace it. As a replacement, you can choose between two alternatives that are identical in terms of design, capacity and quality of the cooling system. Refrigerator A costs HK\$4,000 and uses 360kWh per year and refrigerator B costs HK\$6,000 and uses 260kWh per year. Assume the average cost of energy is HK\$1.25 per kWh and the lifespan of the refrigerator is 15 years.*
- a Which refrigerator minimises costs over its lifetime?
- |   |   |      |            |
|---|---|------|------------|
| A | B | Same | Don't know |
|---|---|------|------------|
- b How did you arrive at your answer?
- |              |                                  |   |            |
|--------------|----------------------------------|---|------------|
| A is cheaper | B efficiency justifies its price | B efficiency does not justify its price | Don't know |
|--------------|----------------------------------|---|------------|
- 24 If subsidised financing was available to replace your older appliances with new more efficient Grade 1 models, how likely would you take advantage of a scheme like this?
- |            |            |        |             |            |
|------------|------------|--------|-------------|------------|
| Not at all | Not Likely | Likely | Very likely | Absolutely |
|------------|------------|--------|-------------|------------|
- 25 a Are you a beneficiary of the Government's Comprehensive Social Security Assistance (CSSA) Scheme; or participating in HK Electric's Concessionary Tariff Schemes; or residing at transitional housing?
- |     |    |
|-----|----|
| Yes | No |
|-----|----|
- b If you answered Yes to the previous question, were you aware that HK Electric offers a one-off subsidy of up to HK\$5,000 for the replacement of existing household electrical appliances to more energy-efficient models or for the provision of new energy-efficient household electrical appliances?
- |     |    |
|-----|----|
| Yes | No |
|-----|----|