Public Media Campaign and Energy Conservation: A Natural Experiment in Singapore

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Abstract

Singapore uses public media campaigns to motivate public housing residents to conserve energy as part of its strategies to achieve sustainable energy goals. Using the energy conservation campaign conducted in selected housing estates in Singapore in January 2016, we ran a natural experiment to evaluate the effectiveness of the public campaign in nudging residents to save energy. Using a difference-in-differences (DID) design, we find an average saving of 0.4% in electricity consumption by residents in public housing blocks within 1.0-kilometer (km) of the campaign (treatment) zones compared to those outside 1.0 km. The interventions persisted through the post-intervention period. Using the cost-benefit analysis, we estimate approximately S$350,000 in welfare gains from this intervention program.

Keywords: *Energy Sustainability, Energy conservation, Media Campaign, Public Housing, Behavioral Intervention.*

JEL Code: D1, D4, R2, R3

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1. Introduction

During the 1970s, research primarily focused on countering the threat of fossil fuel depletion. However, many researchers put more attention to issues of global warming and biodiversity threats. Cities consume 60 to 80 percent of energy and are responsible for a large share of Greenhouse Gas (GHG) emissions (The United Nations, U.N., 2008). There is an urgent need for countries globally to find practical solutions to conserve energy and cut down harmful GHG emissions (Gardener and Stern 2002). The United Nations Framework Convention on Climate Change (UNFCCC) adopted the landmark Paris Agreement by setting a long-term goal to keep global warming below 2^0C. Singapore signed the Paris Agreement on April 22, 2016, pledging to reduce emissions intensity by 36% of the 2005 level by 2030.

In supporting the global effort to combat climate change, Singapore runs regular public media campaigns to create awareness of energy conservation and cultivate good energy consumption behavior (Appendix 1). In one of the campaigns running from January 2016 to June 2016, the National Environment Agency (NEA), in collaboration with the Town Council (the local municipal authority in Singapore), put up posters and banners in public places, including hawker centers.[1] The posters and banners containing salient energy conservation messages (see Appendix 2) made energy conservation pitches to residents and shared various energy tips for promoting good practices at home.

In our experiment, we evaluate the efficacy of the media campaign conducted by the NEA as a behavioral intervention mechanism to change public attitudes towards energy conservation. The paper's objectives are twofold: (1) to evaluate the effectiveness of the media interventions in nudging residents toward energy conservation; and (2) to quantify the economic effects of the public media campaign, if significant.

We sort housing blocks within a 1.0-kilometer (km) buffer zone from the closest hawker centers participating in the poster campaign into a treatment group and other housing blocks outside a 1.0 km but within a 3.0 km buffer zone into a control group. Our results showed a 0.4% reduction in the block-level electricity consumption when the campaign's posters and banners were put up. The effect persisted through the post-intervention period after removing the posters and banners. We find significant heterogeneity in behavioral responses of residents living in different housing types near the treated hawker center. Based on the block-level electricity bills, the campaign cost about S$30,000 and generated positive electricity savings of more than ten times at around S$350,000.

The paper contributes to the literature on behavioral interventions and energy conservation in two broad areas. First, many previous experiments involved only a small sample of residents Casado et al. (2017); (He & Kua, 2013; Sampei & Aoyagi-Usui, 2009). This study tested the efficacy of a public energy conservation campaign that covers more than 6,000 housing blocks or more than one million residents in Singapore. The study shows that the information campaign creates effective antecedent intervention in nudging people to save energy. We affirm Reiss and White (2008) study that public campaigns effectively appeal to residents to adopt good conservation energy behavior. The non-pricing information intervention strategies have weak intervention effects on changing the pro-environmental behavior of the public in the exercises conducted in Japan and the Netherland (Sampei & Aoyagi-Usui, 2009; Staats et al., 1996). Second, our results show persistent energy conservation behavior, where people keep their energy conservation behavior even after the campaign has ended. The results are

[1] In Singapore, hawker centers are open-air complexes with a collection of stalls selling various cooked food. These hawker centers near housing estates are popular places for residents to meet for lunch and dinner.

consistent with Allcott and Rogers (2014) study, which found that people continue to respond to repeated treatments after social comparison interventions were carried out through the US Opower program.

The remainder of this paper is organized as follows: Section 2 reviews relevant literature on various approaches to promoting energy. Section 3 describes the empirical design and data used in this study. It details Singapore's public media campaign that nudges residents to adopt good energy conservation practices at home. Section 4 discusses the empirical tests and results from the quasi-experiment. Section 5 concludes with policy implications.

2. Literature Review

Researchers have designed various randomized controlled trials (RCTs) and field experiments to nudge people to conserve energy. They apply two types of behavioral intervention strategies: antecedent and consequence strategies. The antecedent interventions start before desired actions. These take the forms of written or oral commitments (Katzev & Johnson, 1983; Pallak & Cummings, 1976), goal setting (Becker et al., 1981), information or knowledge about energy-related problems or solutions communicated via mass media campaigns, workshops, or tailored home energy audits and advice (Abrahamse et al., 2007; Jessoe & Rapson, 2014; Luyben, 1982; Winett, Hatcher, et al., 1982; Winett et al., 1985; Winett, Love, et al., 1982). The consequence strategies are conducted on individuals after behavioral actions have occurred. Feedback (Allcott & Rogers, 2014; Katzev et al., 1981; Schleich et al., 2013; Sexton et al., 1987; Winett, Hatcher, et al., 1982) rewards system (Agarwal et al., 2017; Allcott, 2011; Hayes & Cone, 1977) are examples of such interventions. Monetary interventions and information, such as nonlinear pricing, rewards, rebates, and carbon taxes, have shown promising results (Campbell, 2018; Fischer, 2008; Hargreavesn et al., 2010; Reiss & White, 2005; Yang et al., 2018; Yi & Li, 2018; Zhao & Li, 2020). In the meta-analysis covering 112 field trials and 13,998 subjects, Mi et al. (2021) showed that non-monetary intervention strategies could also produce effective nudging effects. Rajapaksa et al. (2019) found similar results: non-monetary incentives seem to have a greater impact than monetary incentives on households' resource consumption behavior. However, some interventions show mixed outcomes (De Young, 1993; Delmas et al., 2013; Osbaldiston & Schott, 2012).

Meta-analyses of various pro-environmental studies have shown that knowledge about the environmental problem and related actions or strategies can help bring about pro-environment human behavioral changes (Abrahamse et al., 2005; Hines et al., 1987;). Abrahamse et al. (2005) reviewed 38 papers on field experiments conducted in different countries using both antecedent and consequence types of interventions. Hines et al. (1987) found that antecedent interventions through knowledge of issues, action strategies, locus of control, attitudes, verbal commitment, and an individual's sense of responsibility effectively nudge environmentally responsible behaviors. Delmas et al. (2013) reviewed 156 energy conservation field trials in their meta-analysis and found that information on pro-environmental activities effectively reduced average energy consumption by 7.4%. They found that providing individualized audits and consulting is more effective than other consequence interventions, such as feedback and peer comparison. The same outcomes in the Eco-Living field trials in Singapore were reported by He and Kua (2013). Andor and Fels (2018) systematically reviewed 44 International studies on four behavioral interventions: social comparison, commitment devices, goal setting, and labeling, in inducing residential energy conservation. The meta-analysis attempted to disentangle causation from the correlation effect. The study found that the four reviewed interventions have significant potential effects but vary by degrees in reducing the energy consumption of residential households. The results suggest that policy interventions should evaluate the magnitude of potential impact before being rolled out.

Previous studies have estimated 6.4% to 7.4% in electricity savings through various antecedent and consequential studies. In a meta-analysis study, Buckley (2020) argued that the 1.9% to 3.9% electricity savings are more realistic estimates. He found that providing real-time feedback on electricity costs via in-home displays (IHDs), smart energy monitors (SEM), and other customized advice was more effective than general electricity-saving tips. Recent studies echoed the claims that using real-time feedback interventions could be enhanced by technologies that enable the transmission of high-frequency energy consumption data (Aydin et al., 2018; Buckley, 2020; Jessoe & Rapson, 2014). However, Hargreaves et al. (2013) found that feedback effects were not persistent in nudging households to reduce energy consumption. They tend to revert to the regular routines and practices over time. Despite using a small sample, the study showed that making information on energy consumption visible alone is not enough to motivate households to conserve energy. More field experiments were conducted in recent studies to evaluate feedback technologies using large samples.

Mass media campaigns have been one of the antecedent intervention mechanisms widely adopted to inform and educate people on pro-environmental motives. Sampei & Aoyagi-Usui, (2009) and Staats et al. (1996) showed that the mass media campaigns on climate issues conducted in Japan and the Netherland created public awareness but did not have lasting effects on pro-environmental behavior in people. Staats et al. (1996) found that knowledge and problem awareness in public media campaigns were ineffective in changing people's habits on energy consumption. They argued that people face a social dilemma when trading off personal comfort for a long-term social cause (such as prevention of ecological disaster) if there are uncertainties about collective actions and ways to achieve the goals. Studies have shown that such behavioral responses to the energy conservation nudges are correlated with attitudinal and demographic factors (Becker et al., 1981; Black et al., 1985; Brandon et al., 1999).

Reiss and White (2008) found that the public media campaigns in California, USA, effectively appealed to people to reduce energy consumption by about 7% of the pre-crisis consumption levels. However, the consumption rebounded once the campaign has discontinued. On the contrary, our findings of the large-scale energy-saving campaign conducted in Singapore showed a smaller reduction in electricity consumption of about 0.4% relative to the pre-intervention period. Still, the behavioral impact on households persisted into the post-campaign period. The media campaign in Reiss and White (2008) study effectively appealed to the public to restrain energy consumption during the campaign period. Our results using banners and posters with energy-saving tips in the campaign were not inconsistent with their findings, though with smaller and significant treatment effects of 0.4%. However, we find that encouraging residents to adopt better energy efficient practices in Singapore's energy conservation campaign instead of restraining usage in San Diego's campaign produced persistent treatment effects even into the post-campaign period.

Casado et al. (2017) found that public campaigns as an intervention mechanism are effective if messages are combined with information on economic benefits (Hargreavesn et al., 2010) and specific guidelines and tips on energy conservation (Brandon et al., 1999; Fischer, 2008; Steg, 2008). Before rolling out public awareness campaigns, evaluating the subjects' education level and how deviated it is from reality is also helpful. Loi and Loo (2016)[2] argue that a gap between perception and reality on what appliances consume the most electricity may exist. Understanding such information could help improve awareness and achieve better and long-term outcomes of campaigns. Our study affirms the above recommendation, where we find that public awareness of information on electricity consumption on various appliances generates more positive and sustainable outcomes.

Despite the extensive research into various intervention tools, finding the right combination of interventions to effect behavioral changes in people in energy conservation is still a significant challenge. Our results find optimism for using public campaigns to nudge people to conserve energy in daily activities.

3. Public Energy Saving Campaign in Singapore

Singapore is a highly urbanized city-state with a land area of about 719.1 km² and a population of 5.3 million, translating into a population density of over 7736 persons per km² (World Bank, United States Census Bureau). Facing land scarcity and natural resource constraints, Singapore depends on imported fuel to meet its energy requirements. In Singapore, natural gas is the primary fuel source constituting about 95% of the fuel mix for electricity generation in 2014 (Figure 1). The rest of Singapore's fuel mix comprises diesel and fuel oil (0.7%) and other energy products such as municipal waste and biomass (2.9%) and coal (Singapore energy statistics 2015).

[Insert Figure 1 here]

Figure 2 shows the major electricity consumers in Singapore as of 2015. The household sector is the third-highest electricity consumer after the industrial and commercial sectors. Among the non-contestable consumers[3], households consume more than half of the electricity, followed by commercial, service-related, and industrial sectors. (Singapore Energy Statistics 2017). The housing sector is a potential area for energy conservation. Hence, the government's effort to conserve energy in the housing sector significantly contributes toward a more sustainable environmental mission.

[Insert Figure 2 here]

In an energy conservation campaign in 2016, the NEA displayed educational banners and posters on energy conservation in 52 randomly selected hawker centers for six months, from January 2016 to June 2016. This program was intended to capture the population of all ages, from school-going children to older adults, to educate them on how small changes in regular chores can conserve household electricity usage. [4] Physical banners and posters visible at eye

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[2] They found that a survey that around one-fifth of the households in Singapore were aware of the existence of a nationwide energy reduction campaign conducted by the National Environmental Agency (NEA's 2012 Household Residential Energy Consumption Survey (NEA, 2013)). They found that many residents have the wrong impression of which appliance actually consumes the most energy (NEA, 2013), choosing refrigerator over air-conditioner as the top choice for their correct answer.

[3] From May 2019, Singapore electricity consumers are divided into two main groups: contestable consumers and non-contestable consumers. All households across Singapore will be contestable consumers (*See the Appendix for the explains of the two groups).*

[4] During the treatment period except for specific product advertisement such as electricity efficiency ticks, the government did not make any specific public television appeal for energy conservation in households, after checking through the government websites and other sources. The details of the timeline of various government initiated public campaigns are described in the Appendix.

level were used to convey information to a broader population.[5] These banners and posters were printed with the eye-catching headline "SAVE ENERGY SAVE MONEY." They also contained information on energy conservation practices that help nudge households to save electricity. The messages were written in four national languages, namely English, Chinese, Malay, and Tamil, to better communicate to residents of different ethnic groups.

There were no prizes or awards given out in the interventions. The posters and banners contain information on monetary benefits for electricity-saving tips that could nudge households to adopt those recommended practices.[6] A sample message was used: "*switching off the power sockets when not in use could help save up to $25 a year or buying an air-conditioners and refrigerator with 3 ticks (energy efficient appliances) will help save $350 and $75 a year, respectively*." (The samples of posters and banners are shown in the Appendix)

The banners were hung in hawker centers surrounded by public housing blocks (or "HDB blocks," named after the Housing and Developmental Board, the housing authority). Electricity consumption data in Kilowatts hour (KWh) for the HDB blocks within a buffer range of 3 km of the hawker centers were collected. The data cover the sample period from a year before the intervention (before the banners were put up) to six months after the intervention and six months after the posters and banners were taken off (the post-intervention period).

This study examines if energy-saving tips motivate families near the hawker centers to be more salient in energy conservation behavior than those who live further away and are less likely to visit the hawker centers. If such nudging were effective, we also want to test if such intervention effects are persistent. The findings from the field experiment provide valuable lessons that help to improve the efficacy of future public media campaigns.

4. Data and Identification

In Singapore, there are about 107 hawker centers distributed across the island. These hawker centers are located near HBD housing estates, selling cooked food for people in the neighborhoods. Singaporean citizens and Singapore's permanent residents above 21 years old are eligible to apply and lease stalls in the hawker centers to operate cooked food businesses. The operations and management of hawker centers, including tenancy, licensing, and allotment of stalls, come under the purview of the NEA.[7]

The NEA ran a public campaign with the Town Councils[8] by putting up posters and banners with energy-saving tips in selected hawker centers. The 6-month campaign spanned from January 2016 to June 2016. This study covers 52 hawker centers randomly chosen by the NEA

[5] When the program was designed and implemented in 2015, social media platforms such as Twitter or Instagram were not prevalent among users. Social media was mainly used by young adults aged 25 to 34 years. As commented by one of the referees, if the campaign was run with advertisements on social media and television, it will be harder to separate the treatment effects at the local level. Like the public appeal campaign in Reiss and White (2008), we may expect stronger overall treatment effects on a wider population.

[6] Casado et al. (2017), Delmas et al. (2013) and others show that messages in media campaigns that combine information on economic benefits and specific behavioral guidelines (such as energy-saving tips) increase the effectiveness of informative persuation and interventions.

[7] The NEA is responsible for the tenancy, licensing, and allotment of stalls, and it will advertise available stalls for lease in selected hawker centers via local newspapers, including Straits Times, Lianhe Zaobao, Berita Harian, Tamil Murasu (in the four national languages of Singapore).

[8] Like a local municipality, a Town Council is led by elected Members of Parliament (MPs) responsible for the day-to-day operations in managing the common property of HDB residential flats and commercial property within the town.

to participate in the public campaign in 2016. The large-scale field campaign covers more than 6,000 housing blocks.[9] Figure 3 shows the locations of the participating hawker centers.

[Insert Figure 3 here]

In the analyses, we use the block-level electricity consumption in Kilowatts hour (KWh) from January 2015 to December 2016. A unique 6-digit postal code is assigned to each public housing block in Singapore. We obtained the monthly electricity consumption data for 6296 HDB housing blocks from January 2015 to December 2016. We know the composition of housing type (such as two-room, three-room, four-room, and executive unit) for each block, but not the information on building attributes, such as unit size and floor height. We control for heterogeneity of buildings and room types using the postal code and the room type fixed effects.

In Singapore, it is common for families to eat out at least 3 to 4 meals a week at the local hawker centers. We assume that families will go to the nearest hawker centers within 1.5 km of their homes. We use the ArcGIS 10.2V to geocode each postal code and draw different buffer rings (based on 1km, 1.5 km, and 3 km radius). Figure 4 plots the 1.0 km, 1.5km, and 3 km buffer rings around the hawker centers. Figure 5 shows the location of the hawker centers and HDB blocks within the different buffer rings.

[Insert Figure 4 here]

[Insert Figure 5 here]

Based on the buffer rings, we sort the treated HDB blocks into two treatment groups, i.e., "Treat Group =1": one within 1.0 km and one within 1.5 km of the treated hawker centers participating in the NEA campaign.[10] The control group consists of HDB blocks located outside 1.5 km but within 3.0 km, i.e., "Treat Group =0". We restrict the outermost ring at 3.0 km to control the boundary discontinuity and exclude HDB blocks outside this ring from the sample. We compare the intervention effects on those HDB residents living within 1.0 km and 1.5 km buffers (the treatment groups) of the hawker relative to those outside the 1.5 km buffer (the control group).

To compare the HDB block density surrounding the treated and control zones, we conducted a *t-test* of the HDB block samples within 1.0 km and outside 1.0 km of the hawker centers. The t-test result[11] is insignificant, indicating that the density of HDB blocks is evenly distributed between the treated and control zones hawker centers. There is no selection bias in the distributions of sample HDB blocks around the hawker centers.

5. Empirical Methodology

We use the difference in differences (DID) empirical strategy to capture and quantify the intervention effect of the public media campaign conducted by the NEA. We estimate the DID model using the electricity consumption data of more than 6000 HDB housing blocks from January 2015 to December 2016. The DID. model specification with Y_{ijt} as the dependent variable denoting the average electricity consumption in the logarithm term for housing type *i* in block *j* in month *t* is written as:

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[9] Based on an average household size of 3, and a block consisting of approximately 80 housing units, the experiments may cover a sample of nearly 1.45 million residents

[10] The results of the treatment effect for different buffer ranges and reason for selection of 1km as the cutoff is given in table 9 in the appendix of the paper.

[11] See Tables 6 and 7 in the Appendix.

$$y_{ijt} = \alpha_1 + \beta_1 \, Treat\ Group + \beta_2 \, Treat\ Time + \beta_3 (Treat\ Group \times Treat\ Time) + \beta_4 \, Post\text{-}Treat + \beta_5 (Treat\ Group \times Post\text{-}Treat) + \lambda_{ij} + \epsilon_{ijt} \quad (1)$$

where "Treat Time" is a dummy variable that takes a value of 1 for the intervention period. The posters and banners were made salient from January 2016 to the end of June 2016; otherwise, the value is 0. "Post-Treat" is a dummy variable used to capture the post-intervention effect of the program from July 2016 to December 2016, during which the posters and banners were taken off.

In the specification, the coefficient of interest, β_3 (interaction term), captures the impact of the intervention program on energy consumption when the posters and banners were made salient. The coefficient β_4 on the "Post Treat" variable captures the persistence of the intervention effects in the post-intervention period, and the coefficient β_5 captures the post-intervention effect on the electricity consumption pattern for the treated group during the period the posters and banners were taken off (July 2016- December 2016). λ_{ij} are the fixed effects controlling housing, neighborhood, and temporal heterogeneities. We include the month and year, the room type, and district fixed effects in the specification. α_1 is the intercept term; ϵijt is the error term.

We use two different treatment groups in the DID models. "Treat Group (1.0 km)" includes HDB blocks within the 1 km buffer zone of the treated hawker centers. HDB blocks located beyond a 1km to 3km buffer zone are the control group in the model. We set the outer limit for the control group at 3 km and assume that residents will not go to hawker centers outside the 3 km buffer zone to have their meals. We then repeat the model using the "Treat Group (1.5 km)" that extends the treatment buffer zone to 1.5 km and the control buffer zone to 1.5 km to 3 km. While we test heterogeneous treatment effects for the two treatment buffer rings, we keep the 1.0 km treatment zone as the baseline results and use this treatment group in other robustness tests.

6. Empirical Results

6.1. Tests for Parallel Pre-Trend

We use the model specification in Equation to test the parallel pre-trend of electricity consumption for the treatment and the control groups using the pre-dated period, such that "Pre-trend" is 1 from July 2015 to December 2015, and otherwise 0 from July 2015 to June 2016. The dependent variable is the Log-average electricity consumption by housing type within a block. Columns 1 and 2 of Table 1 report the regression results for the two treatment groups (1.0km & 1.5km). The outer boundary for the control HDB blocks was set at 3km to control boundary discontinuity. We control neighborhood heterogeneity and seasonality effects using the district-level and the month and year fixed effects.

The results show that the coefficient of interest, "Treat Group × Pre-trend," is statistically insignificant, suggesting that the treatment and the control groups have similar electricity consumption patterns before the onset of the intervention from January 2016 to June 2016. The electricity consumption patterns of households in the treatment and the control blocks are not different in the absence of interventions, thus confirming the parallel pre-trend.[12]

Figure 6 plots the average electricity consumption for the treatment (within 1km) and the control groups of the participating hawker centers. The graph again affirms the parallel trend in the consumption pattern for the two groups before the intervention period.

[Insert Table 1 here]

[Insert Figure 6 here]

6.2. Intervention Effects

We estimate the main regression in Equation (1), where "Treat Time" is the treatment time dummy that takes the value of 1 during the *intervention period from January 2016 to June 2016* and 0 otherwise. Columns (1) of Table 2 show the results with the treatment groups represented by HDB blocks within 1km of the participating hawker centers. Column 2 extends coefficients on the treatment group are negative but insignificant, which implies that the electricity consumption behavior of households in the treatment and the control groups are, on average, not dissimilar.

However, the coefficient on "Treat Group × Treat Time" is statistically significant in Column 1. The result suggests that HDB housing blocks within 1 km from the participating hawker centers consume approximately 0.4% on average lower electricity consumption than blocks outside the 1km range (the control group) during the intervention period. The public campaign effectively nudged households near the hawker centers with energy-saving posters and banners to consume less electricity than those who did not visit the hawker centers. However, in Column 2, where we extend the treatment zone to 1.5 km, the sign on the interactive term is negative but statistically insignificant. The district-level (three-digit postal code) and the month and year fixed effects are included to control unobserved spatial and seasonal effects. We also control building-level heterogeneity using the room-type fixed effect (such as two-room, three-room, four-room, and executive-type (five-room) housing units).

Columns 3 and 4 report the results where we use the 6-digit postal code fixed effects for the treatment zone 1 km and 1.5 km instead of the district-level fixed effects. Column 3 shows an improvement in the R-square from 71% to 82%, with significant results. Insignificant results are reported in column 4 with a negative sign on the coefficient.[13]

[Insert Table 2 here]

6.3. Income Effect

Large houses, such as four-room or five-room flat types, are more expensive. There is a natural sorting of low-income families into smaller public housing units in Singapore. Policies such as

[12] The daily temperature variations affect the energy consumption behaviors of residents in both treatment and control groups of housing blocks. If residents in the treated blocks reduce consumption less during hot and humid days, the estimated treatment in our results could represent the lower bound of the treatment effects.

[13] To check the robustness of the results, we repeat the above model and cluster the standard errors at the postal code level and the results are still robust and significant (*The results are reported in Table .8 in the appendix section of the paper*).

step-up grants impose further constraints on second-time buyers with income not exceeding S$7000, restricting them to purchasing only three-room and smaller housing units in non-mature housing estates. We, therefore, expect housing size to be highly correlated with the income of households, i.e., higher-income households are more likely to occupy bigger housing types.

Table 3 reports the results of heterogeneity testing where we interact with the DID term, "Treat Group ×Treat Time," with the housing type dummies, which include "4-room" and "5-room" types, with the smaller housing types ("2-room" and "3-room" types) as the reference. The triple interaction term captures the treatment effect on different housing types during the treatment time. The results on the triple interaction terms suggest that the treatment was more effective on families in larger housing types. The results imply that income elasticity in saving electricity is stickier for low-income families, who are more conscientious in cutting down consumption. Therefore, the intervention has a relatively weaker effect on changing the electricity consumption behavior of these families than high-income families.

Our results align with Agarwal et al. (2017), which show that the intervention effects are more effective in high-income families. Another possible explanation is that bigger housing flats may have more family members who may have come across the energy-saving messages when visiting hawker centers. They may have responded to the messages and nudged their family members to adopt good practices at home to save electricity.

[Insert Table 3 here]

6.4. Falsification Test – Non-Participating Hawker Centers

For the falsification tests, we ran the above regression model (Equation 1) for a group of hawker centers not selected to participate in the campaign. To avoid possible spillover effects from the treatment housing blocks, we carefully select these non-participating hawker centers. Overlapping housing blocks within 1.5 km of the "true" treatment buffer rings of the adjacent treated hawker centers are excluded. We create the buffer rings of 0.5 km, 1.0 km, and 1.5 km around these non-treated hawker centers and sort HDB blocks within these rings into the "false" treatment group. We did not include those HDBs beyond the 1.5 km buffer ring to avoid overlapping HDB blocks that may fall into the adjacent "true" treatment group.

Columns 1 and 2 in Table 4 present the results of the "false" treatment of HDB blocks within 0.5 km and 1.0 km rings of the non-participating hawker centers. The coefficients on the DID term are insignificant, indicating that HDB residents living within 0.5 km to 1.0 km of non-participating hawker centers did not change their electricity consumption patterns during the intervention period. Residents in the "false" treatment HDB blocks near the non-participating hawker centers did not respond to the public campaign. Their electricity consumption behaviors were not different from those living in the control HDB blocks more than 1.0 km away from the hawker centers.

The falsification results affirm that the public campaign was effective and targeted in nudging only residents living near the participating hawker centers. Only residents near the participating hawker centers subject to the poster and banner intervention responded by lowering the electricity consumption during the campaign months. The same intervention effect was not found in comparable housing blocks near non-participating hawker centers.

[Insert Table 4 here]

6.5. Post-Treatment Effect

Table 5 reports the regression results during the post-intervention period from July 2016 to December 2016, after the posters and banners were removed from the hawker centers. We define the "Post Treat" dummy to have a value of 1 for the whole post-treatment period from July 2016 to December 2016 and 0 otherwise (Column 1). We further subdivide the post-treatment period into two segments: Column (2): the "Post Treat" period from July 2016 to September 2016; and Column (3): the "Post Treat" period from September 2016 to December 2016. We interact the respective post-intervention period dummies with the treatment block within 1 km of participating hawker centers. The interactive variable, "Post Treat period × Treat Group," captures the persistence of the intervention effects after the public campaign.

The positive and significant coefficients on the interactive variable show that the intervention effects from the energy-saving campaign persisted into the post-treatment period from July 2016 to December 2016. The persistence in the treatment effect is observed in HDB Blocks' residents within 1.0 km from the participating hawker centers and remains stable throughout the post-intervention period. The public campaign has effectively nudged residents near the participating hawker centers to save electricity during the treatment period, i.e., from January 2016 to June 2016. The residents' behavioral changes persisted even after the campaign had ended (from July 2016 to December 2016). Unlike Sampei and Aoyagi-Usui (2009) study that found no lasting treatment effects in many public media campaigns, our study shows persistent effects that lasted nearly six months after the NEA.'s energy-saving campaign had ended.

[Insert Table 5 here]

6.6. Cost-Benefit Analysis

The above analyses find a saving of about 0.4% in electricity consumption during the intervention period from January 2016 to June 2016. To translate the intervention effect into monetary value, we calculate the total savings in electricity of S$394,009 for the housing blocks within 1km of the treated hawker centers from January 2016 to June 2016. According to the NEA, the total cost of the public campaign was approximately S$30,000, excluding the labor cost. If we add the labor and transportation costs, the campaign's cost was estimated at around S$40,000, and the net welfare gain from the public campaign was estimated at S$354,000.

If we omit possible peer effects by friends and relatives of families living close to the participating hawker centers, this amount could underestimate the true treatment effects. The treatment groups of households may discuss with friends and relatives living in nearby housing blocks outside the treatment zone and nudge them to adopt the energy-saving practices. Other people who may not be in the treatment neighborhoods but patron hawker centers because of good food may also access the banners and posters in the hawker centers. These people may also have been aware of the campaign and brought the energy-saving messages back home to nudge their family members to change their energy consumption behaviors. Suppose we were able to measure more extensively the treatment effects through the peer and neighbors, the public campaign conducted by the NEA could have resulted in electricity savings or more than the estimated 0.4%. Aside from the monetary benefits accrued to families who were nudged to change energy consumption behavior, the campaign, if succeeded, could instill in families more persistent awareness and salience to take extra steps to conserve energy. The campaign could also have a broader impact on creating a more sustainable energy source, averting the twin threats of depleting fossil fuel sources and harmful GHG emissions.

6.7. The pre-and post-intervention surveys

The pre-intervention survey was conducted to assess the awareness of residents on energy-efficient practices and appliances. We conducted two rounds of surveys, one in December 2015 before the start of the campaign and one in August 2016 after the campaign ended. The surveys cover 200 respondents of different races, gender, and age each round. (*The survey results and details on how it was conducted are given in an online Appendix*).

The rationales and goals of conducting the two surveys, one before and another after the campaign, were to determine if the energy conservation messages were communicated effectively to residents in the treated blocks. The survey helped to assess how sensitive the residents were towards electricity consumption in their homes. The behavioral changes could be observed before and after the campaign.

The pre-intervention survey reveals that residents did not pay close attention to electricity consumption at home, and only some regularly checked their electricity bills. Many respondents would switch lights, fans, and appliances off when not used; few used more energy-efficient appliances, including fluorescent and LED lights. The pre-intervention survey shows that many residents were unaware of alternative ways to save electricity. For example, they could use more efficient ways than electric air-pots to boil and keep water hot and reduce air-conditioning usage by using fans when sleeping once the room cools down. Like in the Netherlands (Brounen & Kok, 2011), the adoption rate for energy-labeled appliances is low as people feel that appliances with energy labeling ticks are more expensive and cannot comprehend the monetary benefits of their usage.

After removing the posters and banners, a post-intervention survey was conducted in August 2016. The survey was done to supplement the empirical results of the intervention. The survey questions were based on whether the residents could recall the messages on the posters and if they could gain relevant information regarding energy efficiency. The survey covered about 200 respondents who stayed within 2km of the treated hawker centers. The post-intervention survey revealed that residents living near the participating hawker centers noticed the posters and banners put up during the campaign. 35% of the residents recalled the energy conservation messages. 42% may have changed their electricity consumption behavior at home and noticed a drop in their electricity bills. In contrast, the others were unsure or did not check their electricity bills.

The surveys showed an incremental rise in residents' awareness of energy-saving practices after the 6-month campaign. These results provide supplementary evidence to support the main empirical findings in the paper. The surveys show that communication campaigns that include information on economic benefits and special behavioral guidelines on efficient usage (including energy-saving tips) effectively nudge residents' energy consumption behaviors. The results add new evidence to the early studies (Abrahamse et al., 2007; Casado et al., 2017; Delmas et al., 2013; Loi & Loo, 2016; Spence et al., 2014; Whitmarsh, 2009).

7. Discussion and Conclusion

Singapore's government has experimented with various interventions to motivate residents to conserve energy.[14] In a survey conducted by the NEA in 2012 (*Household Residential Energy Consumption Survey, NEA 2013*), Tian Sheng et al. (2016) found that the residents lacked knowledge of energy-efficient appliances and electricity consumption, thus creating a gap between perception and reality. They suggested that campaign awareness can be improved by providing relevant information across a broader population to achieve more effective and

[14] Timeline and details of the various interventions are included in the appendix of the paper.

sustainable results. In January 2016, the NEA ran a large-scale public campaign covering the population of all ages, from school-going children to the elderly, by putting up banners and posters with energy conservation messages and tips in selected hawker centers. Families in nearby public housing blocks (within 1km) were likely to regularly visit the hawker centers and be salient to information on the banners and posters. The knowledge and awareness of economic benefits and energy conservation tips could improve the effectiveness of nudging to change residents' energy consumption behaviors.[15]

This paper quantifies the effect of a large-scale field intervention campaign in Singapore. The results show that the treatment effect is significant for those HDB blocks within 1km of the hawker centers. The treated HDB blocks showed a reduction in electricity consumption by approximately 0.4% during the campaign period relative to other control blocks located more than 1.0 km from the hawker centers. The treatment effects become insignificant when the treatment buffer ring increases beyond 1.5 km of hawker centers. The treatment effects persisted in the post-treatment period even after the campaign ended. The results withstood a battery of heterogeneity and robustness tests. The results suggest that residents in larger HDB housing units reduced their electricity consumption more than residents in smaller housing units.

Reiss and White (2008) reported a 7% reduction in electricity consumption in response to a large-scale public appeal campaign in the U.S. The conservation of such a large magnitude comes mainly from cutting the use of large electricity consumption appliances, such as air conditioners and dryers. The study also reports a rebound effect once the public appeal campaign was over. This paper reports a reduction in electricity consumption in a smaller magnitude of about 0.4%, but the effect is persistent through the post-intervention period. More people were aware of the benefits of using energy-efficient appliances, such as changing to LED lighting or using energy-efficient appliances with more energy-labeling ticks and adopting minor conservation habits. In Singapore, about 24% of household electricity consumption is attributable to air conditioning. It is unlikely that residents would sacrifice air-conditioning comfort, which otherwise would have translated into even larger savings. This is also evident in a survey by the NEA in 2017, which showed that 71% of the respondents valued comfort and would not completely switch from air-conditioning to fans.[16]

We ran the pre-and post-intervention surveys, which complemented the empirical results. We found that 35% of the respondents could recall the messages on the posters and banners during the post-intervention survey, and 42% noticed a drop in their electricity bills.

Based on the estimated average marginal treatment effect of 0.4% and the average monthly block-level electricity consumption, the aggregate savings in electricity bills for HDB residents near the hawker centers are estimated at S$350,000 during the intervention and post-intervention periods from January 2016 to December 2016. The economic benefits from the interventions were more than ten times the estimated costs of S$30,000 incurred in running the public campaign, including designing, printing, and putting up the educational posters and banners (as confirmed by NEA). The estimated savings could still be an under-estimation of

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15 The treatment effects are stronger because the messages disseminated through the campaign conducted by the government were more credible in nudging residents' behavioral changes. However, our study cannot determine if the effects will differ for other campaigns that promote patriotism organized by the government.

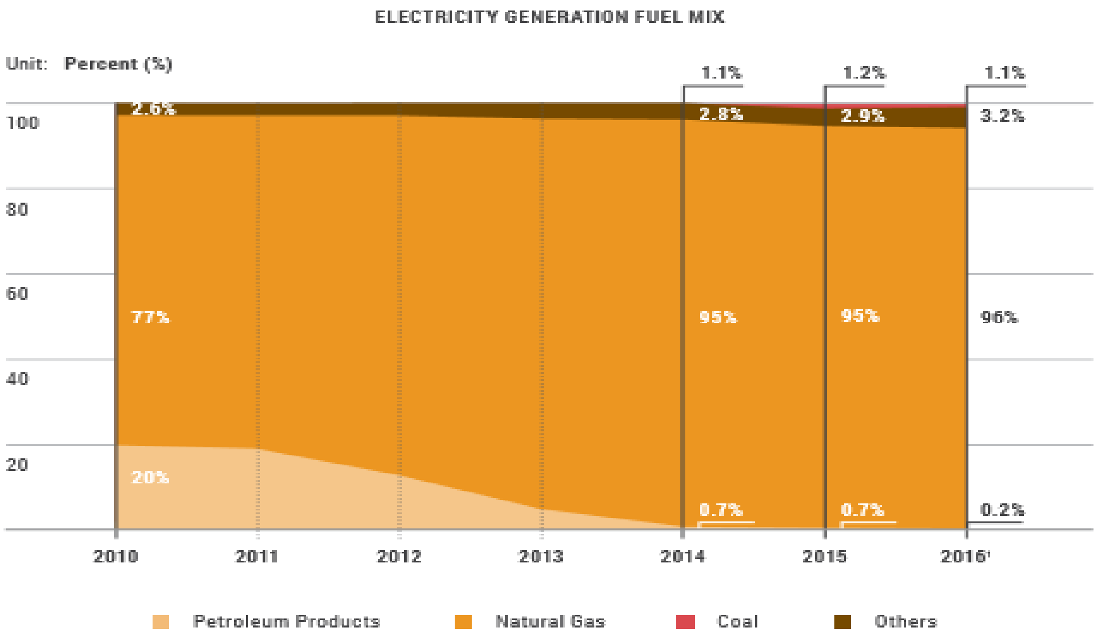
16 "Singapore's household electricity consumption up 17 per cent over past decade," by Zhaki Abdullah, Straits Times, May 5, 2018

the true effect if we could capture peer effects that could spill over to people living elsewhere who may not have visited the hawker centers during the campaign period.

Many studies showed that public campaigns did not have persistent effects on residents' energy conservation behavior (Reiss & White, 2008; Sampei & Aoyagi-Usui, 2009; Staats et al., 1996). There were significant rebound effects, where the consumption pattern reverted to the pre-intervention level after removing the intervention. Therefore, there is a need to reinforce public awareness regarding using energy consumption appliances, available substitutions, and associated economic benefits. However, this study shows encouraging results in nudging residents by educating them on energy savings by changing to more energy-efficient appliances. The intervention messages with monetary savings produce persistent effects in energy conservation.

FIGURES AND TABLES

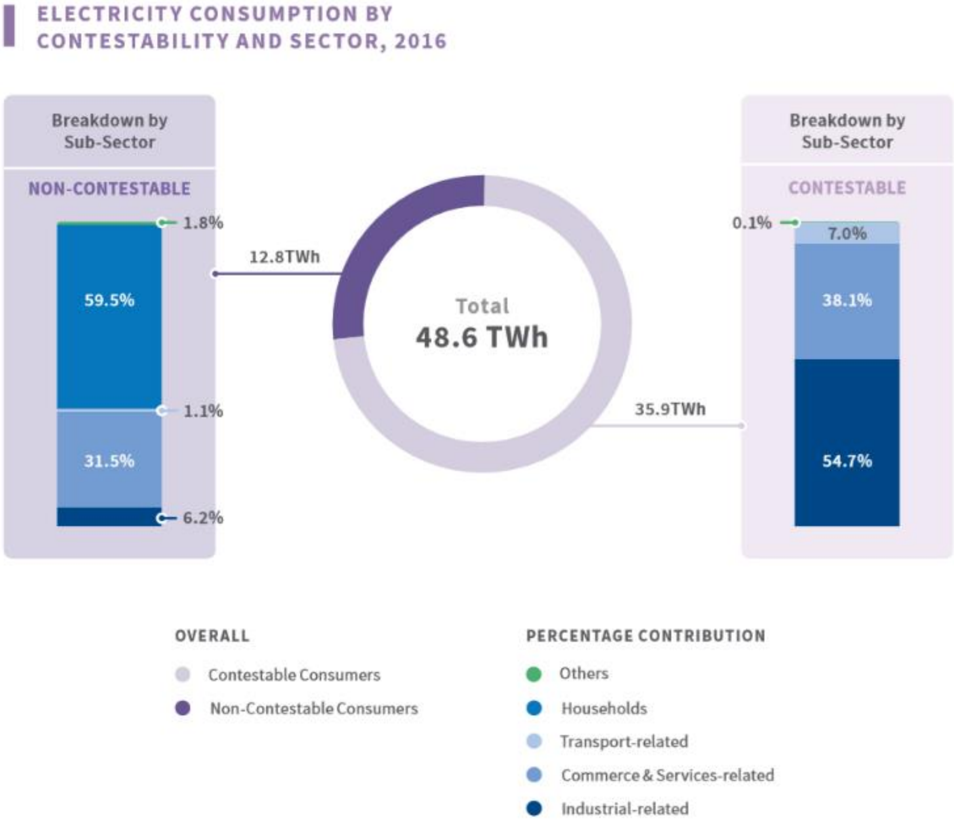
Figure 1. Singapore Electricity Generation Fuel Mix



Source: Singapore energy statistics 2016

Note: The figure above shows the fuel mix composition used for the generation of electricity in Singapore.

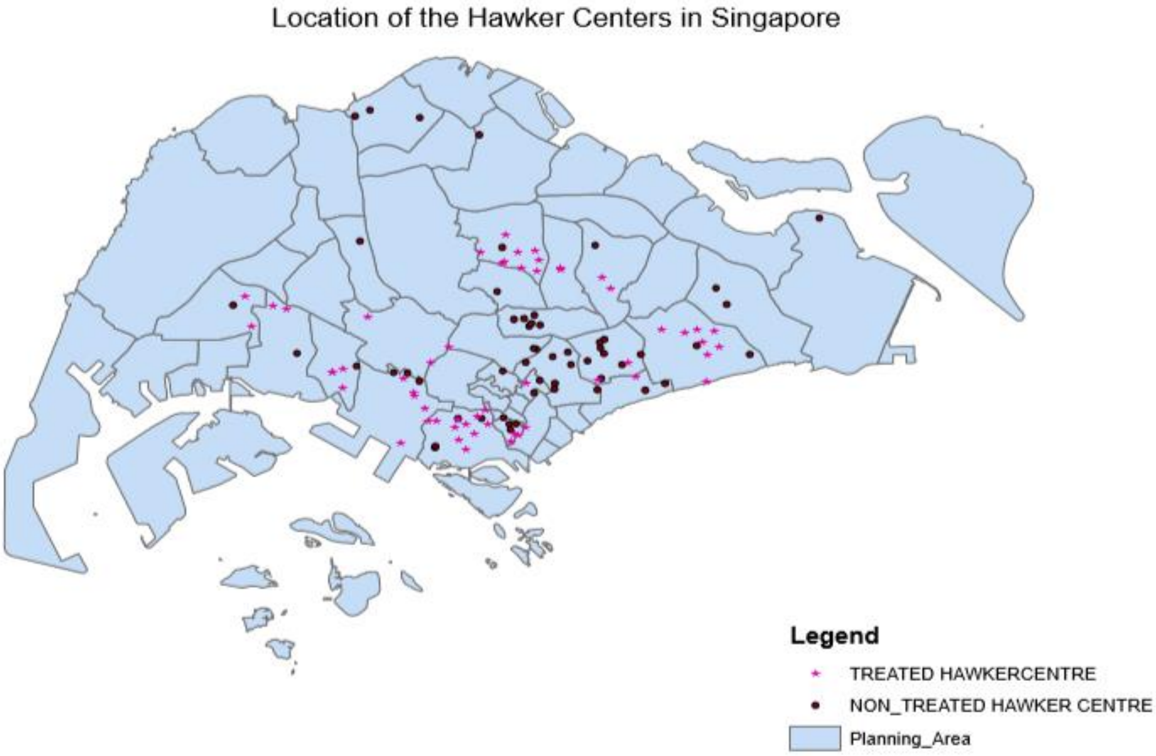
Figure 2. Electricity Consumption by Contestability



Source: Singapore Energy Statistics 2017.

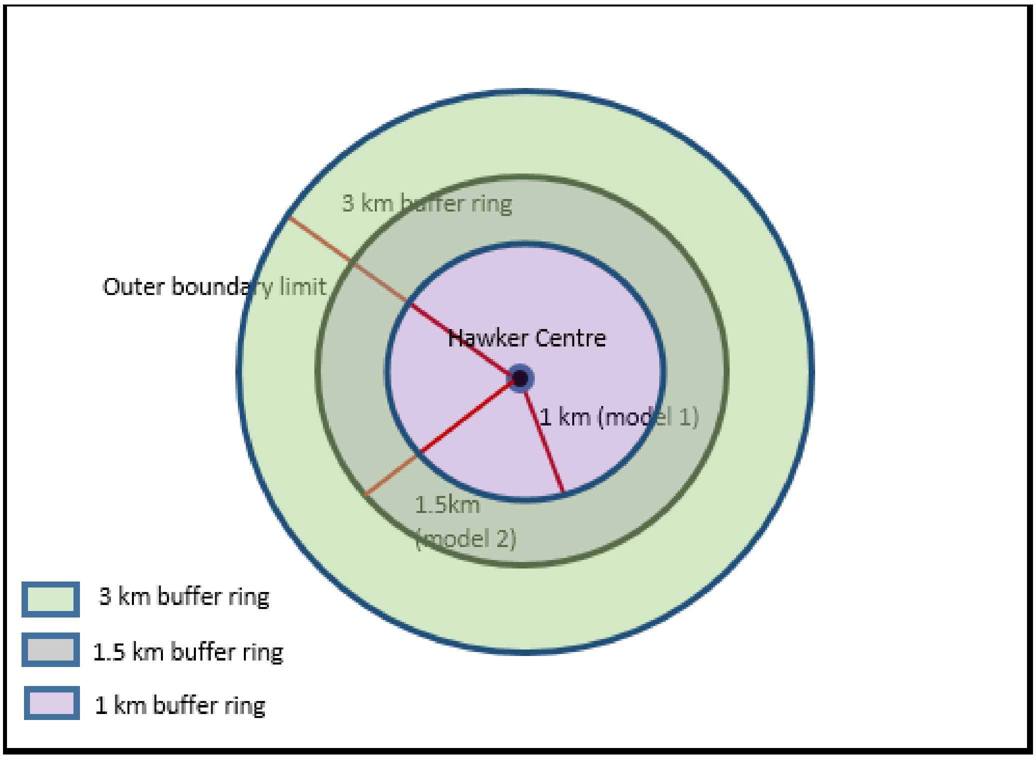
Note: The figure above shows the breakdown of electricity consumption by the contestable and non-contestable consumers of electricity in Singapore.

Figure 2. Location of the Treated and Non-Treated Hawker Centres in Singapore



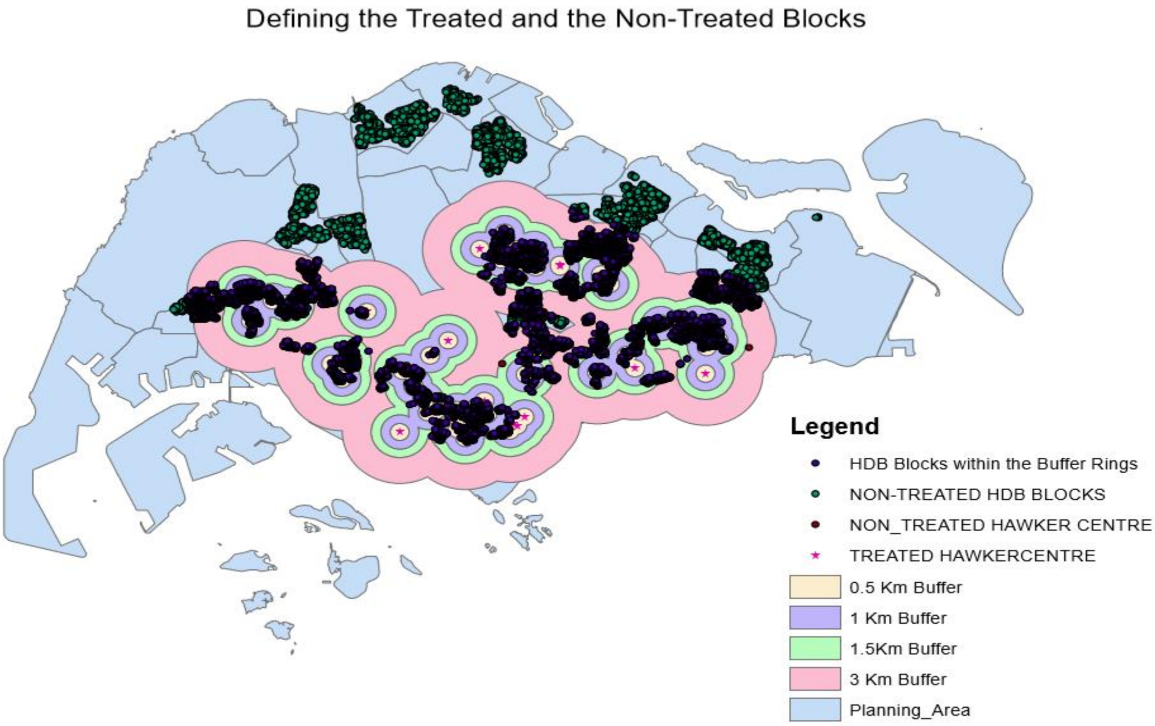
Note: The Figure shows the location of the treated hawker centers where educational banners and posters were placed on electricity conservation. The area demarcated by the lines shows the planning areas in Singapore. Figure reconstructed with ArcGIS using the geographic information system (GIS.) data. Information on the treated Hawker centers was obtained from NEA.

Figure 3. Illustration of the Buffer rings used in defining the treated and the control groups



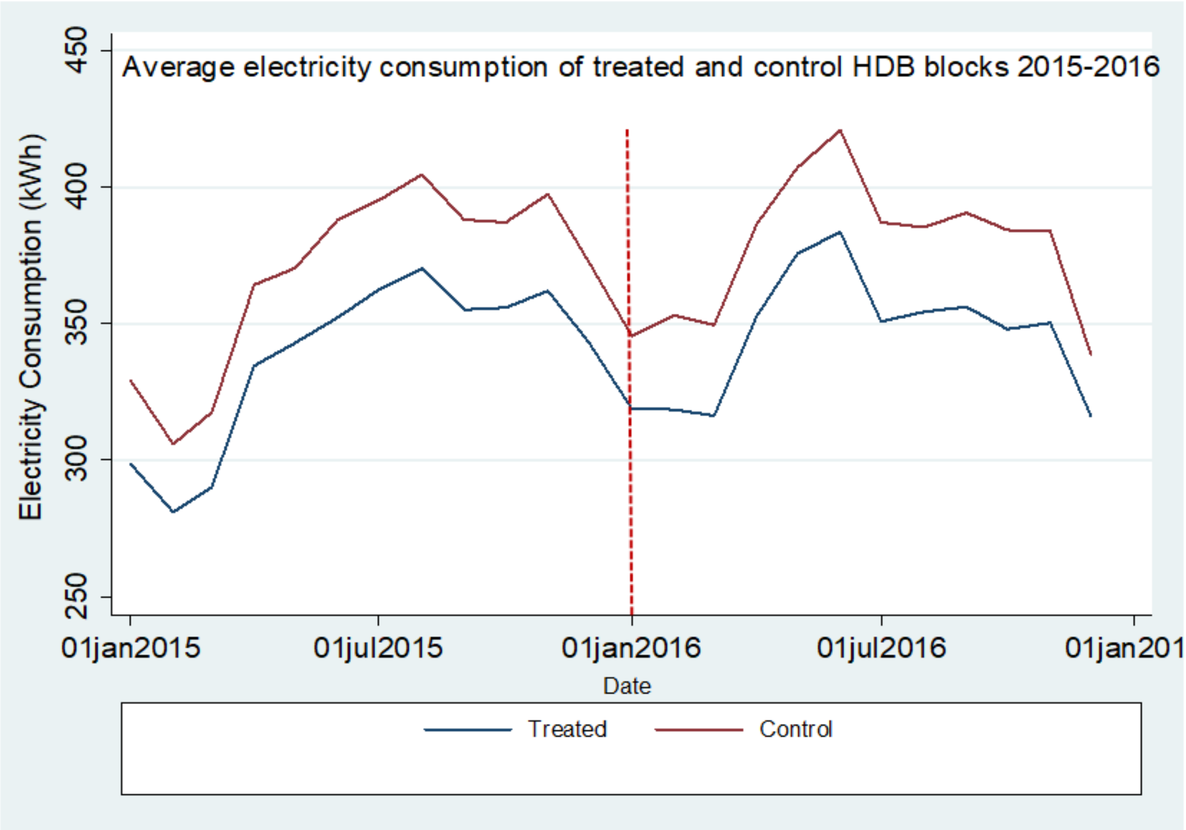
Note: The figure illustrates the buffer rings used to define the treated and the control groups in the regression. In model (1), we define a 1.0 km radius from the hawker center as the treated and beyond 1km to 3 km of the Hawker center is defined as the control group. For model (2), a 1.5 km radius from the hawker center is defined as treated, and a control group is defined beyond 1.5km to 3km.

Figure 4. Locations of the Treated Hawker Centres



Note: The figure shows the locations of the hawker centers around Singapore where the educational posters and banners were put up. The different color shaded rings represent the buffers that define the treated and control Group of HDBs. We set the outermost boundary of a control group as 3.0 km, beyond which the HDBs are not considered in our sample. The image is constructed with ArcGIS using geographic information systems (GIS) data. Data on the treated hawker centers is obtained from the NEA.

Figure 5. Average Electricity Consumption Trend Graph



Note: The figure shows the average electricity consumption of the treated and the control HDB blocks from January 2015 to December 2016. The dotted vertical lines represent the start of the Intervention period (January 2016), when the posters and banners were put up in hawker centers. The figure plots the average electricity consumption (Kilowatt hour) of treated HDB blocks within 1km of the treated hawker centers and the control HDB blocks (those beyond 1km up to 3km buffer range).

Table 1. Pre- Intervention Consumption Trend

Date Frequency	Monthly frequency	
Model estimator	(1) 1.0km	(2) 1.5km
Treat Group × Pre-Trend	0.002 (0.001)	-0.003 (0.001)
Treat Time (July 2015-Dec 2015)	0.114*** (0.001)	0.116*** (0.001)
Treat Group	-0.002 (0.004)	0.0003 (0.003)
Constant	5.942*** (0.002)	5.941*** (0.002)
Observations	241180	241180
R-square	0.71	0.71
District level Postal code fixed effects	yes	yes
Month and year fixed effects	yes	yes
Room type fixed effects	yes	yes
Robustness Clustering of std. errors (postal code level)	yes	yes

*Notes: The above table reports the baseline regression results when the treatment time is pre-dated from July 2015 to December 2015 instead of January 2016 to June 2016. Treat Group stands for the Treatment Group, Treat time for the treatment time, and the Treat Group x Pre-Trend is the coefficient of interest which is the interaction term between Treat Group and Treat time. We use the first 3 digits of the 6-digit postal code to control for heterogeneity at the district level. Treat time is a dummy variable that will take the value of 1 from July 2015 to December 2015 and is equal to ZERO otherwise. The dependent variable is the Log of the average electricity consumption for different housing types within a block. Model (1) is the regression results for those housing blocks within 1 km of the treated blocks. Model (2) is the results for housing blocks within 1.5km of the treated hawker centers. The robust standard errors are given in parentheses. *** Significant at the 1% level, ** Significant at the 5% level, *Significant at the 10% level.*

Table 2. Main Regression Results

Data Frequency	Monthly Frequency			
Model estimator	(1) 1.0 km	(2) 1.5 km	(3) 1.0 km	(4) 1.5 km
Treat group × Treat Time	-0.0041** (0.001)	-0.0008 (0.001)	-0.0042*** (0.001)	-0.0009 (0.001)
Treat Time	0.117*** (0.001)	0.116*** (0.001)	0.117*** (0.001)	0.116*** (0.001)
Treat Group	-0.0004 (0.001)	-0.0001 (0.001)	0.427*** (0.053)	0.426*** (0.053)
Constant	5.941*** (0.001)	5.941** (0.001)	5.756*** (0.023)	5.689*** (0.031)
Observations	241180	241180	241180	241180
R-squared	0.71	0.71	0.82	0.82
Room type fixed effects	yes	yes	yes	yes
Month and year fixed effects	yes	yes	yes	yes
District level-Postal Code Fixed Effects	yes	yes	no	no
6-digit Postal Code fixed effects	no	no	yes	yes

*Note: The above table reports the regression results where the dependent variable is Log of the average electricity consumption for different housing types within a postal code. Treat group stands for the Treatment Group, Treat Time stands for the Treatment Time and the Treat Group x Treat Time is the coefficient of interest and is the interaction term. We use the first 3 digits of the 6-digit postal code to control for heterogeneity at district level (District level Postal Code Fixed Effects). Treat time is a dummy variable which will take the value of 1 during the intervention period (January 2016 to June 2016) and is equal to ZERO otherwise. model (1) is the regression results for those housing blocks that are within 1km of the treated hawker centres and model (2) is the results for housing blocks within 1.5km from the treated hawker centres. Column 3 & 4 are the results of the regression where we use the 6 digit postal code fixed effects instead of the district level postal code fixed effects.*** Significant at the 1% level, ** Significant at the 5% level, *Significant at the 10% level*

Table 3. Income Effect

Data frequency	Monthly frequency	
Model estimator	(1) (1.0km)	(2) (1.5km)
Treat Group × Treat Time	-0.002	0.001
	(0.002)	(0.002)
Treat Time	0. 117***	0.116***
	(0.001)	(0.002)
Treat Group	0.003**	0.003**
	(0.001)	(0.001)
4-Room	0.340***	0.341***
	(0.001)	(0.001)
5-Room	0.529***	0.530***
	(0.001)	(0.001)
Treat Group(1.0km) ×Treat Time ×4-Room	-0.005*	
	(0.002)	
Treat Group(1.0km) × Treat time × 5-Room	-0.001	
	(0.003)	
Treat Group(1.5km) ×Treat Time ×4-Room		-0.0034
		(0.002)
Treat Group(1.5km) × Treat time × 5-Room		-0.002
		(0.002)
Constant	5.617***	5.616***
	(0.001)	(0.001)
Observations	241180	241180
R-squared	0.69	0.69
Month and year fixed effects	yes	yes
District level Postal code fixed effects	yes	yes

*Note: The table above reports the regression results where the dependent variable is the Log of the average electricity consumption for different housing types within a postal code block. Model (1) is the regression results for those housing blocks that are within 1km of the treated hawker centres. Model (2) is the results for housing blocks that are within 1.5km from the treated hawker centres. Treat Group is the treatment group, Treat Time is the treatment time from January 2016 to July 2016 and Treat group X Treat Time is the interaction term. Treat Group(km) ×Treat time × 4,5-Room is the triple interaction term between treatment Group that is within 1km and 1.5km of the treated hawker centres, the treatment time and the different types of public housing flats for 4 room and 5 room within a block which is suffixed as 4-room and 5-room respectively. The standard errors are given in parentheses. *** Significant at the 1% level, ** Significant at the 5% level, *Significant at the 10% level.*

Table 4. Falsification Test

Date Frequency	Monthly frequency	
Model Estimator	(1) 0.5 km	(2) 1 km
“False” Treat Group × Treat Time	-0.0003 (0.004)	0.0013 (0.003)
Treat Time	0.070*** (0.002)	0.069*** (0.002)
Treat Group	0.004 (0.003)	0.007*** (0.002)
Constant	5.48*** (0.016)	5.48*** (0.016)
Observations	62154	62154
R-squared	0.59	0.59
Room Type fixed effects	yes	yes
Time fixed effects	yes	yes
District level postal code fixed effect	yes	yes

*Note: The above table reports the falsification test as a robustness check. The dependent variable is the Log of the average electricity consumption for different housing types within a postal code. Treat group stands for the Treatment Group, Treat Time for the Treatment Time (Jan 2016 to June 2016), and the "False" Treat Group X Treat Time is the coefficient of interest and is the interaction term. We use the first 3 digits of the 6-digit postal code to control for heterogeneity at the district level (district level postal code fixed effect). Treat time is a dummy variable with a value of 1 during the intervention period (January 2016 to June 2016), or otherwise, 0. Models (1) and (2) are the regressions for housing blocks within 0.5 km and 1km of the non- treated hawker centers, which do not fall in the buffer range of treated hawker centers. The standard errors are given in parentheses. *** Significant at the 1% level, ** Significant at the 5% level, *Significant at the 10% level*

Table 5. Post Treatment Effect

VARIABLES	Post treatment period(July 2016 to December 2016) (1)	Post treatment period_1 (July 2016-September 2016) (2)	Post treatment period_2(October 2016-December 2016) (3)
Post Treat period× Treat Group	-0.005***	-0.004**	-0.004***
	(0.001)	(0.001)	(0.001)
Treat Group	-0.0002	-0.0009	-0.0008
	(0.004)	(0.004)	(0.004)
Post Treat Period	-0.113***	-0.058***	-0.093***
	(0.001)	(0.001)	(0.001)
Constant	5.324***	5.345***	5.340***
	(0.034)	(0.035)	(0.035)
Observations	241,180	241,180	241,180
R-squared	0.71	0.70	0.71
Room fixed effects F.E.	yes	yes	yes
Month and year fixed effects	yes	yes	yes
District level postal code F.E.	yes	yes	yes
Clustering at postal code level	yes	yes	yes

*Notes: The above table reports the regression results for the post treatment period from July 2016 to December 2016 during which time the posters and banners were taken off. The dependent variable is Log of the average electricity consumption for different housing types within a block. Treat group stands for the Treatment Group. Model (1) is the results for those housing blocks within 1km range of treated hawker centres during post Treat period July2016 to December 2016. Model (2) and (3) reports the results of those Treat Groups within 1km of treated hawker centres during the Post Treat period July 2016 to September 2016 and October 2016 to December 2016.The Post Treat period X Treat Group is the interactive tem and the coefficient of interest. We use the first 3 digits of the 6-digit postal code to control for heterogeneity at district level (District level postal code F.E.). The Robustness standard errors are given in parentheses. *** Significant at the 1% level, ** Significant at the 5% level, *Significant at the 10% level*

Table 6. HDB blocks density Surrounding the Treated and Non-treated Hawker Centers (for all hawker centers)

Group	Observations	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
Non-Treated HWK centres	51	62.75	8.072	57.65	46.53158	78.95862
Treated HWK centres	52	66.37	7.42	53.53	51.46195	81.26882
Combined	103	64.57	5.46	55.36	53.7525	75.39313
Difference		-3.62	10.96	-25.36	18.11907	
t value	-0.330					
Degrees of freedom	101					
Pr(T < t) = 0.3709		Pr(|T| > |t|) = 0.7418		Pr(T > t) = 0.6291		

Note: The above table reports the results of the t test for the HDB density around all the treated and non-treated hawker centres.

Table 6. HDB blocks density Surrounding the Treated and Non-treated Hawker Centres (for non-overlapping hawker centers).

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
Non-Treated HWK centres	9	94.22	31.85	95.55	20.77643	167.668
Treated HWK centres	51	73.019 61	10.01	71.51	52.90714	93.13208
Combined	60	76.2	9.69	75.032	56.81714	95.58286
Difference		21.202	27.22	-33.281	75.68693	
t value	0.779					
Degrees of freedom	58					
Pr(T < t) = 0.7804		Pr(|T| > |t|) = 0.4392		Pr(T > t) = 0.2196		

Note: The above table reports the results of the t test for the HDB density surrounding the treated and non-treated hawker centres whose buffer rings do not overlap each other.

Table 8 showing the clustering of standard errors of the main results for robustness checking

Data Frequency	Monthly Frequency			
Model estimator	(1) 1.0 km	(2) 1.5 km	(3) 1.0 km	(4) 1.5 km
Treat group × Treat Time	-0.0041** (0.001)	-0.0008 (0.001)	-0.0041*** (0.001)	-0.0008 (0.001)
Treat Time	0.117*** (0.001)	0.116*** (0.001)	0.117*** (0.001)	0.116*** (0.001)
Treat Group	-0.0004 (0.001)	-0.0001 (0.001)	-0.0004 (0.004)	-0.0001 (0.003)
Constant	5.941*** (0.001)	5.941** (0.001)	5.941*** (0.002)	5.941*** (0.035)
Observations	241180	241180	241180	241180
R-squared	0.71	0.71	0.71	0.71
Room type fixed effects	yes	yes	yes	yes
Month and year fixed effects	yes	yes	yes	yes
District level Postal Code Fixed Effects	yes	yes	yes	yes
Robustness Clustering of std. errors (postal code level)	no	no	yes	yes

*Note: The above table reports the regression results where the dependent variable is the Log of the average electricity consumption for different housing types within a postal code. Treat group stands for the Treatment Group, Treat Time stands for the Treatment Time, and the Treat Group x Treat Time is the coefficient of interest and is the interaction term. We use the first 3 digits of the 6-digit postal code to control for heterogeneity at district level (District level Postal Code Fixed Effects). Treat time is a dummy variable which will take the value of 1 during the intervention period (January 2016 to June 2016) and is equal to ZERO otherwise. model (1) is the regression results for those housing blocks that are within 1km of the treated hawker centres and model (2) is the results for housing blocks within 1.5km from the treated hawker centres. Column 3 & 4 are the results of the regression where the standard errors are clustered for the robustness check at postal code level. The robust standard errors are given in parentheses for column 3 and 4. *** Significant at the 1% level, ** Significant at the 5% level, *Significant at the 10% level*

Table 9. Regression showing the treatment effect for different buffer ranges.

Model Estimator	(1) 0.5km	(2) 1km	(3) 1.5km
Treat group X Treat Time	-0.005***	-0.004***	-0.0008
	(0.001)	(0.001)	(0.001)
Treat Time	0.116***	0.117***	0.116***
	(0.001)	(0.001)	(0.001)
Treat Group	0.0132***	-0.0004	-0.0001
	(0.004)	(0.004)	(0.003)
Constant	5.317***	5.324***	5.323***
	(0.036)	(0.035)	(0.035)
Observations	241,180	241,180	241,180
R-squared	0.71	0.71	0.71
Room fixed effects F.E.	Yes	Yes	Yes
Month and Year F.E.	Yes	Yes	Yes
District level postal code fixed effects	Yes	Yes	Yes
Clustering at postal code level	Yes	Yes	Yes

*Note: The above table reports the regression results where the dependent variable is the Log of the average electricity consumption for different housing types within a postal code. Treat Group stands for the Treatment Group, Treat Time stands for the Treatment Time, and the Treat Group x Treat Time is the coefficient of interest and the interaction term. We use the first 3 digits of the 6-digit postal code to control for heterogeneity at the district level (District level Postal Code Fixed Effects). Treat time is a dummy variable that will take the value of 1 during the intervention period (January 2016 to June 2016) and is equal to ZERO otherwise. model (1) is the regression results for those housing blocks that are within 0.5 km of the treated blocks and model (2) & (3) is the results for housing blocks within 1km and 1.5 from the treated hawker centers. The standard errors are given in parentheses. *** Significant at the 1% level, ** Significant at the 5% level, *Significant at the 10% level*

Appendix:

The government initiated Conservation Programs in Singapore

Singapore's housing sector accounts for about 15% of the total electricity consumption and about 57% of the non-contestable consumers' total electricity consumption (Singapore energy statistics 2016). The Singapore authorities actively reach out to the public to encourage them to conserve electricity within their homes. The government conducts various public campaigns to nudge its residents to save energy at home.

The NEA collaborated with the Singapore Environment Council (SEC) in organizing the "Project Carbon Zero" competition for school children from May to August 2009. The competition sets a goal for students to reduce the overall electricity usage at home by 10% or more. (Agarwal et al., 2017)found that the intervention reported a 1.8% reduction in the electricity consumption by households within 2km from the participating schools during the contest period. The South-West Community Development Council (CDC), a council responsible for local municipality matters in Singapore, ran the "*Energy conservation intervention program*" in 2010 involving 151 households in public housing flats in Hong Kah North, one of the local districts in Singapore. The participating households were divided into three groups, where the first two groups were given energy-saving tips via leaflets or stickers (Group 1) and via verbal counseling (Group 2), and the control group was not given any energy-saving tips (Group 3). The households with leaflets or stickers (Group 1) recorded the highest average reduction in electricity consumption (15.8%) compared to the other groups (He & Kua, 2013).

The Energy Conservation Act (2012) introduced in 2012 requires mandatory Energy Labelling for all electrical appliances (refrigerators, air conditioners, etc.) sold in Singapore. The Minimum Energy Performance Standards (MEPS) aimed to raise the average energy efficiency of regulated goods in the market (NEA website). This initiative aimed to help consumers compare the energy efficiency of electrical appliances and make more informed purchase decisions.

In an intervention program in 2013-2014 jointly conducted by Energy Market Authority (EMA.) Housing & Development Board (HDB), Economic Development Board (EDB), and Panasonic, the Home Energy Management Systems (HEMS) were installed for about ten housing units in the Punggol district. This system helped homeowners track their energy consumption and control their appliances via a management system. The study showed a 20% reduction in energy consumption after implementing the HEMS.

Energy conservation messages

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Online Appendix

Pre and post-intervention survey

We conducted two rounds of surveys of residents in conjunction with the energy-saving campaign. This online Appendix covers the methodologies, respondents' characteristics, and key findings from the two rounds of surveys conducted in December 2015 and August 2016.

A1. The Pre-intervention Survey

The pre-campaign survey was conducted in December 2015 to find residents' awareness and attitude towards electricity conservation. After the pre-intervention survey, the NEA worked with the Town Councils[1] to run the energy conservation campaign (hereinafter referred to as the campaign) with the theme "SAVE ENERGY SAVE MONEY" for six months. They put up posters and banners containing electricity conservation messages in selected hawker centers. The posters and banners containing graphics on energy-saving tips for everyday chores were used to educate and nudge households to adopt good practices that reduce electricity consumption.

The posters share various energy-saving tips and nudge households by giving them information on how much savings (in terms of monetary benefits) are possible if they adopt good practices on energy usage at home. Examples of the messages include:

- "Cutting down on the usage of air conditioners and switching to fans after a short period which will help save up to $400 a year."
- "Switching off the power sockets when not in use will help save about $25 a year."
- "Always buy appliances having more number of energy efficiency ticks."
- "Using of thermos flasks instead of electric air pots can save up to $300 a year."
- "Switching off the storage water heaters can help save about $110 a year."

A1.1. Respondents' Characteristics

In the pre-intervention survey in December 2015, we conducted in-person interviews with 200 residents living in HDB blocks within 1.0 km of the participating hawker centers. The ages of the responders surveyed varied from 14 years to 91 years old, and they were made up of 55% females and 45% males. Figures A1(a) and A1(b) show the respondents' compositions and characteristics. By race, the respondents comprise 76% (152 respondents) Chinese, 14% (28 respondents) Malay, 7.5% (15 respondents) Indian, and 2.5% (5 respondents) from other races; and the composition is representative of the national-level racial composition of the multi-racial society in Singapore.

[Insert Figures A1(a) and A1(b) here]

A.1.2. Awareness of Energy Saving Practices

When conducting on-site interviews, we use a structured questionnaire to assess the residents' awareness of electricity consumption and their knowledge of electricity-saving practices. We

[1] Town Councils are the equivalent of local municipal authorities in other countries set up with the responsibilities of overseeing the day-to-day operations and management of common property in HDB estates in Singapore. Town Councils are led by the elected Members of Parliament, and comprise grass root leaders and residents, and they outsource some of the estate management and maintenance services to third-party service providers.

asked them whether they knew their monthly electricity consumption and monthly electricity bills paid. The responses serve to reference the pre-intervention behavior of residents in the campaign.

Out of the 200 respondents, 40% (80 respondents) said they did not check their bills because they were not the family members who pay the bill every month. They were not aware of their electricity consumption levels. 39.5% (79 respondents) regularly checked their electricity consumption on their electricity bills, and 20.5% (41 respondents) checked only occasionally. The responses to how much they pay for monthly electricity bills varied from S$50.00 (US$35.24) to S$500.00 (US$352.41).[2]

When we asked the question: "*if they are aware of the ways by which they can reduce the electricity consumption at home*," 17.0% of the 200 respondents answered "NO," 54% answered "YES," and the rest did not respond. When asked about energy conservation practices at home, 55% of the respondents indicated the most common practices are switching off fans and lighting and switching off appliances from the main socket when they are not used. The other practices are shown in Figure A2, which include using air-conditioners only when necessary (14%), using water heaters only when necessary and switching them off immediately after use (7.5%), and using energy-efficient appliances and energy-saving lighting (4.5%). Other responses, such as switching on the T.V. only at night, not charging the phones overnight, switching off the fridge when on holidays, not using washing machines too often, and not using dishwashers, constitute 14.5%.

[Insert Figure A2 here]

A.1.3. Use of Energy-Efficient Electrical Appliances

The above results show that most people know switching off fans and lighting helps reduce electricity consumption. However, only 4.5% of them buy energy-saving appliances and lighting that help them conserve energy. We asked them about their awareness of some of these lighting and appliances:

a) Lighting

About 50% of the people used fluorescent tubes and LED bulbs at home, while a smaller number of responses indicated that they used incandescent bulbs. 92% indicated that they always switch off lights when not used. People were highly aware of not leaving the lights switched on when not used and changing to energy-saving lighting.

b) Electric air-pot

About 33% of the respondents used air pots at home, and about 60% did not know of alternative ways by which they could keep the water warm without using the air pots.[3] They are more likely to change electric air pots if they know other efficient ways to boil and keep water hot.

c) Air conditioning usage

55% of the respondents used fans and air-conditioning to cool their homes, whereas 35% used fans and 10% used air-conditioning only. We asked them about the duration of air-conditioning usage (in hours per day). Figure A3 shows that 27% of the respondents used air-conditioners

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[2] Based on the US$: S$ exchange rate fo 1:1.4188 as of 31 December 2015.

[3] An electric air-pot uses electricity constantly to boil and keep water at a constant temperature. The electric air-pot consumes more electricity than using a kettle to boil water as and when needed.

for more than 8 hours, while 31.5 % used when sleeping (around 8 hours) and 8.5% used less than 8 hours daily. The rest did not respond to the question. This means that 65% of the respondents used the air-conditioning at home, and 58.5% used it more than 8 hours daily.

[Insert Figure A3 here]

d) Buying energy-efficient appliances

NEA introduced the Mandatory Energy Labelling Scheme (MELS) to help consumers compare the energy efficiency of regulated goods and make more informed purchasing decisions. Suppliers must obtain the certification of registration (COR) from NEA to affix the energy label on their electric goods sold in Singapore.

When we asked the respondents if they knew of the NEA energy efficiency label, about 66% had some idea about the label on the electrical appliances. Still, they did not consider the label when purchasing the appliances. When we asked them "why," the most common answer was that they found that appliances with more "ticks" of energy-efficient labels are more expensive. Some respondents were not impressed by the design of the appliances. Some were unsure how much savings these energy-efficient appliances could bring, and others had reservations about using energy-labeled appliances to help conserve energy. The results imply that the energy label has not been well communicated and understood by consumers in Singapore.

A.1.4. Summary of the pre-intervention survey

The pre-intervention survey reveals that residents did not pay close attention to electricity consumption at home, and only some regularly checked their electricity bills. Many respondents would switch off lights, fans, and appliances when not used; few used more energy-efficient appliances, including fluorescent and LED lights. Many respondents had reservations about savings from using the energy-efficient labeled appliances. Only about 35% of the surveyed people used only fans and not air-conditioning at home [Note: air-conditioners consume more than 30% of household electricity bills].

The pre-intervention survey shows that many residents were unaware of alternative ways to save electricity, such as replacing electric air-pots to boil and keep water hot and cutting down air-conditioning usage when sleeping. Therefore, the NEA posters and banners campaign could help change households' behavior and inculcate good habits in electricity usage at home.

A.2. The post-Intervention survey

A post-intervention survey was conducted in August 2016, covering HDB blocks around the hawker centers after removing the posters and banners at the end of the 6-month campaign. The findings from the survey are summarized below.

A.2.1. Respondents' Characteristics

We interviewed 200 randomly selected residents on-site to seek feedback on the intervention during the NEA energy-saving campaign. Figure A4 shows the respondents' composition, whose ages vary from 19 years to 78 years. 52% of the respondents were females, and 48% were males. By race, 57% were Chinese, 19% were Malay, 15% were Indian, and 9% were from other races.

[Insert Figure A4 here]

A.2.2. Feedback on the NEA posters and banners

When asked if they had seen the NEA posters and banners in the neighborhood during the campaign period, 35% responded "yes," whereas 65% responded "no" or did not respond to the question. To verify that they had seen the displayed messages and not just said "yes" without noticing them, we followed up by asking those who said "yes" if they recalled the messages on the posters and banners. All the respondents who claimed to have seen the posters and banners could recall the "SAVE ENERGY SAVE MONEY" message, even after the campaign had ended.

When asked if they found the energy-saving tips helpful, 42% said that they had seen a drop in electricity bills, whereas the rest did not notice or were not sure about the savings as they were not the ones paying the bills.

We also asked if they would like and how they prefer to receive energy-saving tips in the future to help them save on electricity bills. Most respondents prefer to find out more tips via the channels, such as social media, television, radio, and roadshows organized at the community centers. Other suggestions include organizing educational events in primary and secondary schools, door-to-door visits with relevant pamphlets and flyers, and putting up mobile advertisements on buses and trains.

A.2.3. Summary of the post-intervention survey

The post-intervention survey revealed that residents living near the participating hawker centers noticed the posters and banners put up during the campaign. 35% of the residents recalled the energy conservation messages. 42% may have changed their electricity consumption behavior at home and noticed a drop in their electricity bills. In contrast, the others were unsure or did not check their electricity bills.

Some residents suggested that the messages could be more salient to the public using the media channels, such as social media, televisions, radios, and mobile advertisements on public transport. Running education events at primary and secondary schools, organizing roadshows at community centers, and handing out pamphlets and flyers during the door-to-door visits to residents are other ways to nudge them to save energy in the future.

A.3. Conclusion

The two rounds of pre-and post-intervention surveys provide on-the-ground verifications of the efficacy of the energy-saving campaign conducted by the NEA in 2016. The pre-intervention surveys established residents' awareness level of energy conservation before the campaign started. We assessed how people practice energy conservation at home before the intervention. Using the pre-intervention survey to set the baseline, we could then evaluate how the campaign has impacted residents' energy conservation behavior after the campaign. Based on the residents' feedback near the participating hawker centers in the post-intervention survey, we could determine if the messages shared during the campaign have effectively nudged residents to adopt more energy-saving practices, thus cutting down their electricity consumption.

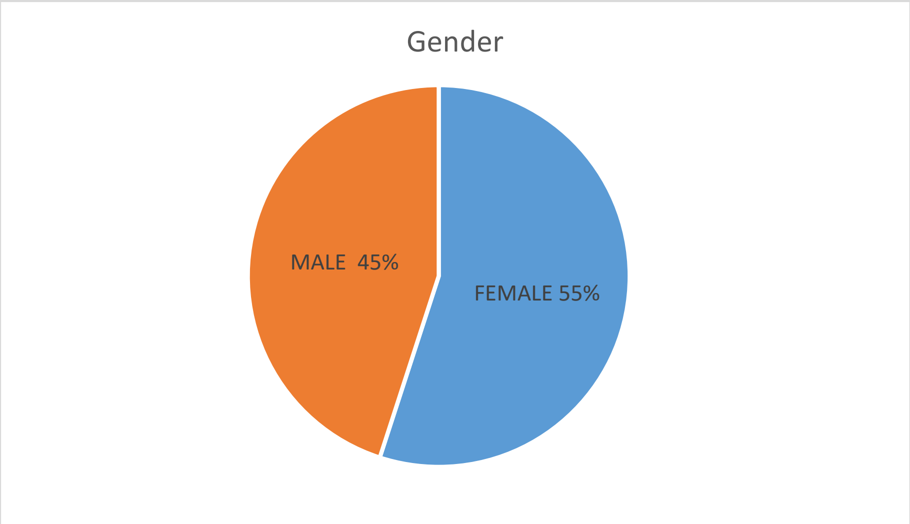
Before the campaign started, residents were salient about adopting common energy-saving practices, such as switching off lights, fans, and appliances when not used. For example, they could use fans when sleeping instead of air-conditioners and buy energy-labeled appliances. However, we found that residents were less informed about other energy-saving tips.

When we conducted the post-intervention survey at the end of the 6-month campaign, 35% of the surveyed residents noticed and recalled the energy-saving messages on the posters and banners. Some residents had also seen a drop in their electricity bills. These residents could have noticed the energy-saving messages and brought them back home to nudge their family members to practice good electricity consumption behaviors. Many households were still not salient of the energy-efficient labeled appliances, and some were put off by the high costs of appliances with these labels. More education could change people's perception of the NEA energy-efficient labels and their electricity consumption habits.

The pre-intervention and post-intervention surveys showed an incremental rise in residents' awareness of energy-saving practices after the 6-month campaign. These results provide supplementary evidence to support the main empirical findings in the paper. The surveys' results show that communication campaigns that include information on economic benefits and special behavioral guidelines (including energy-saving tips) are more effective in nudging the energy consumption behaviors of residents. The results add new evidence to the early studies (Casado et al., 2017; Delmas et al., 2013; Spence et al., 2014; Steg, 2008; Whitmarsh, 2009).

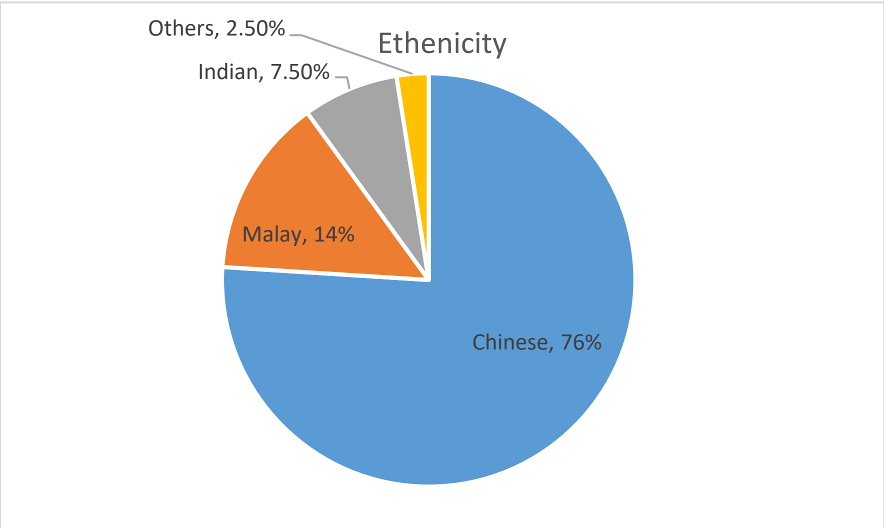
Figures and tables for the survey

Figure A1(a). Gender Representation



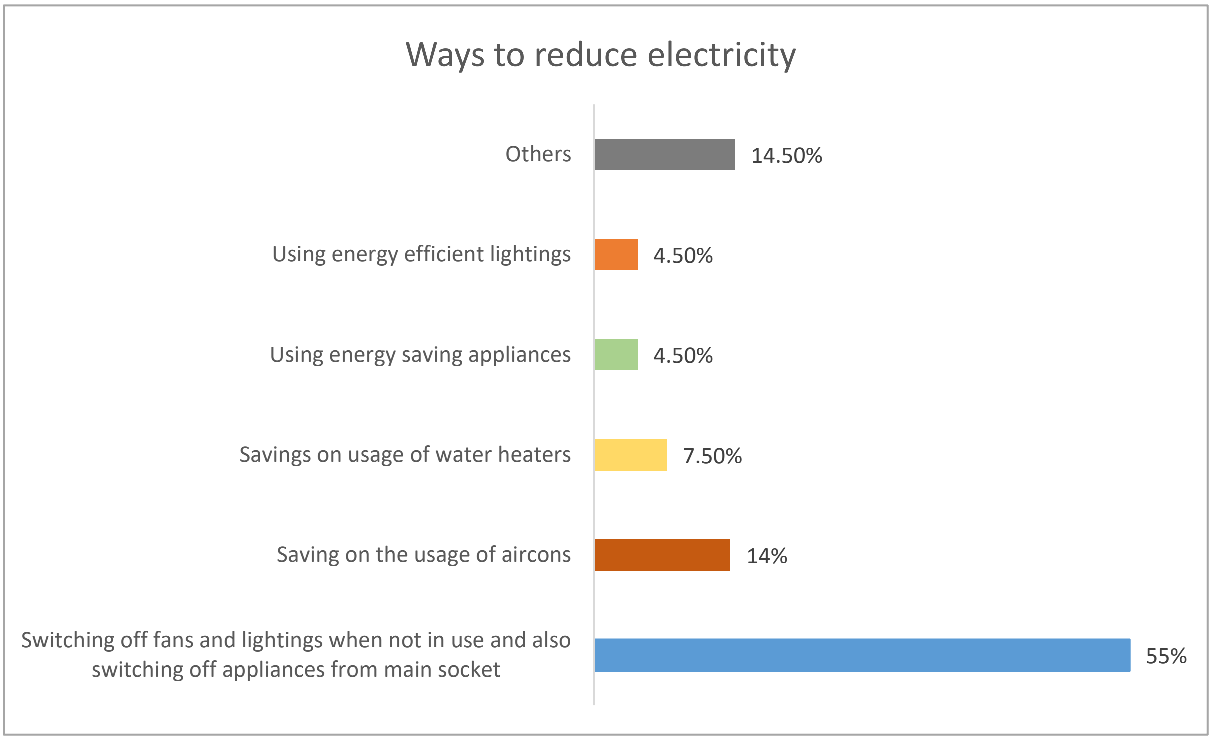
Note: The figure shows a graphical representation of the pre-intervention survey by gender. 45% of the respondents were males, and 55% were females.

Figure A1(b) Ethnic Representation



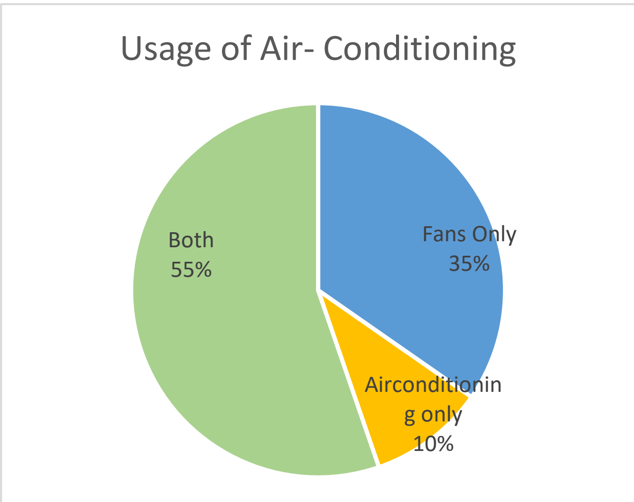
Note: The figure shows a graphical representation of the pre-intervention survey by Ethnicity.

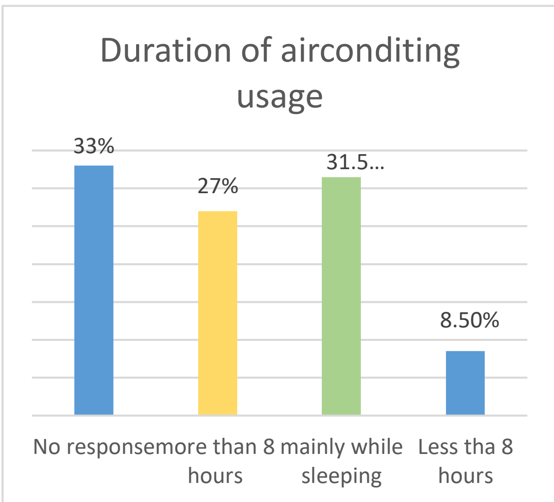
Figure A2 Awareness on ways to reduce electricity consumption



Note: The figure shows a graphical representation of the awareness on the different ways to reduce electricity at home

Figure A3 Usage of Air-conditioning

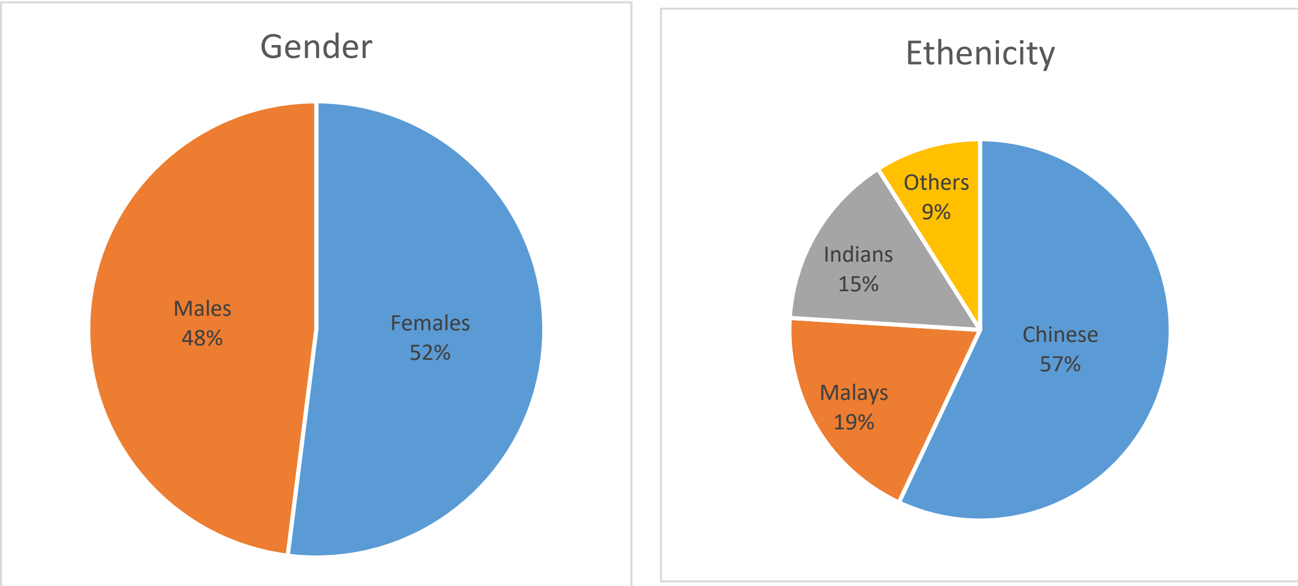




Note: The figure shows a graphical representation of the percentage of people using air-conditioning at home and the duration of its usage.

Figures for the Post- intervention survey

Figure A4 .Gender and Ethnic Representation



Note: The Figure shows a Graphical representation of the post-intervention survey by gender and Ethnicity.

Casado, F., Hidalgo, M. C., & García-Leiva, P. (2017). Energy efficiency in households: The effectiveness of different types of messages in advertising campaigns. *Journal of Environmental Psychology*, *53*, 198-205. https://www.sciencedirect.com/science/article/pii/S0272494417301032

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