Task 5: Cost-Benefit Analysis

Thailand

Pan Piyasil [1]

[1] MECON's project researcher and coordinator, The Joint Graduation School of Energy and Environment, Bangkok, Thailand

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Abstract

Energy efficiency (EE) means the ratio of output of performance, service, goods or energy, to input of energy. However, many of the potential EE gains remain untapped. The aim of this study is to explore new modern energy consumers (MECON) household, defined to be energy consumers who connect to the grid and have low incomes (USD 2-5 per day). The study will analyse costs and benefits of using energy efficient appliances on consumers, effect of improving EE among MECON household to the national level, and the rebound effect of EE improvements.

The results from cost-benefit analysis point out that lighting technology has the highest potential for the energy efficiency improvement. It should be consider as the low-hanging fruit for policy makers, especially on the substitution from fluorescent to LED light bulb. The widely used appliances, for example, rice cooker, electric kettle, and electric fan also play a crucial role in the total energy consumption of MECON households. More policy intervention should emphasize on these appliances, for example, tightening the energy standard and encouraging more adoption of efficient appliances through informational campaign. Moreover, the energy consumption of MECON households tend to decrease, not because they become more energy efficient, but this is likely to be the result from changes in demographic of this group toward being higher income groups in the future. Further investigation on other higher income group is highly recommended. The result on rebound effect suggests that MECON households may consume more energy when their income increased on cooking fuels, purchase of new appliances, and more usage on existing ones.

1 Introduction

Energy efficiency (EE) means the ratio of output of performance, service, goods or energy, to input of energy. EE improvement means an increase in energy efficiency of an appliance due to a technological change. EE improvements offer multiple benefits, such as reduced household energy expenditure and improved productivity, thus contributing to economic growth, enhancing energy security and facilitating cheaper and faster energy access to populations. The 2012 World Energy Outlook highlights the importance of EE in reducing greenhouse gas emissions (GHG) in the coming decades: EE is responsible for 75% of emissions reductions by 2020 in a 2°C temperature increase scenario (IEA, 2012). For developing countries, EE will be important since it curbs demand growth, thereby reducing additional power capacity needs and facilitating cheaper and faster energy access to populations. Improved EE will also reduce energy consumption, leading to lower fossil fuel imports for the countries. Moreover, EE can make it easier for lower income households to pay energy bills, freeing up funds for other needs (Sarkar and Singh, 2010). Although the adoption of EE measures has few technical challenges, and numerous energy efficient technologies with accountable payback times do exist, there remain important non-technical barriers, particularly at the household level. As a result, many of the potential EE gains remain untapped.

Implementing EE measures within households will reduce the energy needed to produce the same quantity of energy services such lighting, heating, air conditioning, cooling, etc. As a consequence of reduced energy use, householders may benefit from lower energy bills. However, the overall cost and benefits to the householders depends on the cost of the appliance, the level of efficiency improvement and the price of fuel (for example electricity tariff) as well as any tax/subsidies applicable. Conversely, reduced bills may also lead to an increased level of energy consumption and real energy savings may be well below the expected level. One explanation is that improvements in EE encourage greater use of the services (for example heat or mobility) which energy helps to provide. Behavioural responses such as these have come to be known as the EE "rebound effect". While rebound effects vary widely in size, in some cases they may be sufficiently large to lead to an overall increase in energy consumption - an outcome that has been termed 'backfire' (UKERC, 2007). In the MECON project, due to the nature of the target group – those who have access to electricity and are affordable to pay only for certain energy services at present – it is likely that they will use part of their extra income to consume more energy in two key ways. The first by buying more appliances and using them more for the same energy services to which they already have access (for example, buying more bulbs or using the them more). The second is buying a new appliance to meet an energy service, which they did not have before (for example, buying a fan which they did not previously have).

In the Greater Mekong Subregion (GMS - Cambodia, Laos, Myanmar, Thailand and Vietnam), it will be the 'new Modern Energy CONsumers' (the MECON) i.e. people who

have access to grid electricity but who live on low incomes (USD 2-5 per day), who will be responsible for a large share of expected increase in energy demand and thus GHG emissions. This report is one of five country-specific reports, which present the results of cost-benefit analysis carried on MECON project.

1.1 Objectives of the cost-benefit analysis

The aim of this study is to assess the cost-benefits at the household (new modern energy consumers) and at the national level. The study will also analyse the rebound effect of EE improvements.

2 Methodology

Task 5 has three sub-tasks:

5.1: carrying out a cost-benefit analysis of selected energy efficient technologies at the individual household level

5.2: analysing energy-economic impact of energy efficiency policy packages at a national level. Two energy efficiency scenarios are defined under this task.

5.3: analysing the behavioural response of the households and the impacts on a household's energy services demands. A questionnaire survey will be carried out under this task.

2.1 Cost-benefit analysis at household level

The cost-benefit analysis (CBA) has been in use since the 1940s. Traditionally, the CBA has been applied to those costs and benefits to which an accepted basis of monetary valuation is available. In addition there are environmental factors and factors such as economic development, employment and energy use. The evaluation compares the benefits with and without the project. CBA involves defining the project, listing the costs and benefits, putting money values for them, and comparing the time streams of the benefits and costs.

The Life-Cycle Cost (LCC) of an appliance accounts for all expenditures associated with purchase and use. From the consumer perspective, the two main components of LCC are the equipment cost (capital cost) and the operating costs which is the fuel cost and maintenance cost. Equipment cost is the retail price paid by the consumer purchasing the appliance. Operating cost is the cost of energy, in the form of utility bills, for using the equipment. Life-Cycle Cost is given by:

$$LCC = CC + \sum_{t=1}^{n} \frac{FC_t + MC_t}{(1+DR)^t} \qquad \text{Equation (1)}$$

Where:

LCC – life cycle cost CC – capital cost of the appliance

FC_t – fuel cost in year t (Annual electricity consumption in year t X price in year t)

MC_t – maintenance cost in year t DR – Discount rate

N – life of the appliance

The CBA can be carried out for selected technologies by comparing the LCC of efficient and inefficient technologies. Equation (1) shows the traditional way of calculating CBA. The MECON project focuses on a particular consumer group whose income is relatively low. This particular consumer group sometimes needs financial support, as they do not have sufficient capital to buy an efficient appliance. Rather, these households may have to borrow money from different institutions, or from friends and family members in order to buy an energy efficient appliance. In some countries, the shop owners also allow consumers to make payments in instalments. Irrespective of where the consumers get the financial support, they have to pay a higher price for the appliances due to the interest rate. This could be added to the cost of capital to the consumers. Therefore, here the capital cost of the appliance is annualised using a different discount rate, which is defined as the hurdle rate, which represents the interest rate and is normally higher than that of the discount rate. Equation (1) is then modified to take into account the hurdle rate:

$$LCC = \sum_{t=1}^{n} \frac{AC_t + FC_t + MC_t}{(1+DR)^t} \qquad \text{Equation (2)}$$

$$AC = \frac{CC \quad HR}{1 \quad (1+HR)^{l}} \qquad \text{Equation (3)}$$

Where:

AC – annualised cost

HR – Hurdle rate (interest rate)

l – Number of years by which the loan is repaid.

If there is a government subsidy programme for energy efficient appliances, then consumers will pay net of subsidy for the capital cost.

$$LCC = CC \quad SS + \sum_{t=1}^{n} \frac{FC_t + MC_t}{(1+DR)^t} \qquad \text{Equation (4)}$$

SS – is the amount of subsidy the consumer receives under the programme.

Analysis will compare the benefits of energy efficient over inefficient technologies. At least five appliances (such as TV, rice cooker, fan or refrigerator) are analysed here. The selections of appliances for the CBA are based on three criteria: energy consumption, ownership and future potential for each country.

2.2 Energy-economic impact of energy efficiency policy packages (national impacts)

The calculations shown above provide an estimate of the financial impacts of an efficient appliance for each household. Though the individual household level analysis is crucial, a second critical aspect to evaluate in an EE policy package is the national-level impacts. The three main national impacts calculations can be: Net Present Value; national energy savings potential; and reduced environmental impacts, including GHG emissions reductions.

The LEAP model has been used for the CBA at the national level under different scenarios, which have been defined through consideration of each country's EE policy packages. Appliance stock and national end use consumption are driven by population growth and trends in appliance ownership rates. Unlike in developed countries, where the market for most major appliances is saturated, in developing countries the ownership rates of even basic appliances are dynamic, and depend critically on household income level, degree of urbanisation and electrification; this is particularly true for the emerging middle classes and the target group of this research, the MECON. The EE policy packages will define the diffusion of efficient technologies among the consumer groups and its saturation levels, which can be modelled in LEAP. The existing LEAP model, which has been developed under Task 1 of the MECON project, will be further improved by adding costs to appliances for both efficient and less efficient technologies under this Task.

2.2.1 Scenario Definitions

Three scenarios have been defined in the LEAP model for each country: the Base Case (BC) modelled under the Task 1, a High Energy Efficiency (HEE) scenario, and a Moderate Energy Efficiency (MEE) scenario.

- **High Energy Efficiency (HEE) scenario**: this scenario assumes 100% penetration of efficient appliances by end of the modelling period (2030) for each energy service. This scenario assumes that the share of efficient appliances will increase gradually from the current level to reach 100% by 2030. This scenario aims to explore what the potential impacts on energy, emission and costs will be when all households use efficient appliances.
- **Moderate Energy Efficiency (MEE) scenario**: this scenario assumes a moderate penetration of efficient appliances in 2030. The appropriate share of efficient appliances for each energy service demand is defined by linking them to the energy efficiency policies discussed in Task 4. The share of energy efficient appliances in 2030 will be different for different energy services, which will vary according to each country. For example, the share of efficient refrigerators in 2030 will be different to the share of efficient televisions in 2030. Since each country team was best placed to make assumptions on the penetration levels of energy efficient appliances, the assumptions vary.

Under Task 5, two activities were undertaken using the LEAP model: firstly, to model the cost for each end-use appliances and the price for each fuel (i.e. electricity, gas, kerosene,

biomass,); and secondly to develop the two new scenarios - HEE and MEE. In order to model the costs in LEAP, each country partner had to develop a technology database which shows the cost for each appliance. This was done by adding cost data, generated in Task 2, to the existing technology Excel-based database developed under Task 1. Once the modelling was completed, the results generated were used to analyse the impact of EE scenarios on the energy system. The results are discussed in Section 3. The data course for Thailand's LEAP modelling and lists of key assumptions for Thailand's scenario analysis is presented in **Appendix B**.

2.3 Behavioural response of the households

In order to understand how individual households may respond to reducing energy consumption as a result of EE policy packages, the final sub-task involved a short questionnaire survey. This will help us to understand how reductions in the cost of electricity bills might be spent, whether households prioritise energy or other (non) essential items.

For this sub-task, a questionnaire was developed (**Appendix C**) which used many of the same questions as the Task 3 survey. The questionnaire focused on characteristics of the household, current energy consumption as well as how additional, future income might be spent. Analysis of these data, also examined whether there were any differences between those households who used electricity a) solely for lighting, b) for lighting and small appliances, and c) for other energy services. Grouping the consumers will help to carry out detailed analysis and to capture the rebound effect as discussed in the introduction.

Each partner country carried out the questionnaire with at least 100 households. In Thailand, 154 questionnaires were carried out in Bangkok (76 households) and Nakhon Ratchasima Province (78 households). The surveyed sites in Bangkok were in slum areas representing the urban low-income households, while the sites in Nakhon Ratchasima were in Meung district but outside of the municipality area, which is referred as rural low-income households. A low-income household is defined in this study as a household with total income between 3,000-15,000 baht (around 100-500 USD) per month. Most of the households in Bangkok have monthly incomes between 8,000-15,000 baht (267-500 USD) per month, while the majority of those in Nakorn Ratchasima earn between 3,000-8,000 baht (100-267 USD) per month. There are few households that earn slightly above and below this range, and they are also included in the analysis.

The table in **Appendix D** shows the list of low-income communities surveyed in this study. These communities were identified based on average income levels and conducted the survey during February to April 2015. The enumerators went around these neighbourhoods to interview the households on face-to-face basis in order to encourage a higher response rate and higher quality responses. The surveys took place mostly on the daytime, and the enumerators conducted the surveys on any households that had family members available for the surveys up to 80 households in each province. Those households that did not answer most of the questions were then removed from the rest of the samples.

3 Results

3.1 Cost-benefit analysis

This study conducts CBA on five types of appliances, which are lighting, rice cooker, electric fan, refrigerator, and air conditioning unit. For lighting, the analysis compares between fluorescent and light emitted diode (LED) light bulb, while for other appliances, the comparisons are between the products with Thailand's energy efficiency label[1] and ones without. An average electricity price is 3.96 baht per kWh or 0.1320 USD per kWh, and it is assumed to increase by 1.25% annually. The discount rate used in this analysis is 5%. **Appendix A** shows the data, assumptions, and the cost-benefit analyses of all types of appliances. The following sections illustrate the comparisons of life cycle cost (LCC) between conventional and efficient appliances.

3.1.1 Lighting appliances

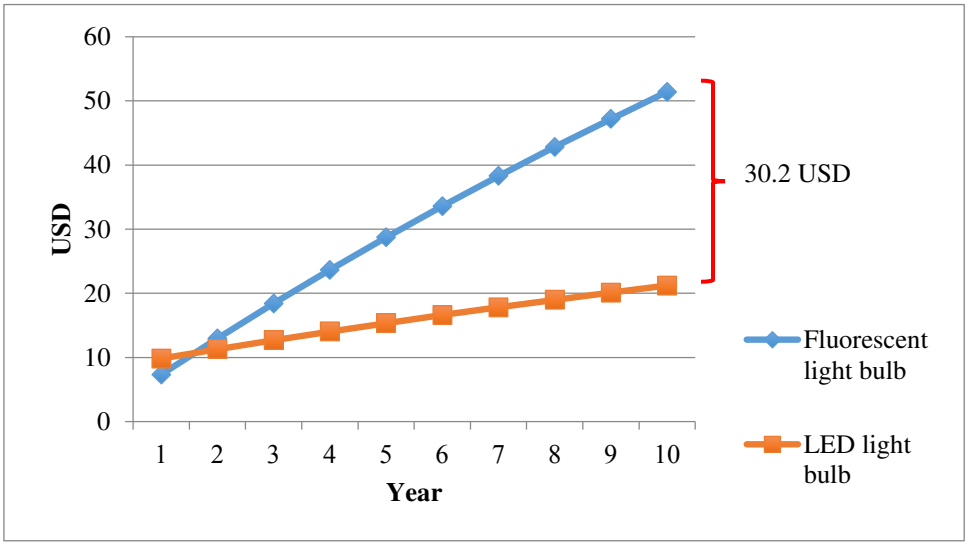


Figure 3.1: Cumulative life-cycle costs of fluorescent and LED light bulb

Figure 3.1 shows that a LCC of LED light bulb is substantially lower than that of fluorescent lamp. While the LCC of LED light bulb is 51.4 USD, a fluorescent light bulb costs 21.2 USD throughout its lifetime[2]. Although a LED light bulb has much higher initial cost (8.33 USD) than its fluorescent bulb (1.50 USD), the annual electricity consumption of LED bulb is much lower (12 kWh per year) as opposed to its counterpart (46.5 kWh per year). Therefore, the substitution from LED to fluorescent light bulb has a large potential for efficiency improvement and cost saving on electricity bills.

[1] Thailand has an energy efficiency label referred as 'Label No. 5'. The value 5 is the highest efficiency standard, while 3 is the lowest. The appliances that cannot comply to the No.3 standard are not allow to sell in the market, and so No.3 standard also serves as the minimum energy performance standard. For more information on the label, please see the MECON's project report, 'Thailand Task 3 country report'.
[2] Table A.2 in **Appendix A** shows the calculation of LCC between fluorescent and LED light bulbs.

From the result of the household survey in Task 3, none of the surveyed households in Thailand owns LED light bulb, while more than 95% of them use fluorescent light bulbs. Encouraging the adoption of LED light bulb could be a key policy recommendation for the MECON households.

3.1.2 Rice cooker

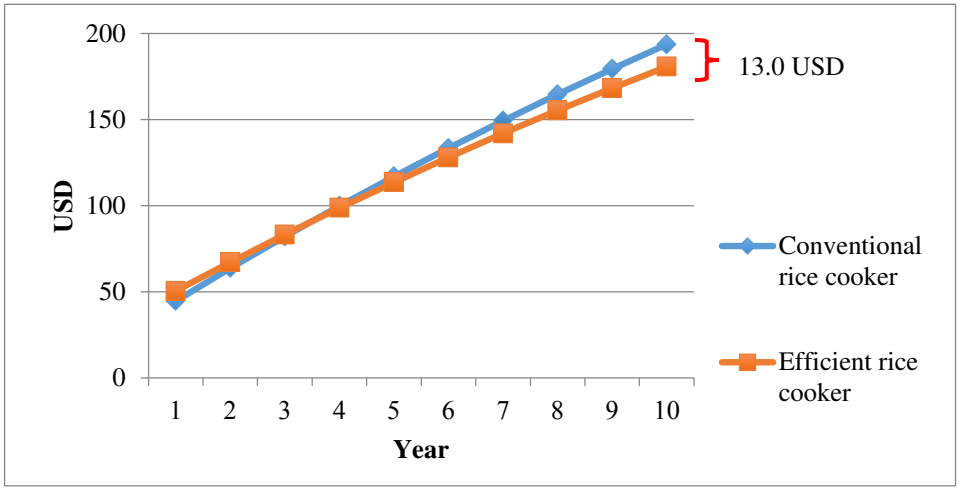


Figure 3.2: Cumulative life-cycle costs of conventional and efficient rice cooker

An efficient rice cooker has a lower life cycle cost than a conventional one by 13 USD as shown in Figure 3.2[3]. This difference is quite small and consumers may not think it is so significant. This suggests that the standard of efficient rice cooker should be tightened, so it can create sufficient saving to attract consumers.

3.1.3 Air conditioning (AC) unit

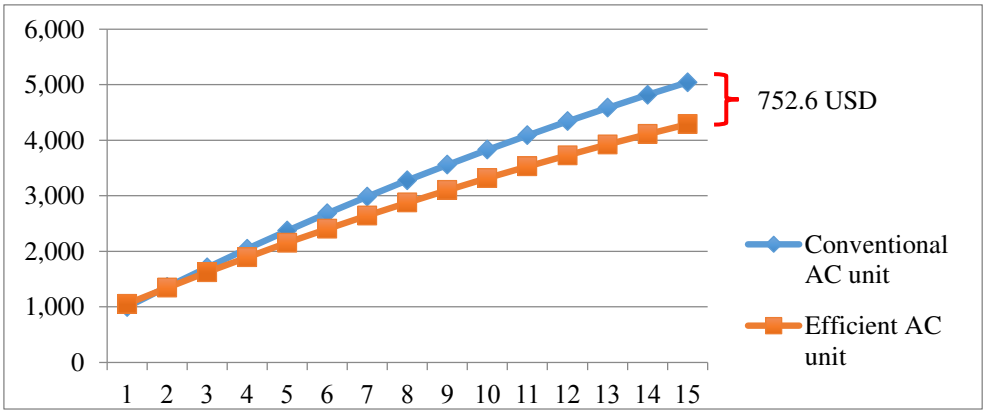


Figure 3.3: Cumulative life-cycle costs of conventional and efficient AC units

A potential for energy conservation in an AC unit is the largest among compared appliances. Using an efficient AC unit can save a household's electricity bill by 752.6 USD

[3] See the calculation of LCC in Table A.3, **Appendix A**

throughout its lifespan in comparison to a conventional one[4]. Considering that the initial costs between those two are not so different, an efficient AC unit is highly beneficial for households. From the results of the household survey, most of the MECON households have not owned AC unit yet. This suggests that they might start using it more in the near future due to their increasing incomes. Therefore, it is important to design a proactive policy to help them realising these potentials for energy conservation from their first purchases.

3.1.4 Refrigerator

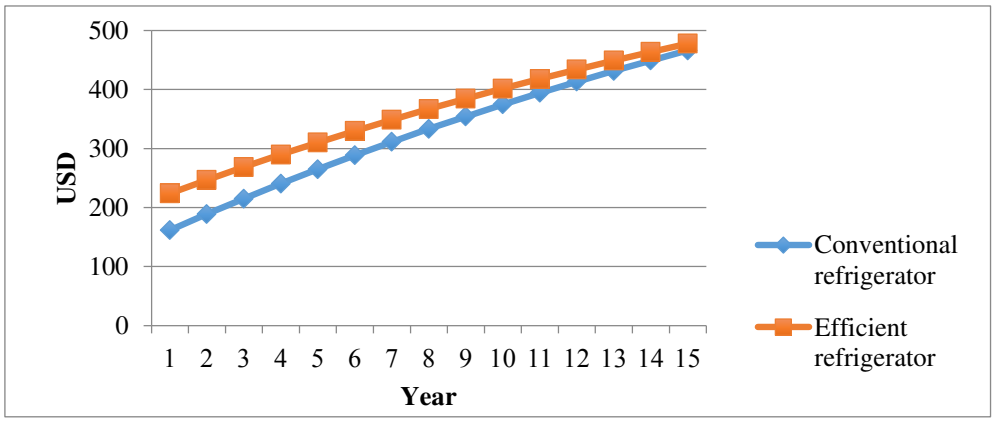


Figure 3.4: Cumulative life-cycle costs of conventional and efficient refrigerators

The result in Figure 3.4 suggests that consumers do not benefit from using efficient refrigerator in comparison with the inefficient one[5]. However, refrigerator is the only appliance that the conventional one has lower life cycle cost than the efficient one. This is possibly because the differences in electricity consumption and the initial cost of the products between those two are not so large.

Both efficient and conventional refrigerators are a one-door type with the size of 6.4 cubic feet, or approximately 183 litres. This study collected data of several refrigerators with EGAT's EE labels (Label No.5), which shows average energy consumption per year (in kWh) and estimated electricity cost. On the other hand, a refrigerator without Label No.5 is really hard to find in the market because consumers would not buy it; so inefficient refrigerators used in this comparison are mostly second-handed. Unlike refrigerators with EGAT's EE label, these products often do not have any detail on energy consumption, and so we assume inefficient refrigerator to consume 20% more than the efficient one, and so the efficiency factor is 1.2 for the conventional one. The price for inefficient refrigerator is assumed to be 4,000 baht or around 133,33 USD.

Considering that most of the households in Thailand own at least one refrigerator, further policy study can evaluate the cost effectiveness of refrigerator offered in the market, which should include the variety of model and technology of refrigerator in the analysis as

[4] See the calculation of LCC in Table A.4, Appendix A
[5] See the calculation of LCC in Table A.5, Appendix A

well[6]. The standard of efficient refrigerator should be tightened, so it can create sufficient saving to attract consumers.

3.1.5 Electric fan

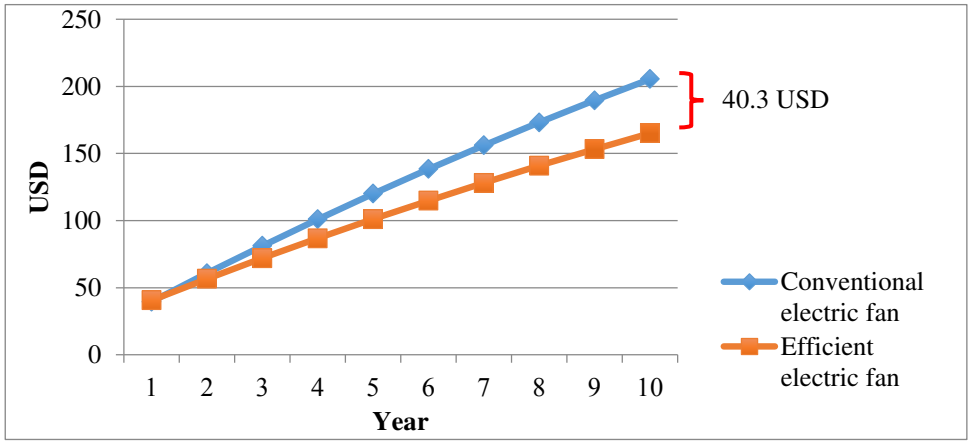


Figure 3.5: Cumulative life-cycle costs of conventional and efficient electric fans

Electric fan also has high potential for electricity conservation. From Figure 3.5, the efficient electric fan has 40.3 USD lower life cycle cost in comparison with the conventional one[7]. This difference in life cycle costs is actually very large considering the initial cost for one electric fan is usually lower than 30 USD. Policy makers should put an extra emphasis on electric fan not only because it has high potential for energy saving and benefit to consumers, but also it is widely and heavily used in low-income households[8].

3.1.6 Role of hurdle rate

This study also conducts a sensitivity analysis on the differences in discount and hurdle rate. The choice of discount rate can significantly alternate the result of the LCC and the cost of capital reflected in the hurdle rate can also determine the investment choice from consumers' perspective. Table 1 below shows the scenario with various discount and hurdle rates. The second column from the left presents the LCC of 5% discount rate as mentioned in section 3.1.1-3.1.5, while other columns demonstrate the changes in LCC under various scenarios.

There are two hurdle rates used in this analysis. The first hurdle rate is the minimum retail rate (MRR) at 8% by the announcement of Bank of Thailand in April 2015[9], referred as MRR hurdle rate. Another hurdle rate is 15.48%. This rate was retrieved from the market survey by MECON staffs in 2015, which found that many stores offered instalment plans when

[6] See also the work of Foran, T., Du Pont, P. T., and Parinya, P. (2009). Securing energy efficiency as a high priority: scenarios for common appliance electricity consumption in Thailand. *Energy Efficiency.* DOI 10.1007/s12053-009-9073-7

[7] See the calculation of LCC in Table A.6, Appendix A

[8] See more on the energy consumption of electric fan in Thailand's low-income households in Thailand's MECON report '*Household Energy Efficiency: a socio-economic perspective [Thailand]*'

[9] The data is available online at http://www2.bot.or.th/statistics/BOTWEBSTAT.aspx?reportID=223&language=ENG.

consumers purchasing these appliances at 1.29% per month. It was, therefore, converted to annual rate at 1.29%*12 month or 15.48%, referred as market hurdle rate. The effect of hurdle rate reflects the sensitivity on the cost of capital, which could alternate the outcome of the purchasing alternative.

Table 3.1: Sensitivity analyses on various scenarios of discount and hurdle rate

Appliance	LCC at discount rate (5%)	LCC at discount rate (2%)	LCC at discount rate (8%)	LCC at MRR hurdle rate (8%)[10]	LCC at market hurdle rate (15.48%)[11]
Fluorescent light bulb	$51.4	$59.7	$44.7	$51.5	$51.9
LED light bulb	$21.2	$23.4	$19.5	$21.9	$23.8
Difference in LCC[12]	**$30.2**	**$36.4**	**$25.3**	**$29.6**	**$28.1**
Conventional rice cooker	$193.6	$221.7	$171.1	$195.7	$201.2
Efficient rice cooker	$180.6	$205.2	$160.9	$183.4	$190.8
Difference in LCC	**$13.0**	**$16.5**	**$10.1**	**$12.3**	**$10.4**
Conventional AC unit	$5042.1	$6,130.7	$4,243.7	$5,119.0	$5,327.7
Efficient AC unit	$4289.5	$5,160.0	$3,651.0	$4,383.0	$4,636.8
Difference in LCC	**$752.6**	**970.7**	**$592.7**	**$736.0**	**$690.9**
Conventional refrigerator	$347.8	$415.0	$342.6	$482.9	$528.1
Efficient refrigerator	$401.8	$435.3	$374.9	$503.0	$570.9
Difference in LCC	**-$27.0**	**-$20.3**	**-$32.24**	**-$20.1**	**-$42.9**
Conventional electric fan	$205.5	$236.9	$180.4	$209.9	$214.4
Efficient electric fan	$165.2	$188.7	$146.4	$171.3	$177.5
Difference in LCC	**$40.3**	**$48.2**	**$34.1**	**$38.7**	**$36.9**

From Table 3.1, the result suggests that a lower discount rate contributes in favour of efficient technologies. On the other hand, a higher discount rate would lessen the gab between the LCCs of conventional and efficient appliances. A higher discount rate means that the present values of energy saving in the future would be smaller due to the discount process, and so it largely consequences in diminished advantage of efficient appliances. However, the changes in discount rates, either 2% or 8%, do not change the outcomes of choices between conventional and efficient appliances, and most of the efficient appliances (except refrigerator) are still more beneficial to consumers.

On hurdle rate, the result suggests that a higher hurdle rate contributes in favour of conventional technologies. A higher hurdle rate results in smaller gab between the LCCs of conventional and efficient appliances. This is because an efficient appliance generally has higher initial cost, and so the initial cost of purchasing efficient appliances is higher because

[10] The loan repayment is within 5 years, and the discount rate is set to 5%.
[11] The loan repayment is within 5 years, and the discount rate is set to 5%.
[12] LCC of conventional (less efficient) appliance deducts by the LCC of efficient one.

of the cost of borrowed capital. However, the magnitude of this effect is rather small and would not be likely to alternate the results on benefit to consumers.

3.2 LEAP modelling

This study uses the key assumptions and energy consumption data of MECON household in **Appendix B** to create energy forecast model in the LEAP software. As mentioned in the section 2.21, two scenarios are developed, and then compared to the business-as-usual (BAU) scenario[13]. The final energy consumption for MECON target group in Thailand is shown in Figure 3.6.

Total energy consumption

As the amount of MECON households in Thailand is expected to decrease from 2014 to 2030, the final energy consumption for this specific group are likely to reduce as well. In BAU scenario, the final energy consumption would have shrunken from 565.85 ktoe in 2014 to 354.96 ktoe in 2030, or reduced by 37.27%. On the other hand, the final energy consumptions are reduced in even more in the cases of Medium and High Energy Efficiency Scenarios. In the Medium Energy Efficiency (MEE) Scenario, the final energy consumption would reduce from 565.85 ktoe in 2014 to 327.69 ktoe in 2030, or by 42.10%, while it is from 565.75 ktoe to 270.91ktoe for the High Energy Efficiency (HEE) Scenario, or by 49.62%.

Even in the BAU scenario, the total energy consumption of the MECON households in Thailand has a decreasing trend. This is because the amount of MECON households in Thailand also has a decreasing trend, unlike the rest of the GMS countries. Therefore, the decreasing in energy consumption among the MECON households in Thailand is a result from a shift from low-income group to higher. On the other hand, the energy consumption of the higher income group is supposed to increase due to this shift in income classes.

[13] For more information of the BAU scenario, please see Thailand country report on Task 1.2

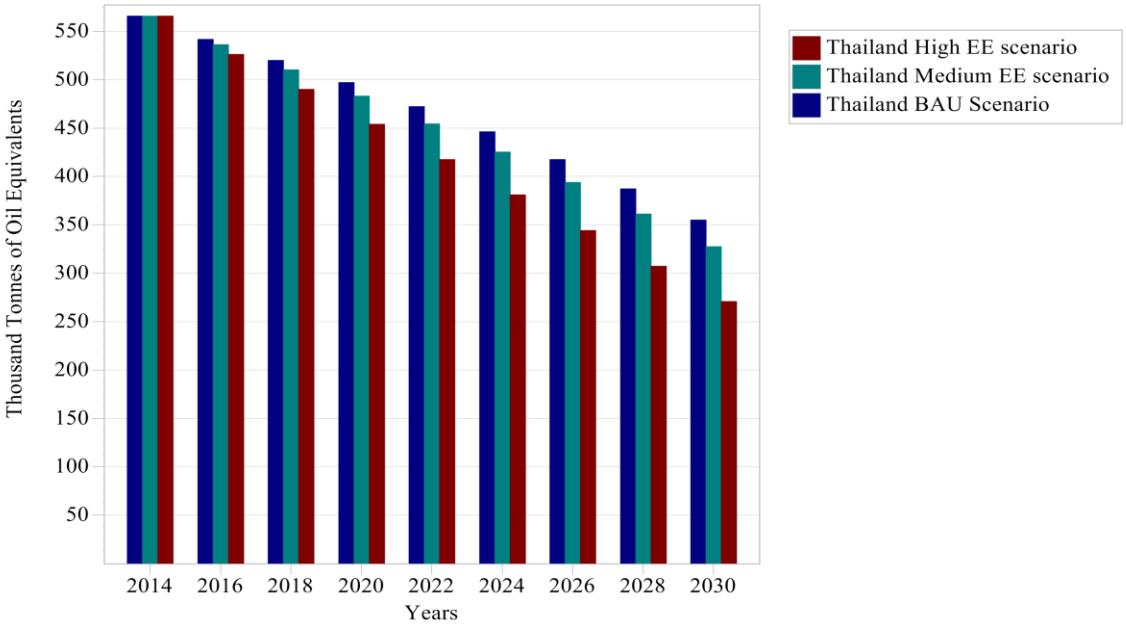


Figure 3.6: Final energy consumption by scenarios during 2014-2030

Energy consumption for lighting

As shown in Figure 3.7, the main contribution for this reduced final energy consumption results from the shift in lighting technology to higher efficiency light bulbs, for example, compact fluorescent light (CFL) bulb and light emitting diode (LED) bulb. In the MEE scenario, increasing EE in lighting appliances can reduce the energy consumption up to 57.9 % in comparison to BAU scenario, while the same figure is 83.2% for HEE scenario.

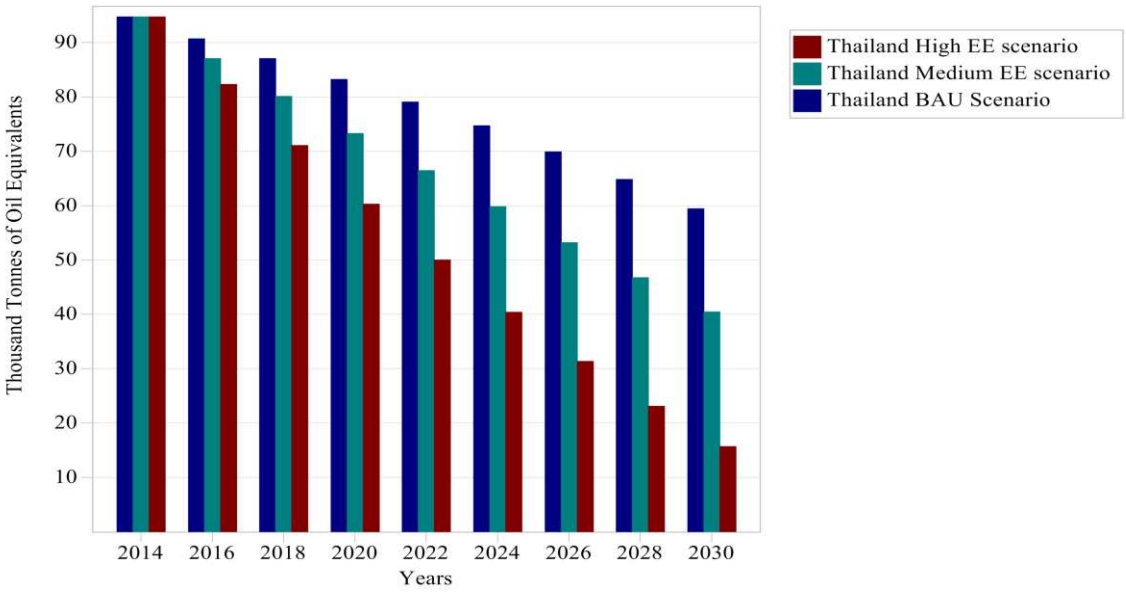


Figure 3.7: Energy consumptions for lighting by scenarios during 2014-2030

Energy consumption for cooking appliances

Among the MECON households, cooking appliances consume the second highest energy consumption. Rice cooker contributes to most of the energy consumption for cooking appliances, 124.20 ktoe in 2014. In HEE scenario, a shift from conventional to efficient rice cooker, and 20% of reduction in energy intensity of rice cooker have potential to shave the energy consumption in half[14]. The energy consumption of cooking appliances in year 2030 will decrease from 124.20 ktoe in BAU to 72.47 ktoe, or reduce by 49.6% in MEE scenario, which assumes that 40% of the MECON households in 2030 would have to adopt efficient rice cookers, raising from only 6% currently.

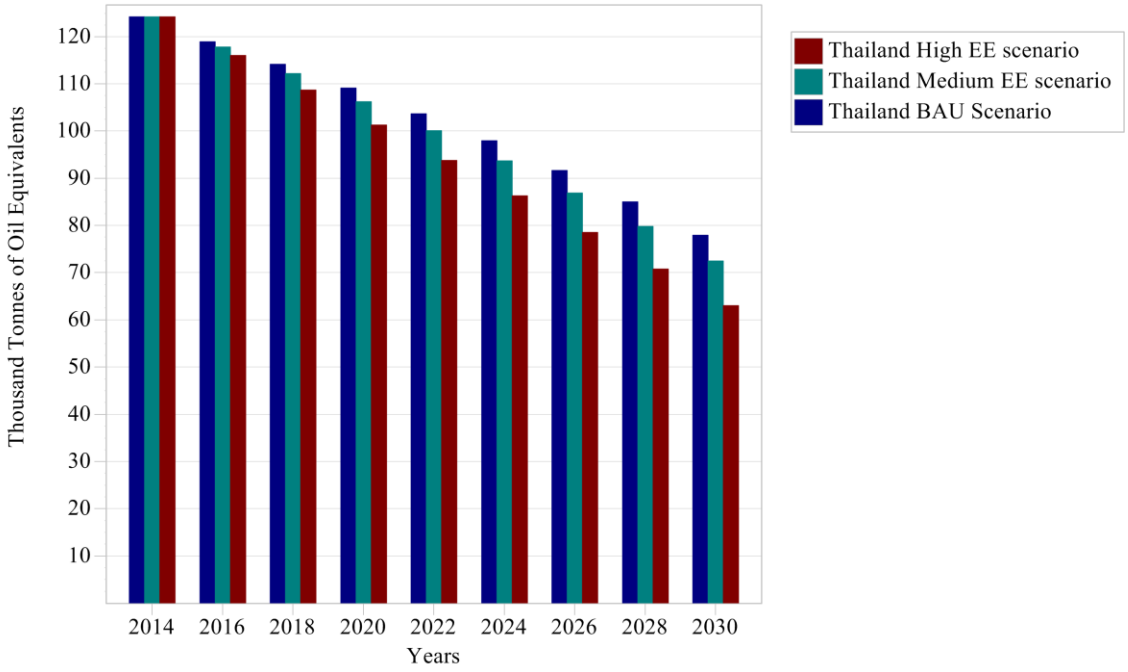


Figure 3.8: Energy consumptions for cooking appliances by scenarios during 2014-2030

Energy consumption for cooling appliances

Cooling appliances contribute to the largest share of energy consumption in MECON households as expected from tropical climate in Thailand. Refrigerator, air conditioning unit (AC) and electric fans are the three main cooling appliances. However, as MECON target group is low-income household, the use of AC is low in comparison to electric fan. From the BAU scenario, 68.4% of energy consumption from cooling appliances come from electric fan while only 9.8% are from AC. As the result, electric fan is the main cooling appliance among low-income households and policy makers should pay more attention to this appliance because more than 90% of the MECON households own it and use it for several hours per day.

Figure 3.9 shows reducing trends in the energy consumption in cooling appliances in all scenarios. MEE scenario has the highest energy consumption among all three scenarios

[14] See the assumptions in Table B.1, Appendix B

because it includes the assumptions that 20% of the households start using AC and the penetration of efficient AC is up to 40% of the appliances used by these households[15].

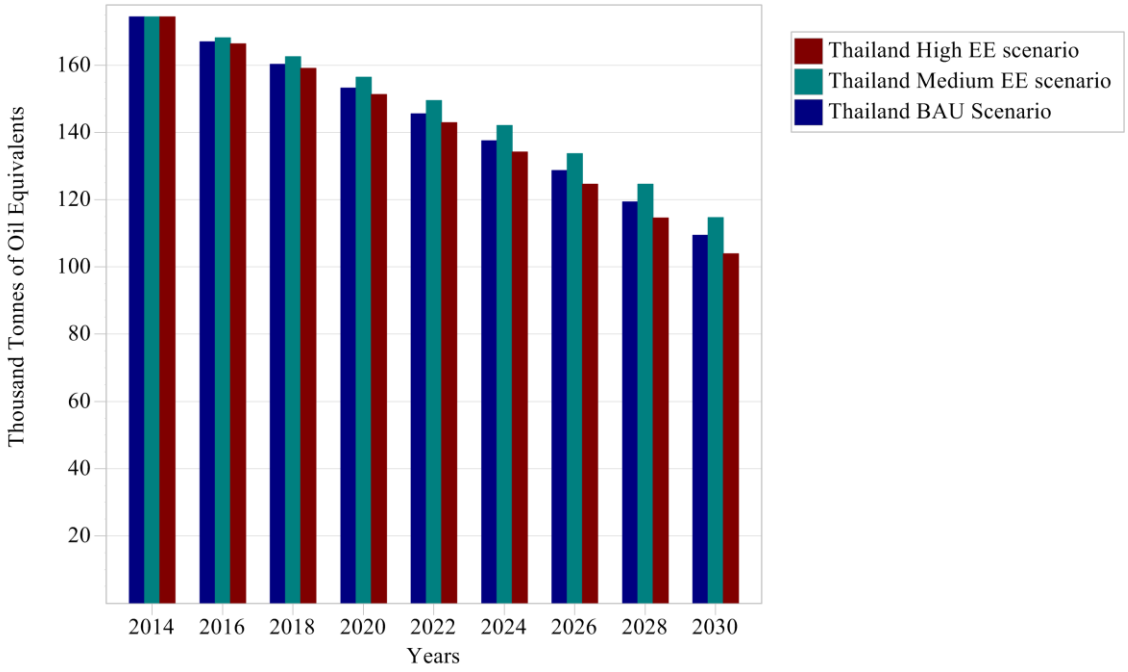


Figure 3.9: Energy consumptions for cooling appliances by scenarios during 2014-2030

Energy consumption for heating appliances

Heating appliances include electric kettle, electric water heater, solar water heater and electric heater. In Thailand, electric heater is not used because of the year-round tropical climate, and the use of solar water heater is not widely introduced. From the current trend and the absent of a specific policy to encourage the solar water heater, it is not likely to be widely adopted in the near future. Therefore, electric kettle is the main energy consumption (more than 90%) in heating appliances. In BAU scenario, the final energy consumption for heating appliances will fall from 90.57 ktoe in 2014 to 56.82 ktoe in 2030, or by 37.3%.

[15] In HEE scenario, it is assumed that 100% of the ACs used by MECON households are efficient ones to explore the extreme scenario.

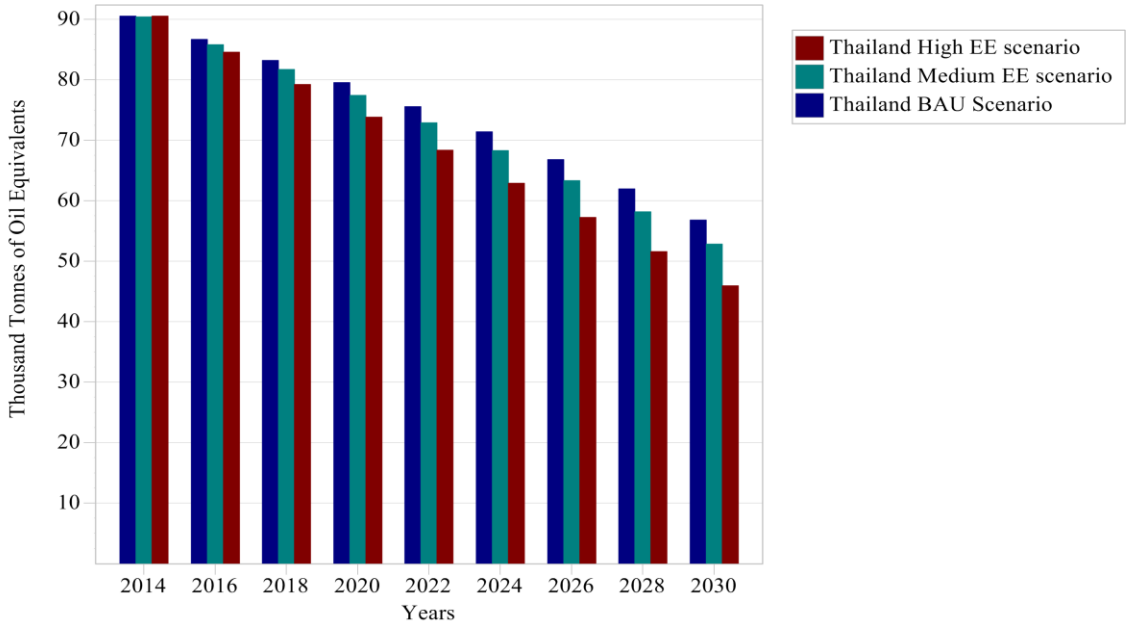


Figure 3.10: Energy consumptions for heating appliances by scenarios during 2014-2030

Energy consumption for entertainment appliances

Television (TV) contributes to the highest share of energy consumption for entertainment purposes, more than 90%. It was found that there are only two technologies, i.e. CRT and LCD technologies, which were used in low-income households. Main reason for the increase in energy consumption in MEE and HEE scenarios is the substitutions from CRT to LCD. This technology substitution will increase the energy consumption in 2030 by 41.7% in HEE scenario, and by 54.2% in MEE scenario comparing to BAU scenario.

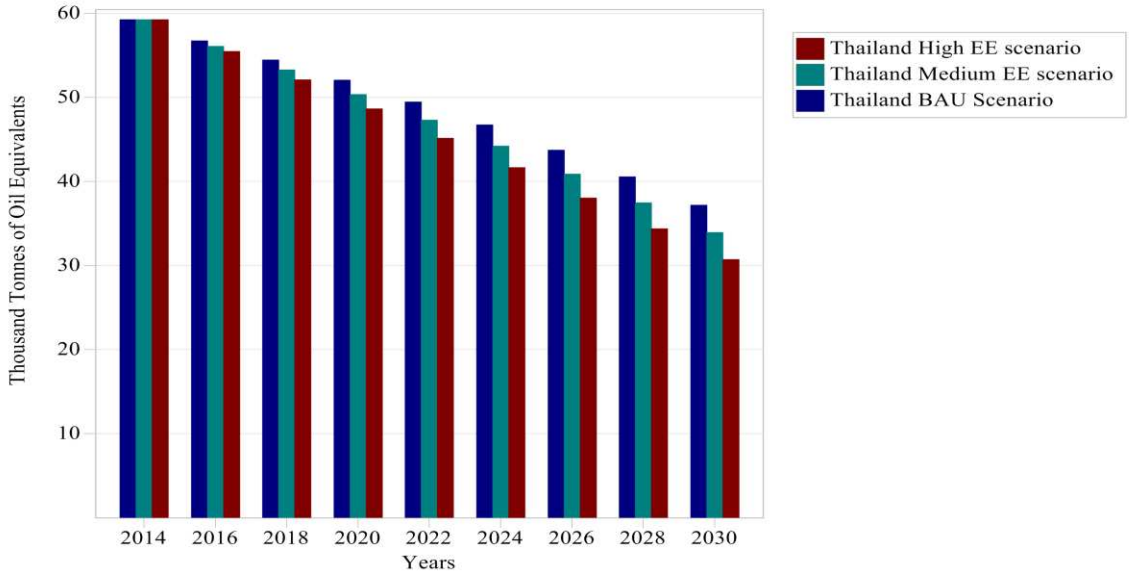


Figure 3.11 Energy consumptions for entertainment appliances by scenarios during2014-2030

Energy consumption for cleaning appliances

Washing machine and vacuum cleaner are the two major devices for this group. According to BAU scenario, the energy consumed is 8.41 ktoe in 2014 and 5.28 ktoe in 2030 (fall by 36.9%). In case of MEE and HEE, the reduction is even more. The Energy consumption in 2030 in HEE and MEE are 4.27 ktoe and 4.91 ktoe respectively. Comparing to the total energy consumption of the MECON households, cleaning appliances do not contribute to a large share of household energy consumption because the majority of the households do not own these appliances and do not use them so heavily. Perhaps these appliances should be given less priority in comparison to other high energy consuming appliances, for example, lighting, rice cooker, AC, and electric fan.

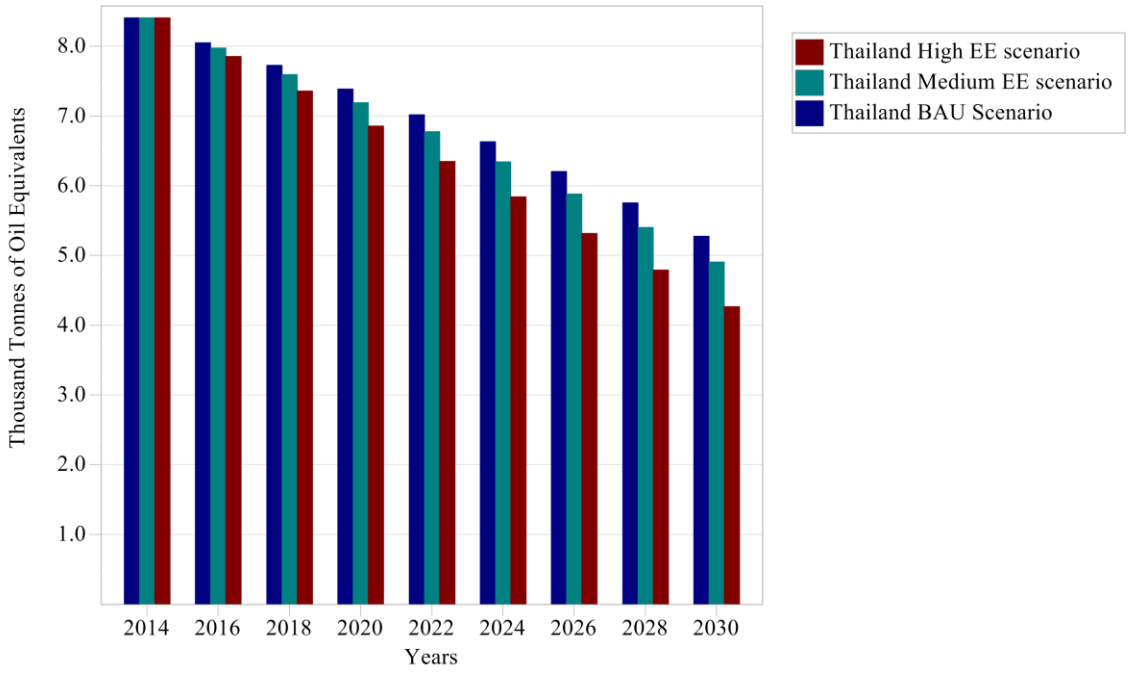


Figure 3.12: Energy consumptions for cleaning appliances by scenarios during 2014-2030

Energy consumption for other appliances

Other appliances include water pump and electric iron. In the year 2030, the energy consumption of these appliances reduces by 7.9%in MEE scenario, and by 19.1% in HEE scenario in comparison to BAU scenario. This reduction is resulted from the assumptions on electric iron when there are replacements from conventional toward 20% more efficient technologies.

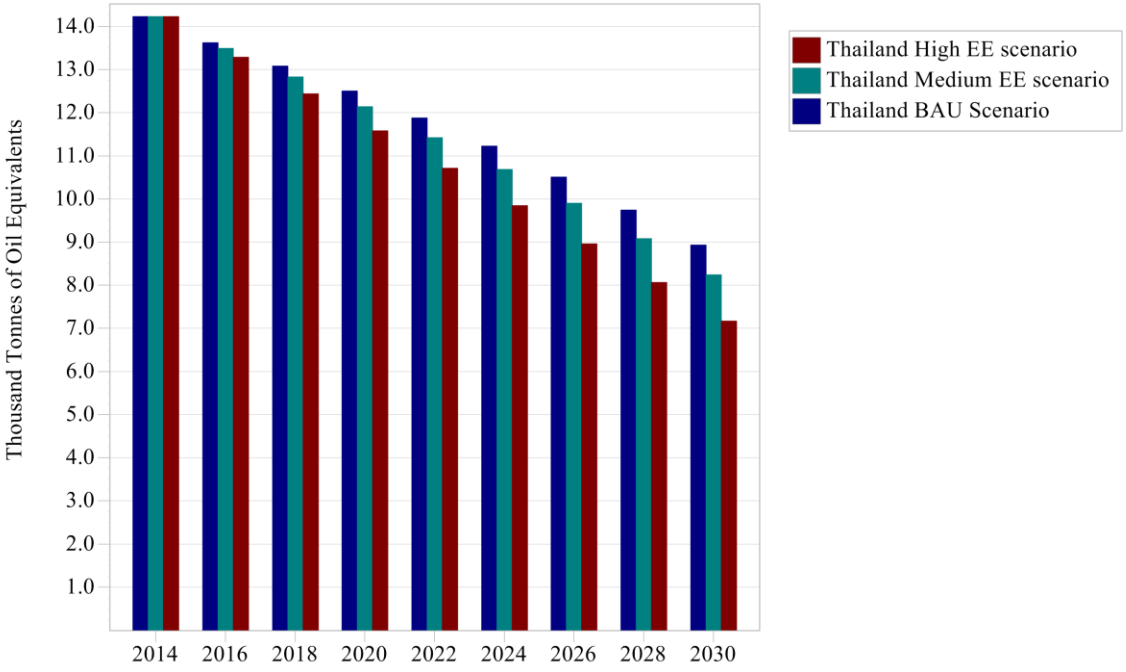


Figure 3.13: Energy consumptions for other appliances by scenarios during 2014-2030

3.3 Rebound Effect

This section presents the results from the household survey in Thailand as explained in Section 2.3. A total of 154 households were surveyed, which can be divided into 76 households in Bangkok and 78 households in Nakhon Ratchasima Province. The aims of the household survey were to investigate the rebound effect among this target group, and so to answer the following questions:

- What is the share of energy-related expenses of total household expenditure (Questions B01-11)?
- Where are the MECON most likely to spend additional income if their electricity bills decrease (Question C03/04)?
- Is the adoption of more energy efficient appliances likely to increase energy consumption e.g. through the purchase of new appliances/ services (Question C05)?
- How does expenditure on energy rank in importance in comparison to other income categories (Question C06)?

The answers to these questions may vary due to the characteristics of the households and the respondents. Therefore, this study categorizes the surveyed households by their locations (Bangkok and Nakorn Ratchasima), gender (male and female respondents), household income (100-267 USD and 267-500 USD per month), and category of energy (category (a), (b), and (c)). With regard to the latter, as discussed in Section 2.3, one of the

aims of this study was to examine whether there was any difference between categories of energy use; the surveyed households were therefore divided into those who used electricity (a) solely for lighting, (b) for lighting and small appliances, and (c) for other energy services. For other energy services, we included households owning large appliances, which are refrigerators, washing machines, air conditioning units, and electric water heaters.

The results from the household survey shows that all households use electricity for lighting, and have at least one of incandescent, fluorescent, and/ or compact fluorescent light bulbs[16]. On the large appliances, the majority of the households owned refrigerators (88.3%), and some households have washing machine (40.3%). On the other hand, air conditioning unit and electric water heater were not well adopted among these households as shown in Table 3.2.

Table 3.2: Percentage of households owning large appliances

	All households	Bangkok	Nakorn Ratchasima
Refrigerator	88.3%	85.5%	93.4%
Washing machine	40.3%	36.8%	44.7%
Air conditioning unit	5.8%	11.8%	0.0%
Electric water heater	10.4%	13.2%	7.9%

Therefore, none of the surveyed households in Thailand falls into category (a), while only 11.0% of the households belong to category (b)[17], and the rest is category (c) as presented in Table 3.3. This is not surprising because all households have been connected to national grid for quite some time, and most electrical household appliances are common and widely accessible. Presumably, low-income households consider air conditioning unit and water heaters to be luxury goods, and they cannot afford these appliances with their current incomes.

Table 3.3: Categories of the surveyed households

Household category	Purpose of electricity consumption	Amount of Households in Bangkok	Amount of Households in Nakorn Ratchasima	Total	Percentage
(a)	Solely for lighting	0	0	**0**	0%
(b)	For lighting and small appliances	11	6	**17**	11.0%
(c)	For lighting, small appliances, and other energy services	65	72	**137**	89.0%

In terms of household monthly incomes, the surveyed households in Bangkok have higher incomes on average than their counterparts in Nakorn Ratchasima. As shown in Table 3.4, 85.5% of the households in Bangkok have incomes between 267-500 USD per month, while only half of the surveyed households in Nakorn Ratchasima have the same level of income.

[16] Only one surveyed household uses light emitting diode (LED) lamp.
[17] These households only have lighting and small appliances. They do not own refrigerator, electric water heater, washing machine, or air conditioning unit.

Table 3.4: Comparison of households' monthly income between households in Bangkok and Nakorn Ratchasima

Monthly income	Bangkok		Nakorn Ratchasima	
	Household	%	Household	%
< 100 USD	1	1.3	6	7.7
100 - 267 USD	10	13.2	32	41.0
267 - 500 USD	65	85.5	39	50.0
> 500 USD	0	0.0	1	1.3
Total	76	100	78	100

Comparing the households' monthly income between households in category (b) and (c), there are no clear patterns to suggest a difference in incomes among these households. However, the households with income range between 257-500 USD are the majority in both categories as shown in Table 3.5. Presumably, the further research to further explore on these household categories should increase the sample size, which should provide a clearer comparison among these households.

Table 3.5: Comparison of households' monthly income between households in category (b) and (c)

Households' monthly income	Category (b)	%	Category (c)	%
< 100 USD	2	11.8%	5	3.6%
100 - 267 USD	5	29.4%	37	27.0%
267 - 500 USD	10	58.8%	94	68.6%
> 500 USD	0	0.0%	1	0.7%
Sum (households)	17		137	

After identifying the categories of the surveyed households, the following sections examine the rebound effect and the questions mentioned earlier starting from the share of energy-related expenses, the spending of additional budget, likeliness of rebound effect, and ranking of expenditure.

Table 3.6: Categories of the surveyed households

Household category	Purpose of electricity consumption	Amount of Households in Bangkok	Amount of Households in Nakorn Ratchasima	Total	Percentage
Category (a)	Solely for lighting	0	0	0	0%
Category (b)	For lighting and small appliances	11	6	17	11.0%
Category (c)	For lighting, small appliances, and other energy services	65	72	137	89.0%

In term of households' monthly incomes, the surveyed households in Bangkok have higher income on average than their counterparts in Nakorn Ratchasima. As shown in Table 3.7, 85.5% of the households in Bangkok have the income between 267-500 USD per month, while only half of the surveyed households in Nakorn Ratchasima have the same level of income.

Table 3.7: Comparison of households' monthly income between households in Bangkok and Nakorn Ratchasima

Households' monthly income	Households in Bangkok	%	Households in Nakorn Ratchasima	%
< 100 USD	1	1.3%	6	7.7%
100 - 267 USD	10	13.2%	32	41.0%
267 - 500 USD	65	85.5%	39	50.0%
> 500 USD	0	0.0%	1	1.3%
Total	76		78	

Comparing the households' monthly income between households in category (b) and (c), there is no clear evidence or pattern suggesting income difference among these households. However, the households with income range between 257-500 USD are the majority in both categories as shown in Table 3.8. Presumably, the further research to further explore on these household categories should increase the sample size, which should provide a clearer comparison among these households.

Table3.8: Comparison of households'monthly income between category (b) and (c)

Households' monthly income	Category (b)	%	Category (c)	%
< 100 USD	2	11.8%	5	3.6%
100 - 267 USD	5	29.4%	37	27.0%
267 - 500 USD	10	58.8%	94	68.6%
> 500 USD	0	0.0%	1	0.7%
Sum (households)	17		137	

After identifying the categories of the surveyed households, the following sections examine the rebound effect and the questions mentioned earlier starting from the share of energy-related expenses, the spending of additional budget, likeliness of rebound effect, and ranking of expenditure.

The Questions B01-11 of the questionnaire ask the respondents to provide their household spending last month on different types of expense as shown in Table 3.9. The surveyed households spend 65% of the monthly expenses on foods, housing and education combined. This result is expectable among low-income households since they would set their basic physical needs as the most priority. On energy-related expense, electricity bills are rank as the fourth expense, while cooking fuels have a lower share in the household total expense. Although these energy-related expenses might not have a large share individually, it can sum up to 9.1% of the total household expenditure, which is a substantial cost for the low-income households.

Table 3.9: Average household monthly expenses by type of expenses

	Type of expenses	Expense (USD)	Percentage
1	**Food**	**150**	**37.1%**
2	**Housing**	**71**	**17.6%**
3	**Education**	**42**	**10.3%**
4	Electricity bills	23	5.8%
5	Other	22	5.4%

6	Transportation	21	5.3%
7	Savings & investment	20	4.9%
8	Clothing & furniture	20	4.9%
9	Healthcare	14	3.5%
10	Cooking fuels (fuel wood, charcoal, gas etc.)	13	3.3%
11	Water bills	8	1.9%
	Sum	**403**	**100.0%**

Table 1E, 2E, 3E, and 4E in **Appendix E** show the comparisons of monthly expenses between households in category (b) and (c); households with monthly income between 100-267 USD and 267-500 USD; households in Bangkok and Nakorn Ratchasima; and between male and female respondents.

It is worth noting here that the expenses on food, housing, and education have the largest shares among the low-income households regardless of household characteristic. The different comparisons between gender, income ranges, areas, or categories of energy consumption may vary the results on the share of energy-related expense, but the low-income households still spend mostly on food, housing, and education.

The questions C03 and 04 of the questionnaire ask the respondents if their electricity bills were to decrease, on which expenses they would spend this additional budget. Enumerators asked the respondents to provide percentage of additional spending on each category of household expense as shown in Figure 3.14.

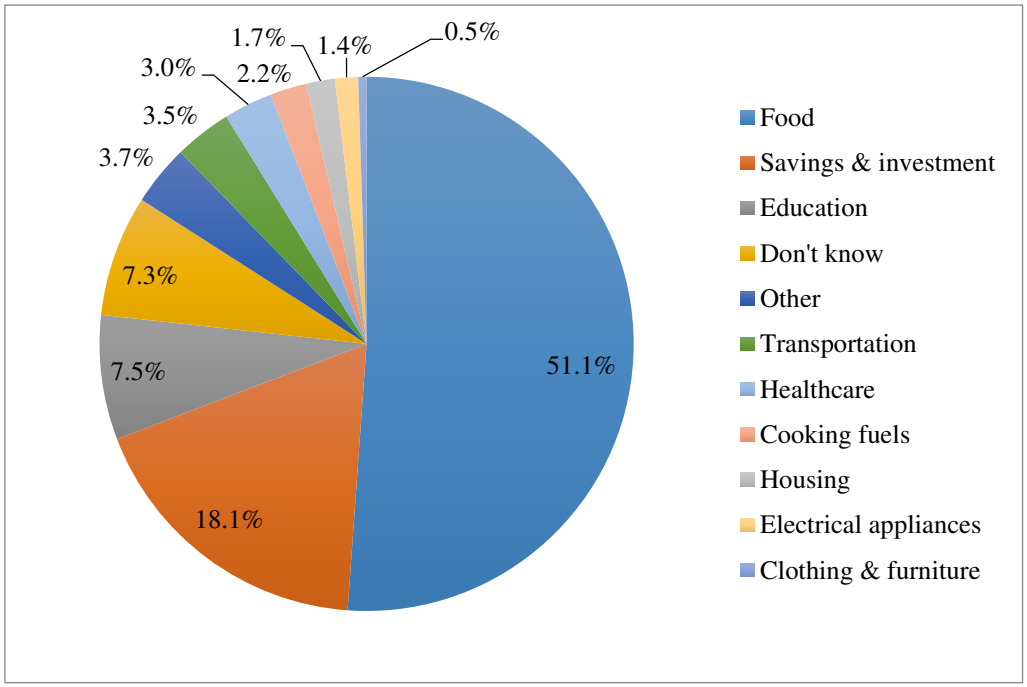


Figure 3.14: Proportion of additional spending from decreasing electricity bills

The surveyed household would spend 51.1% of their additional budget from decreasing electricity bills on food, followed by saving and investment. As expected among low-income households, the rebound effects are small either on the cooking fuels (2.2%) or

electrical appliances (1.4%). From this result, it does not seem that the rebound effect occurred among the low-income households would be substantial if they can save on their electricity bills.

This study also compares the additional spending between households in category (b) and (c); households with monthly income between 100-267 USD and 267-500 USD; households in Bangkok and Nakorn Ratchasima; and between male and female respondents. These are shown in Table 5E, 5E, 7E, and 8E in **Appendix E**. Despite of these comparisons, the surveyed households tend to spend most of their additional budget on foods regardless of household characteristics.

The question C05 of the questionnaire asks the respondents what they would do if they were to spend the money that they had saved through lower electricity bills. The enumerators provide five choices as follows.

a) Use my existing appliances more
b) Buy an appliance that I've never had before
c) Upgrade or replace an appliance I already have
d) Other …….... (please specify)
e) Don't know

In case of Thailand, many respondents who answered choice (d) specified that they would save the money from lower electricity bills for later. Therefore, we add the choice "saving for the future" into the result and present it in Figure 3.15.

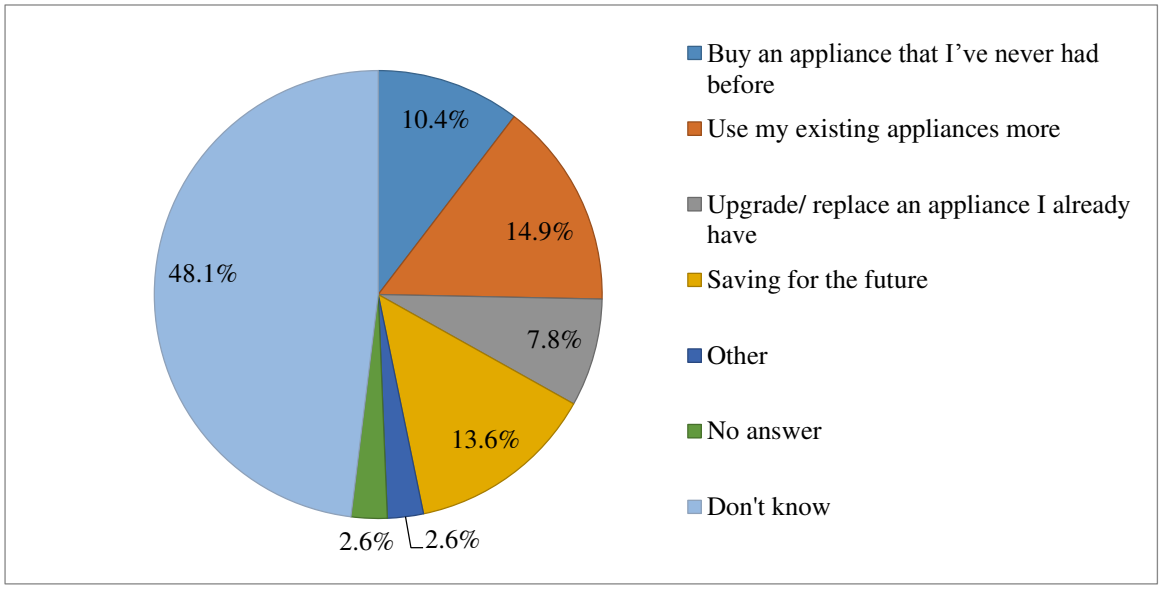


Figure 3.15: Behaviours in responds to lower electricity bills

Although almost half of the respondents answered that they did not know what to do with the money saved from lower electricity bills, there were around 33% of the respondents who would either choose options (a), (b), or (c). This means that if these households can save on their electricity bills, the rebound effect is likely to take place in around one third of them.

Figure 1E, 2E, 3E, and 4E in **Appendix E** show the comparison of these behaviors in responds to lower electricity bills between households in category (b) and (c); households with monthly income between 100-267 USD and 267-500 USD; households in Bangkok and Nakorn Ratchasima; and between male and female respondents. Similar results were found from the comparisons, and the rebound effect from saving electricity bills is likely to occur in 30-40% of the respondents approximately.

The question C06 of the questionnaire asks the respondents to rank expenses on which they would spend if they have an extra 10 USD every month. There were 10 categories of expense presented in the questionnaire, and the respondents had to rank from the most important to the least important expenses. Then, we convert the ranking into scores, from 1 being the lowest important expenses to 10 being the highest, using a simple weighted average method. The result is presented in Figure 3.16.

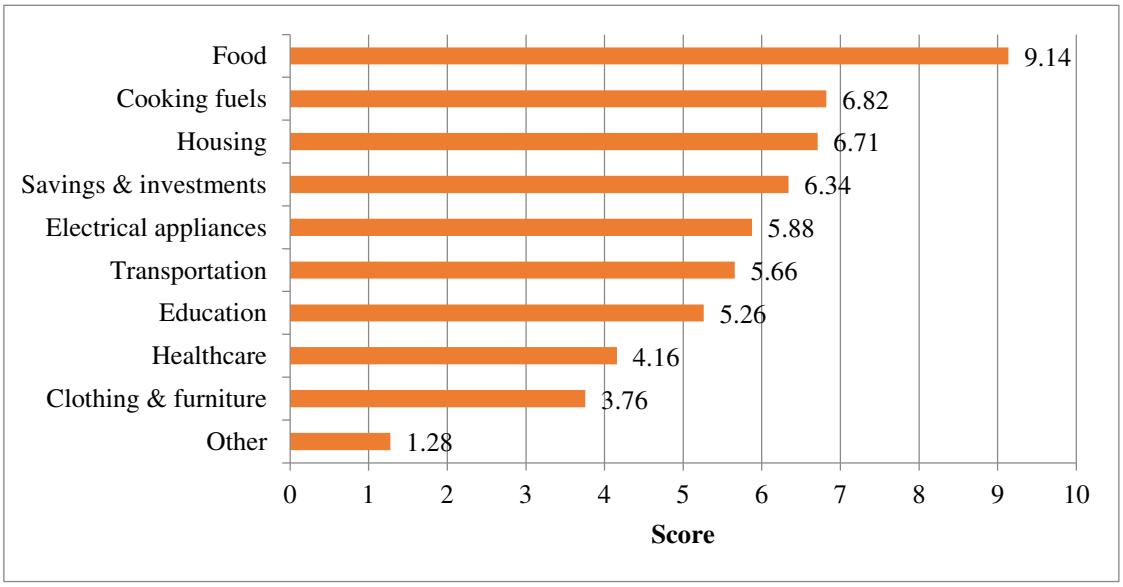


Figure 3.16: Ranking of expenses most likely to occur if having extra 10 USD every month

Figure 3.16 shows that food is still the most important expense among these households, and they are most likely to spend on it if they have extra incomes. The income effect may also contribute to higher consumptions of cooking fuels as it comes in second in the ranking after food.

Table 9E, 10E, 11E, and 12E in **Appendix E** show the comparison of these rankings and scores between households in category (b) and (c); households with monthly income between 100-267 USD and 267-500 USD; households in Bangkok and Nakorn Ratchasima; and between male and female respondents. Similarly, the comparisons show that food is still the most priority expense among the low-income households. Cooking fuels also have high

scores in many comparisons, and this suggests possibility that the expense on cooking fuels may raise if these households have higher incomes in the near future.

4 Discussion

The results from cost-benefit analysis point out that lighting technology has the highest potential for the energy efficiency improvement (Figure 1 and 7). It should be consider as the low-hanging fruit for policy makers, especially on the substitution from fluorescent light bulb to LED light bulb, which is not introduced to the MECON households in Thailand according to the household survey[18]. The result from LEAP modelling shows that this substitution can conserve energy up to one-third of the energy consumption in the BAU scenario (Figure 7). Therefore, it should be the most priority policy intervention in the residential sector on low-income households.

Rice cooker, electric kettle, and electric fan contribute to a large share of total energy consumption in the MECON households because the majority of the households own them and use it regularly for many hours per day. The result from cost-benefit analysis shows great benefit for consumers for using efficient electric fan in comparison to conventional one (Figure 5), while the benefit for using efficient rice cooker is rather small and might not be so 'visible' to consumers (Figure 2). More policy intervention should emphasize on these appliances, for example, tightening the energy standard and encouraging more adoption of efficient appliances through informational campaign.

Considering the decreasing trend of total energy consumption among MECON households in Thailand, it is highly related to shift in demographics and income classes (Figure 6). In other words, the trend of MECON households by definition is declining in Thailand, and so their energy consumption as a whole group decreases as well. This means that they may have higher income and elevate to a higher income group instead. Unfortunately, the scope of this study does not investigate the higher income group, but the expectation is that there will be dramatic increase in energy consumption in the higher income group in Thailand due to this demographic changes. Further investigation on other income group is highly recommended.

Regarding the rebound effect, none of the surveyed household use energy solely for lighting purpose. On the other hand, most of the surveyed households own a wide range of appliances, and so belong to category (c) (Table 6). The most important expenses in these households are on foods, housing[19], and education, respectively. Combining electricity bill

[18] See detailed results of Thailand's household survey in Thailand Task 3 Report: Socio-economic perspective.
[19] Rent or house-related expenses, for example, house retrofit or fix.

and expense on cooking fuel; energy expense is the next-in-line most important household expense. The household survey shows that the households tend to spend their additional income, either from energy saving or else, mostly on food and cooking fuels (Figure 16). On energy consumption behaviour, one-fourth of the households think they will buy more appliances and consume their existing appliances more, indicating a potential for the rebound effect among these MECON households. However, it is not clear whether this result of the rebound effect is 'high' or 'low' without comparing to other income group. A comparative study on the rebound effect between various income groups should be further investigated.

5 Conclusions

This study provides an insight on energy consumption among MECON households and explores into various scenarios, benefits to consumers, and the potential rebound effect, which may occur. This study has limitation when analysing alternative scenarios because the data availability and lack of clear policy in residential consequence in difficulty for making accurate assumptions. Improving data collection in the national level is a general recommendation, which is the key to energy efficiency improvement and the success of policy implementation, not only for Thailand but also for other GMS countries.

This study found that the economic evaluation on energy efficient appliances and their benefit to consumers is rather new in Thailand. Moreover, there are limited studies exploring into the rebound effect among households in Thailand. In conclusion, more variety and interdisciplinary researches on the household energy consumption should be highly beneficial to energy consumers and policy makers in order to design and to successfully implement policy intervention for improving energy efficiency.

Appendix A Data and assumptions for cost-benefit analyses (CBA)

Table 1A: Data and assumptions for cost-benefit analyses (CBA)

	Wattage	Hour used (hours/day)	Efficiency factor	Life span (year)	Energy consumption (kWh/year)	Capital cost (USD)	Maintenance cost (USD/year)	Additional assumptions
Fluorescent light bulb	31	4.11		10	46.50	1.50	0.00	The wattages are 28 watt for fluorescent light bulb and 3 watt for ballast. Data on wattage and capital cost of LED light bulb was collected from the market survey. The life span of appliances is 15,000 hour, assumed to function for 10 years or 1,500 hours per year.
LED light bulb	8	4.11		10	12.00	8.33	0.00	
Rice cooker (efficient)	700	0.54	1	10	137.23	33.33	0.00	The average usage hour for electric rice cooker is 196.04 hours per year as suggested by the Demand Side Management and Planning Division of EGAT. The efficiency factor of 1.145 comes from the thermal efficiency rate, which is the proportion of heat generated from the inputting electricity. The thermal efficiency rate is 87% for the efficient rice cooker and 76% for the conventional one. Therefore, the efficiency factor is 87%/76% or 1.145.
Rice cooker (conventional)	700	0.54	1.145	10	157.09	25.00	0.00	
Air conditioning unit (efficient)	795	8.00		15	2321.40	750.00	10.00	The efficient AC unit used in this study is an inverter type with energy efficiency ratio (EER) of 15.09 and the capacity of 12,000 BTU/hour, while the conventional AC unit is a fixed-speed type with energy efficiency ratio (EER) of 12 and the capacity of 12,000 BTU/hour. AC unit has maintenance cost of 10 USD per year.
Air conditioning unit (conventional)	1000	8.00		15	2920.00	616.67	10.00	
Refrigerator (efficient)			1	15	187.49	200.56	0.00	Both efficient and conventional refrigerators are a one-door type with the size of 6.4 cubic feet, or approximately 183 liters. This study collected data of several refrigerators with EGAT's EE labels (Label No.5), which shows average energy consumption per year (in kWh) and estimated electricity cost. On the other hand, inefficient refrigerators in Thailand are mostly second-handed. Unlike refrigerators with EGAT's EE label, these products often do not have any detail on energy consumption, and so we assume inefficient refrigerator to consume 20% more than the efficient one, and so the efficiency factor is 1.2 for the conventional one. The price for inefficient refrigerator is assumed to be 4,000 baht or around 133,33 USD.
Refrigerator (conventional)			1.2	15	224.98	133.33	0.00	
Electric fan (efficient)	60	6.00		10	131.40	24.17	0.00	The data used for both efficient and conventional electric fan were collected from several products in the market. The hour used is assumed to be 2,190 hour per year.
Electric fan (conventional)	80	6.00		10	175.20	17.50	0.00	

Table 2A: CBA between fluorescent and LED light bulbs

		Fluorescent light bulb					LED light bulb				
Year	Electricity Price ($/kWh)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)
1	0.1320	46.50	1.50	0	6.14	7.35	12.0	8.33	0	1.58	9.84
2	0.1337	46.50	0	0	6.21	5.64	12.0	0	0	1.60	1.45
3	0.1353	46.50	0	0	6.29	5.44	12.0	0	0	1.62	1.40
4	0.1370	46.50	0	0	6.37	5.24	12.0	0	0	1.64	1.35
5	0.1387	46.50	0	0	6.45	5.05	12.0	0	0	1.66	1.30
6	0.1405	46.50	0	0	6.53	4.87	12.0	0	0	1.69	1.26
7	0.1422	46.50	0	0	6.61	4.70	12.0	0	0	1.71	1.21
8	0.1440	46.50	0	0	6.70	4.53	12.0	0	0	1.73	1.17
9	0.1458	46.50	0	0	6.78	4.37	12.0	0	0	1.75	1.13
10	0.1476	46.50	0	0	6.86	4.21	12.0	0	0	1.77	1.09
Total Life Cost:						**51.40**					**21.21**

Table 3A: CBA between conventional and efficient rice cookers

		Conventional rice cooker					Efficient rice cooker				
Year	Electricity Price ($/kWh)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)
1	0.1320	157.1	25.00	0	20.74	44.75	137.2	33.33	0	18.11	50.58
2	0.1337	157.1	0	0	21.00	19.04	137.2	0	0	18.34	16.64
3	0.1353	157.1	0	0	21.26	18.36	137.2	0	0	18.57	16.04
4	0.1370	157.1	0	0	21.52	17.71	137.2	0	0	18.80	15.47
5	0.1387	157.1	0	0	21.79	17.07	137.2	0	0	19.04	14.92
6	0.1405	157.1	0	0	22.06	16.46	137.2	0	0	19.27	14.38
7	0.1422	157.1	0	0	22.34	15.88	137.2	0	0	19.52	13.87
8	0.1440	157.1	0	0	22.62	15.31	137.2	0	0	19.76	13.37
9	0.1458	157.1	0	0	22.90	14.76	137.2	0	0	20.01	12.90
10	0.1476	157.1	0	0	23.19	14.24	137.2	0	0	20.26	12.44
Total Life Cost:						**193.59**					**180.61**

Table 4A: CBA between conventional and efficient air conditioning units

		Conventional air conditioning unit					Efficient air conditioning unit				
Year	Electricity Price ($/kWh)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)
1	0.1320	2920.00	616.67	10	385.44	993.28	2321.40	750.00	10	306.42	1051.36
2	0.1337	2920.00	0	10	390.26	363.05	2321.40	0	10	310.26	290.48
3	0.1353	2920.00	0	10	395.14	349.97	2321.40	0	10	314.13	280.00
4	0.1370	2920.00	0	10	400.08	337.37	2321.40	0	10	318.06	269.90
5	0.1387	2920.00	0	10	405.08	325.22	2321.40	0	10	322.04	260.16
6	0.1405	2920.00	0	10	410.14	313.51	2321.40	0	10	326.06	250.77
7	0.1422	2920.00	0	10	415.27	302.23	2321.40	0	10	330.14	241.73
8	0.1440	2920.00	0	10	420.46	291.35	2321.40	0	10	334.26	233.01
9	0.1458	2920.00	0	10	425.71	280.86	2321.40	0	10	338.44	224.61
10	0.1476	2920.00	0	10	431.03	270.76	2321.40	0	10	342.67	216.51
11	0.1495	2920.00	0	10	436.42	261.01	2321.40	0	10	346.96	208.70
12	0.1513	2920.00	0	10	441.88	251.62	2321.40	0	10	351.29	201.18
13	0.1532	2920.00	0	10	447.40	242.57	2321.40	0	10	355.68	193.93
14	0.1551	2920.00	0	10	452.99	233.84	2321.40	0	10	360.13	186.94
15	0.1571	2920.00	0	10	458.66	225.43	2321.40	0	10	364.63	180.20
Total Life Cost:						**5,042.09**					**4,289.49**

Table 5A: CBA between conventional and efficient refrigerators

		Conventional refrigerator					Efficient refrigerator				
Year	Electricity Price ($/kWh)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)
1	0.1320	224.98	133.33	0	29.70	161.62	187.49	200.56	0	24.75	224.13
2	0.1337	224.98	0	0	30.07	27.27	187.49	0	0	25.06	22.73
3	0.1353	224.98	0	0	30.44	26.30	187.49	0	0	25.37	21.92
4	0.1370	224.98	0	0	30.83	25.36	187.49	0	0	25.69	21.13
5	0.1387	224.98	0	0	31.21	24.45	187.49	0	0	26.01	20.38
6	0.1405	224.98	0	0	31.60	23.58	187.49	0	0	26.33	19.65
7	0.1422	224.98	0	0	32.00	22.74	187.49	0	0	26.66	18.95

		Conventional refrigerator					Efficient refrigerator				
Year	Electricity Price ($/kWh)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)
8	0.1440	224.98	0	0	32.40	21.93	187.49	0	0	27.00	18.27
9	0.1458	224.98	0	0	32.80	21.14	187.49	0	0	27.33	17.62
10	0.1476	224.98	0	0	33.21	20.39	187.49	0	0	27.68	16.99
11	0.1495	224.98	0	0	33.63	19.66	187.49	0	0	28.02	16.38
12	0.1513	224.98	0	0	34.05	18.96	187.49	0	0	28.37	15.80
13	0.1532	224.98	0	0	34.47	18.28	187.49	0	0	28.73	15.23
14	0.1551	224.98	0	0	34.90	17.63	187.49	0	0	29.09	14.69
15	0.1571	224.98	0	0	35.34	17.00	187.49	0	0	29.45	14.17
Total Life Cost:						**466.31**					**478.04**

Table 6A: CBA between conventional and efficient electric fans

		Conventional electric fan					Efficient electric fan				
Year	Electricity Price ($/kWh)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)	Electricity Cons. (kWh/year)	Capital Cost ($/appl.)	Maintenance Cost ($/year)	Fuel Cost ($/year)	Life Cycle Cost ($)
1	0.1320	175.2	17.50	0	23.13	39.53	131.4	24.17	0	17.34	40.69
2	0.1337	175.2	0	0	23.42	21.24	131.4	0	0	17.56	15.93
3	0.1353	175.2	0	0	23.71	20.48	131.4	0	0	17.78	15.36
4	0.1370	175.2	0	0	24.00	19.75	131.4	0	0	18.00	14.81
5	0.1387	175.2	0	0	24.30	19.04	131.4	0	0	18.23	14.28
6	0.1405	175.2	0	0	24.61	18.36	131.4	0	0	18.46	13.77
7	0.1422	175.2	0	0	24.92	17.71	131.4	0	0	18.69	13.28
8	0.1440	175.2	0	0	25.23	17.07	131.4	0	0	18.92	12.81
9	0.1458	175.2	0	0	25.54	16.47	131.4	0	0	19.16	12.35
10	0.1476	175.2	0	0	25.86	15.88	131.4	0	0	19.40	11.91
Total Life Cost:						**205.52**					**165.18**

Appendix B Data and assumptions for LEAP modelling and scenario analysis

Table 1B: Data and assumptions for LEAP modelling and scenario analysis

Appliance	Percentage of households owning the appliance in 2014	Final energy intensity (kWh/household/year)	Final energy intensity (TOE/household/year)
Lighting technologies			
Incandescent light bulb	6.61	48.18	-
Fluorescent light bulb	59.32	242.09	-
Compact fluorescent light bulb	26.78	42.64	-
LED	0.00	16.25	-
Kerosene light bulb	0.00	-	0.001880
Cooking appliances			
Existing electric cooking stove	0.34	137.61	-
Efficient electric cooking stove	0.00	110.08	-
Existing rice cooker	50.24	383.93	-
Efficient rice cooker	2.98	307.15	-
Existing microwave oven	6.78	71.36	-
Efficient microwave oven	0.00	57.09	-
Existing biomass stove	39.32	-	0.002059
Efficient biomass stove	0.00	-	0.001647
Existing charcoal stove	50.85	-	0.009516
Efficient charcoal stove	0.00	-	0.007613
Existing LPG stove	52.88	-	0.006692
Efficient LPG stove	0.00	-	0.005354
Kerosene Stove	0.00	-	0.002824
Cooling appliances			
Existing AC unit	7.43	307.82	-
Efficient AC unit	0.03	246.25	-
Existing refrigerator	20.12	216.15	-
Efficient refrigerator	14.80	172.92	-
Existing electric fan	72.88	219.53	-
Efficient electric fan	22.37	175.62	-
Heating			
Existing electric kettle	24.12	455.47	-
Efficient electric kettle	7.41	364.38	-
Existing electric water heater	3.39	277.40	-
Efficient electric water heater	0.00	221.92	-
Entertainment			
Existing TV (CRT/box TV)	52.88	162.02	-
Efficient TV (LCD/flat screen TV)	8.14	271.75	-

Appliance	Percentage of households owning the appliance in 2014	Final energy intensity (kWh/household/year)	Final energy intensity (TOE/household/year)
Video/DVD player	13.56	27.21	-
Radio	14.92	48.65	-
Computer	3.73	78.59	-
Hi-fi system	3.05	11.13	-
Mobile phone	50.85	3.83	-
Cleaning			
Existing washing machine	33.37	41.76	-
Efficient washing machine	0.19	33.41	
Existing vacuum cleaner	0.34	54.75	-
Efficient vacuum cleaner	0.00	43.80	-
Other appliances			
Water pump	4.07	54.82	-
Existing electric iron	32.07	73.00	-
Efficient electric iron	0.47	73.00	-

Table 2B: Assumptions for High Energy Efficiency (HEE) Scenario

Appliance	Assumptions: High Energy Efficiency Scenario	
	Percentage of household owning the EE appliances in 2030 (%)	**Final energy intensity (kWh/year)**
Lighting technologies		
Incandescent light bulb	Assumed a complete phasing out for Incandescent, and then 100% substitution to LED Incandescent: Interpolation (2014, 100, 2030, 0) LED: Remainder (100)	Incandescent to CFL: Final energy intensity reduces by 80% Incandescent to LED: Final energy intensity reduces by 90%
Fluorescent light bulb (FLS)	Assumed a complete phasing out for FLS, and then 100% substitution to LED FLS: Interpolation (2014, 100, 2030, 0) LED: Remainder (100)	FLS to CFL: Final energy intensity reduces by 50% FLS to LED: Final energy intensity reduces by 75%
Compact fluorescent light (CFL) bulb	Assumed a complete phasing out for CFL, and then 100% substitution to LED CFL: Interpolation (2014, 100, 2030, 0) LED: Remainder (100)	CFL to CFL: Final energy intensity reduces by 50%
LED	Assumed to penetrate the market to 30% of households LED: Interpolation (2014, 0, 2030, 30)	Assumed constant
Kerosene light bulb	No change	No change
Cooking appliances		
Electric cooking stove	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one
Rice cooker	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 94.40, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one
Microwave oven	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Biomass Stove	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 86, 2030, 0)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Improve biomass stove		

Appliance	Assumptions: High Energy Efficiency Scenario	
	Percentage of household owning the EE appliances in 2030 (%)	**Final energy intensity (kWh/year)**
	Efficient technology: Remainder (100)	
Charcoal Stove	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
LPG Stove	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Kerosene Stove	No change	No change
Cooling appliances		
AC	Assumed to penetrate the market to 20% of households AC: Interpolation (2014, 7.46, 2030, 20) Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 99.66, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Refrigerator	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 57.61, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Electric fan	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 76.51, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Heating		
Electric kettle	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 93.91, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Electric water heater	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Solar water heater (SWH)	No change	No change
Electric Heater	No change	No change

Appliance	Assumptions: High Energy Efficiency Scenario	
	Percentage of household owning the EE appliances in 2030 (%)	**Final energy intensity (kWh/year)**
Entertainment		
TV CRT (box TV)	Full substitution from CRT to LCD CRT: Interpolation (2014, 87, 2030, 0) LCD: Remainder (100)	No change
TV LCD (flat screen TV)		
Video/DVD player	No change	No change
Radio	No change	No change
Computer	No change	No change
Hi-fi system	No change	No change
Mobile phone	No change	No change
Cleaning		
Washing machine	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 94.44, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Vacuum cleaner	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Other appliances		
Water pump	No change	No change
Electric iron	Full substitution from existing to efficient technology Existing technology: Interpolation (2014, 98.55, 2030, 0) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.

Table 3B: Assumptions for Medium Energy Efficiency (MEE) Scenario

Appliance	Assumptions: Medium Energy Efficiency Scenario	
	Percentage of household owning the EE appliances in 2030 (%)	**Final energy intensity (kWh/year)**
Lighting technologies		
Incandescent light bulb	Assumed a complete phasing out for Incandescent, and then 50% substitution to CFL and another 50% to LED Incan: Interpolation (2014, 100, 2030, 0) CFL: Interpolation (2014, 0, 2030, 50) LED: Remainder (100)	Incandescent to CFL: Final energy intensity reduces by 80% Incandescent to LED: Final energy intensity reduces by 90%
Fluorescent light bulb (FLS)	Assumed a 50% phasing out for FLS, and then 25% substitution to CFL and another 25% to LED FLS: Interpolation (2014, 100, 2030, 50) CFL: Interpolation (2014, 0, 2030, 25) LED: Remainder (100)	FLS to CFL: Final energy intensity reduces by 50% FLS to LED: Final energy intensity reduces by 75%
Compact fluorescent light (CFL) bulb	Assumed a 50% phasing out for CFL, and then 50% substitution to LED CFL: Interpolation (2014, 100, 2030, 50) LED: Interpolation (2014, 0, 2030, 50)	CFL to CFL: Final energy intensity reduces by 50%
LED	Assumed to penetrate the market to 15% of households LED: Interpolation (2014, 0, 2030, 15)	Assumed constant
Kerosene light bulb	No change	No change
Cooking appliances		
Electric cooking stove	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Rice cooker	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 94.40, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Microwave oven	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Biomass Stove Improve biomass stove	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 86, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Charcoal Stove	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
LPG Stove	Substitution to 40% of the households from existing to efficient technology	Efficient technology is assumed to have 20% less final energy intensity

Appliance	Assumptions: Medium Energy Efficiency Scenario	
	Percentage of household owning the EE appliances in 2030 (%)	**Final energy intensity (kWh/year)**
	Existing technology: Interpolation (2014, 100, 2030, 60) Efficient technology: Remainder (100)	than existing one.
Kerosene Stove	No change	No change
Cooling appliances		
AC	Assumed to penetrate the market to 20% of households AC: Interpolation (2014, 7.46, 2030, 20) Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 99.66, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Refrigerator	Substitution to 70% of the households from existing to efficient technology Existing technology: Interpolation (2014, 57.61, 2030, 30) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Electric fan	Substitution to 60% of the households from existing to efficient technology Existing technology: Interpolation (2014, 76.51, 2030, 40) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Heating		
Electric kettle	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 93.91, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Electric water heater	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Solar water heater (SWH)	No change	No change
Electric Heater	No change	No change
Entertainment		
TV CRT (box TV)	Substitution to 80% of the households from CRT to LCD CRT: Interpolation (2014, 87, 2030, 20) LCD: Remainder (100)	No change
TV LCD (flat screen TV)		
Video/DVD player	No change	No change
Radio	No change	No change
Computer	No change	No change
Hi-fi system	No change	No change
Mobile phone	No change	No change

Appliance	Assumptions: Medium Energy Efficiency Scenario	
	Percentage of household owning the EE appliances in 2030 (%)	**Final energy intensity (kWh/year)**
Cleaning		
Washing machine	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 94.44, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Vacuum cleaner	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 100, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.
Other appliances		
Water pump	No change	No change
Electric iron	Substitution to 40% of the households from existing to efficient technology Existing technology: Interpolation (2014, 98.55, 2030, 60) Efficient technology: Remainder (100)	Efficient technology is assumed to have 20% less final energy intensity than existing one.

Appendix C

Survey questionnaire

มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรีบางมด

หมายเลขของการสัมภาษณ์:

……
……

หมายเลขของผู้สัมภาษณ์ (Enumerator ID):

……

วัน ……เดือน …… ปี 2015

ชื่อหมู่บ้าน/ขุมขน:

……

สวัสดีครับ/คะ ผม/ดิฉัน ชื่อ "____(ชื่อผู้สัมภาษณ์)_____" ผม/ดิฉันกำลังวิจัยให้กับสถาบันบัณฑิตวิทยาลัยร่วมด้านพลังงานและเทคโนโลยี มหาวิทยาลัยพระจอมเกล้าธนบุรีบางมด วัตถุประสงค์ของการศึกษานี้คือศึกษาการใช้ไฟฟ้า และการใช้พลังงานรูปแบบอื่นๆในภาคครัวเรือน ทั้งที่กำลังเกิดขึ้นในปัจจุบันและอาจเกิดขึ้นในอนาคต การเก็บข้อมูลอันนี้ทำขึ้นในห้าประเทศในแถบลุ่มแม่น้ำโขงได้แก่ ประเทศพม่า ลาว กัมพูชา เวียดนาม และประเทศไทย

ผม/ดิฉันคาดว่าการเก็บข้อมูลนี้จะใช้เวลาประมาณ 20 นาที โดยข้อมูลต่างๆที่คุณให้สัมภาษณ์จะถูกเก็บเป็นความลับและจะไม่ถูกอ้างอิงชื่อใดๆ สำหรับการศึกษาครั้งนี้ หากมีคำถามใดที่คุณไม่ประสงค์ที่จะตอบหรือหากคุณต้องการถอนตัวจากการให้สัมภาษณ์ครั้งนี้ ไม่ว่าจะด้วยวัตถุประสงค์ใด คุณสามารถทำได้ทุกเวลาโดย

ไม่ต้องให้เหตุผล สุดท้ายนี้ หากคุณมีคำถามหรือคำท้วงติงใดๆ กรุณาถามในตอนนี้ได้เลยครับ/คะ ขอบคุณสำหรับความร่วมมือ

ส่วนที่ 1 ข้อมูลเกี่ยวครัวเรือน			
ชื่อและนามสกุลของผู้ตอบแบบสอบถาม			
A01	เพศ	□ ชาย □ หญิง	
A02	อายุ	□ 18 – 29 □ 30 – 39 □ 40 – 49 □ 50 – 59 □ 60+	
A03	คุณเป็นหัวหน้าครอบครัวใช่หรือไม่?	□ ใช่ □ ไม่	→ ข้ามไป A05 → A04
A04	ถ้าไม่ คุณมีความสัมพันธ์อย่างไรกับหัวหน้าครอบครัว?	□ สามี/ ภรรยา □ บุตรชาย/ บุตรสาว □ บิดา/ มารดา □ อื่นๆ (โปรดระบุ)_____	
A05	อาชีพของหัวหน้าครอบครัว	□ การเกษตร □ ก่อสร้าง □ ค้าปลีก/ ร้านรถเข็นหาบเร่ □ ข้าราชการ, ครู หรือ อาชีพเฉพาะทางอื่นๆ □ เจ้าของกิจการ □ ว่างงาน □ เกษียณ □ อื่นๆ (โปรด	

		ระบุ):_____
A06	ระดับการศึกษาสูงสุดของหัวหน้าครอบครัว	□ ไม่มีวุฒิการศึกษา □ ประถมศึกษา □ มัธยมศึกษา □ อุดมศึกษา / ปวช / ปวศ □ ไม่ระบุ
A07	ใครเป็นคนตัดสินใจในเรื่องที่เกี่ยวกับการใช้ไฟฟ้าในครอบครัวของคุณ?	□ ผม / ดิฉัน □ คู่สมรส □ บุตรหลาน □ ตัดสินใจร่วมกัน □ อื่นๆ (โปรดระบุ)_____
A08	ใครเป็นคนตัดสินใจในเรื่องที่เกี่ยวกับเชื้อเพลิงอื่นๆ เช่น ก๊าซหุงต้ม ในครอบครัวคุณ?	□ ผม / ดิฉัน □ คู่สมรส □ บุตรหลาน □ ตัดสินใจร่วมกัน □ อื่นๆ (โปรดระบุ)_____
A09	จำนวนสมาชิกในครัวเรือน	
A10	จำนวนสมาชิกที่อายุต่ำกว่า 16 ปี	
A11	จำนวนสมาชิกทีประกอบงานประจำ	
A12	เดือนทีแล้ว คุณมีรายได้เท่าไร? [รวมทั้งรายได้ที่เป็นทางการและไม่ทางการ]	□ < 3,000 บาท □ 3,000-8,000 บาท □ 8,000-15,000 บาท □ 15,000-30,000 บาท □ มากกว่า 30,000 บาท □ ไม่ระบุ

ส่วนที่ 2 การบริโภคพลังงานในครัวเรือน

ลองนึกถึงเดือนที่ผ่านมา, ครัวเรือนของท่านมีใช้จ่ายประมาณเท่าไรต่อเดือนในรายการดังต่อไปนี้		
B01	บ้าน (ค่าเช่า, ค่าซ่อมแซมบ้าน, หรือค่าใช้จ่ายเกี่ยวกับบ้านในรูปแบบอื่นๆ)	
B02	อาหาร (อาหารปรุงเอง, ค่าใช่จ่ายจากการรับประทานอาหารนอกบ้าน. ขนม เป็นต้น)	
B03	เชื้อเพลิงหุงต้มอาหาร (ฟืน, ถ่าน, แก๊สแอลพีซีเป็นต้น)	
B04	ค่าไฟฟ้า	
B05	การเดินทาง	
B06	ค่านำ	
B07	การศึกษา (สำหรับทั้งตัวท่านเองและบุตรหลาน)	
B08	เสือผ้าและเฟอร์นิเจอร์	
B09	ค่ารักษาพยาบาล	
B10	เงินออมและเงินลงทุน	
B11	อืนๆ	

ผู้สัมภาษณ์: ***ต่อไปนี้เป็นคำถามเกี่ยวกับการใช้ไฟฟ้า***

B12	คุณจ่ายค่าไฟฟ้าเมื่อใด?	□ จ่ายล่วงหน้า □ จ่ายหลังจากได้บิลค่าไฟฟ้า
B13	คุณจ่ายค่าไฟฟ้าบ่อยแค่ไหน?	□ รายสัปดาห์ □ รายเดือน □ รายไตรมาส (ทุกสามเดือน) □ เมื่อไรก็ตามที่มีเงินจ่าย □ ครอบครัวฉันไม่ได้จ่ายค่าไฟฟ้า

B14	คุณมีไฟฟ้าใช้ทุกครั้งที่ต้องการ?	ไม่มีเลย	มีนานๆ ครั้ง	มีเป็นบางครั้ง	มีเป็นประจำ	มีตลอดเวลา
		□	□	□	□	□
B15	จากมุมมองของคุณ, คุณคิดว่าค่าใช้จ่ายด้านไฟฟ้าเหมาะสมกับระดับรายได้ของคุณหรือไม่?	ไม่เหมาะสมเลย	เหมาะสมน้อย	เหมาะสมปานกลาง	เหมาะสมมาก	เหมาะสมที่สุด
		□	□	□	□	□

ผู้สัมภาษณ์: ***ครัวเรือนของท่านใช้ไฟฟ้าเพื่อรายการเหล่านี้หรือไม่?***

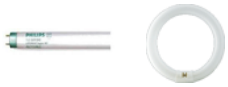
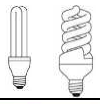
B16	แสงสว่าง	□ ใช่	□ ไม่
B17	ประกอบอาหาร	□ ใช่	□ ไม่

ผู้สัมภาษณ์: ***ครัวเรือนของท่านใช้อุปกรณ์เหล่านี้สำหรับการประกอบอาหารหรือไม่?***

B18	เตาฟืนดั้งเดิม	□ ใช่	□ ไม่
B19	เตาประหยัดพลังงาน	□ ใช่	□ ไม่

B20	เตาไฟฟ้า	□ ใช่ □ ไม่
B21	หม้อหุงข้าวไฟฟ้า	□ ใช่ □ ไม่
B22	เตาแก๊ส (แอลพีจี)	□ ใช่ □ ไม่
B23	เตานำมันก๊าด	□ ใช่ □ ไม่
B24	เตาไมโครเวฟ	□ ใช่ □ ไม่

ผู้สัมภาษณ์: ***ครัวเรือนของท่านใช้อุปกรณ์เหล่านี้สำหรับแสงสว่างหรือไม่?***

B25	เทียน	□ ใช่ □ ไม่
B26	แบตเตอรี่/ คบไฟ	□ ใช่ □ ไม่
B27	ตะเกียงนำมันก๊าด	□ ใช่ □ ไม่
B28	หลอดไฟหลอดกลม 	□ ใช่ □ ไม่
B29	หลอดนีออนแบบแท่งหรือวง (ฟลูออเรสเซน) 	□ ใช่ □ ไม่
B30	หลอดตะเกียบ 	□ ใช่ □ ไม่
B31	หลอดไฟแอลอีดี 	□ ใช่ □ ไม่

ผู้สัมภาษณ์: ***ครัวเรือนของท่านใช้อุปกรณ์เหล่านี้หรือไม่?***

B32	ทีวีตู้	□ ใช่ □ ไม่
B33	ทีวีจอแบน	□ ใช่ □ ไม่

B34	โทรศัพท์มือถือ	□ ใช่ □ ไม่
B35	ตู้เย็น	□ ใช่ □ ไม่
B36	วิทยุ	□ ใช่ □ ไม่
B37	เครื่องเล่นวีดีโอ / ดีวีดี	□ ใช่ □ ไม่
B38	คอมพิวเตอร์	□ ใช่ □ ไม่
B39	พัดลม	□ ใช่ □ ไม่
B40	เครื่องปรับอากาศ	□ ใช่ □ ไม่
B41	กาต้มน้ำไฟฟ้า	□ ใช่ □ ไม่
B42	เตารีดไฟฟ้า	□ ใช่ □ ไม่
B43	เครื่องทำน้ำร้อนไฟฟ้า	□ ใช่ □ ไม่
B44	เครื่องทำน้ำร้อนจากพลังงานแสงอาทิตย์	□ ใช่ □ ไม่
B45	เครื่องซักผ้า	□ ใช่ □ ไม่
B46	เครื่องปั๊มน้ำไฟฟ้า	□ ใช่ □ ไม่
B47	เครื่องดูดฝุ่น	□ ใช่ □ ไม่
B48	ไฮไฟ / เครื่องเสียง	□ ใช่ □ ไม่
B49	เครื่องทำความร้อนไฟฟ้า (ฮีทเตอร์)	□ ใช่ □ ไม่

ส่วนที่ 3 การเพิ่มการบริโภคพลังงานอันเป็นผลจากการประหยัด/เพิ่มประสิทธิภาพ (REBOUND EFFECT)

ผู้สัมภาษณ์: เราอยากทราบว่า หากท่านมีรายได้เพิ่มเติม ท่านจะใช้จ่ายเปลี่ยนไปหรือไม่? อย่างไร? ท่านจะใช้จ่ายกับไฟฟ้าหรือเชื้อเพลิงชนิดอื่นมากขึ้นหรือลดลงหรือไม่? อย่างไร?

C01	บิลค่าไฟฟ้าของท่านในระยะ 6 เดือนที่ผ่านมาเปลี่ยนไปอย่างไร?	□ ลดลง □ เพิ่มขึ้น □ เท่าเดิม □ ไม่ทราบ	→ ไปข้อ C02, C03 [ไม่ต้องทำข้อ C04] → ข้ามไป C04 → ข้ามไป C04 → ข้ามไป C04
C02	ท่านคิดว่าเพราะเหตุใดบิลค่าไฟฟ้าของท่านจึงลดลง		
C03	คำถามนีเจาะจงทีการใช้เงินรายได้ทีเกิดขึนจากประหยัดค่าไฟของท่าน ท่านใช้เงินที่ประหยัดได้เป็นสัดส่วนเท่าไรในรายการต่อไปนี้	□ บ้าน ร้อยละ..... □ อาหาร ร้อยละ..... □ เชื้อเพลิงหุงต้มอาหาร ร้อยละ..... □ อุปกรณ์เครื่องใช้ไฟฟ้าในบ้าน ร้อยละ..... □ การเดินทาง ร้อยละ..... □ การศึกษา ร้อยละ..... □ เสื้อผ้าและเฟอร์นิเจอร์ ร้อยละ..... □ ค่ารักษาพยาบาล ร้อยละ..... □ เงินออมและเงินลงทุน	

		ร้อยละ..... □ ไม่ทราบ □ อื่นๆ (โปรดระบุ)..... ร้อยละ.....
C04	ถ้าค่าไฟของครัวเรือนท่านลดลง ท่านจะใช้จ่ายเงินที่ประหยัดลงได้กับรายจ่ายใดดังต่อไปนี้ โปรดระบุสัดส่วน	□ บ้าน ร้อยละ..... □ อาหาร ร้อยละ..... □ เชื้อเพลิงหุงต้มอาหาร ร้อยละ..... □ อุปกรณ์เครื่องใช้ไฟฟ้าในบ้าน ร้อยละ..... □ การเดินทาง ร้อยละ..... □ การศึกษา ร้อยละ..... □ เสื้อผ้าและเฟอร์นิเจอร์ ร้อยละ..... □ ค่ารักษาพยาบาล ร้อยละ..... □ เงินออมและเงินลงทุน ร้อยละ..... □ ไม่ทราบ □ อื่นๆ (โปรดระบุ)..... ร้อยละ.....
C05	หากท่านสามารถประหยัดค่าไฟในครัวเรือนได้ อะไรในรายการเหล่านี้ที่ท่านน่าจะทำ? (ตอบได้หลายข้อ)	□ ใช้เครื่องใช้ไฟฟ้าที่มีอยู่เดิมให้มากขึ้น บ่อยขึ้น หรือนานขึ้น □ ซื้อเครื่องใช้ไฟฟ้าที่ยังไม่มี □ ซื้อเครื่องใช้ไฟฟ้าที่คุณภาพดีขึ้น □ ไม่ทราบ □ อื่นๆ (โปรดระบุ)

C06	สมมติว่าท่านมีรายได้เพิ่มขึ้นเดือนละ 300 บาททุกเดือน ท่านจะใช่จ่ายไปกับรายการใดต่อไปนี้? กรุณาลำดับความสำคัญจากรายการต่อไปนี้ โดย 1 คือสำคัญที่สุด และ 9 คือ สำคัญน้อยที่สุด	□ บ้าน อันดับ..... □ อาหาร อันดับ..... □ เชื้อเพลิงหุงต้มอาหาร อันดับ..... □ อุปกรณ์เครื่องใช้ไฟฟ้าในบ้าน อันดับ..... □ การเดินทาง อันดับ..... □ การศึกษา อันดับ..... □ เสื้อผ้าและเฟอร์นิเจอร์ อันดับ..... □ ค่ารักษาพยาบาล อันดับ..... □ เงินออมและเงินลงทุน อันดับ..... □ ไม่ทราบ □ อื่นๆ (โปรดระบุ)..... อันดับ.....

ท้ายที่สุดนี้ ถ้าหากยังมีอะไรที่ผมไม่ได้รวมในการสัมภาษณ์ครั้งนี้ คุณอยากจะเพิ่มประเด็นอื่นๆที่เกี่ยวข้องกับการใช้ไฟฟ้าในภาคครัวเรือนหรือไม่?

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ขอบคุณที่ช่วยตอบแบบสอบถาม!

Appendix D List of the surveyed sites

Table 1D: List of the surveyed sites

Code	Commonity/ward (in Thai)	Commonity/ward (in English)	District	Province	Number of surveyed households
TH-R01	ชุมชนบ้านโป่งแมลงวัน	Ban Pong Ma Malang Wan	Meung	NR	4
TH-R02	ชุมชนบ้านหนองบง	Chumchon Nong Bong	Meung	NR	7
TH-R03	ชุมชนบ้านตะเภาทอง	Chumchon Ta Pe Ra Thong	Meung	NR	3
TH-R04	ชุมชนบ้านโคกแฝก	Chumchon Ban Kokfaeg	Meung	NR	4
TH-R05	ชุมชนบ้านบึงขามทะเลสอ	Chumchon Bueng Kam Talay Sor	Meung	NR	8
TH-R06	ชุมชนบ้านโคกสะออน	Chumchon Ban Koksa-on	Meung	NR	4
TH-R07	ชุมชนบ้านโป่งดินสอ	Chumchon Ban Pongdinsor	Meung	NR	4
TH-R08	ชุมชนบ้านมาบเอื้อง	Chumchon Ban Mab Aung	Meung	NR	2
TH-R09	ชุมชนแสนสุข	Chumchon Sansook	Meung	NR	2
TH-R10	ชุมชนสามยอด	Chumchon Samyod	Meung	NR	2
TH-R11	ชุมชนหนองเรือ	Chumchon Nong Ruo	Meung	NR	1
TH-R12	ชุมชนบ้านฝั่งคลอง	Chumchon Ban Phan-klong	Meung	NR	1
TH-R13	ชุมชนภูเขาทอง	Chumchon Phukho Thong	Meung	NR	6
TH-R14	บ้านหนองสาหร่าย	Ban Nong Sao Tiew	Meung	NR	8
TH-R15	ชุมชนใหม่เจริญ	Chumchon Mai Charean	Meung	NR	2
TH-R16	ชุมชนบ้านสีมุม	Chumchon Ban Si Mum	Meung	NR	19
TH-U01	ชุมชนริมคลองอโศกฝั่งใต้ ทางด่วนฉลองรัช	Chumchon Rim Klong Asok (near Chalong Rach Expressway)	Pathum Wan	BKK	12
TH-U02	ชุมชนริมคลองอโศกฝั่งแยกฟอร์จูน	Chumchon Rim Klong Asok (near Fortune junction)	Din Daeng	BKK	3
TH-U03	ชุมชนริมทางรถไฟโค้งอโศก (MRT มักกะสัน)	Chumchon Rim Tang Rodfai Kong Asok (near Makkasan MRT station)	Makkasan	BKK	4
TH-U04	ชุมชนพระเจน	Chumchon Pra Jane	Pathum Wan	BKK	31
TH-U05	ชุมชนเลียบคลองวัดลาดพร้าว	Chumchon Leap Wat Ladprao	Ladprao	BKK	26

NR = Nakhon Ratchasima, BKK = Bangkok

Appendix E Data and results of household survey

Table 1E: Comparison of monthly expenses between the households in category (b) and category (c)

	Households in category (b) (17 households)			Households in category (c) (137 households)		
	Type of expense	Expense (USD)	%	Type of expense	Expense (USD)	%
1	**Food**	**132**	**33.6%**	**Food**	**152**	**37.1%**
2	**Education**	**67**	**17.1%**	**Housing**	**76**	**18.6%**
3	**Housing**	**53**	**13.5%**	**Education**	**41**	**10.0%**
4	Clothing & furniture	39	9.8%	Electricity bills	24	6.0%
5	Other	36	9.2%	Transportation	22	5.5%
6	Savings & investment	17	4.3%	Other	20	4.9%
7	Electricity bills	14	3.7%	Savings & investment	20	4.9%
8	Transportation	13	3.4%	Clothing & furniture	18	4.3%
9	Cooking fuels	11	2.8%	Healthcare	15	3.6%
10	Healthcare	6	1.4%	Cooking fuels	13	3.3%
11	Water bills	5	1.2%	Water bills	8	2.0%
	Sum	392	100.0%	Sum	409	100.0%

Table 2E: Comparison of monthly expenses between the households with monthly income between 100-267 USD and 267-500 USD

	Households with monthly income between 100-267 USD (42 households)			Households with monthly income between 267-500 USD (104 households)		
	Type of expense	Expense (USD)	%	Type of expense	Expense (USD)	%
1	**Food**	**121**	**40.0%**	**Food**	**166**	**37.0%**
2	**Education**	**49**	**16.2%**	**Housing**	**75**	**16.6%**
3	**Housing**	**42**	**13.9%**	**Education**	**40**	**8.9%**
4	Transportation	15	5.1%	Other	35	7.9%
5	Electricity bills	15	5.0%	Electricity bills	27	6.1%
6	Healthcare	14	4.7%	Clothing & furniture	25	5.7%
7	Other	13	4.3%	Transportation	22	4.9%
8	Cooking fuels	9	3.0%	Savings & investment	19	4.3%
9	Clothing & furniture	9	3.0%	Cooking fuels	15	3.4%
10	Savings & investment	9	3.0%	Healthcare	14	3.2%
11	Water bills	6	1.8%	Water bills	9	2.0%
	Sum	303	100.0%	Sum	449	100.0%

Table 3E: Comparison of monthly expenses between the households in Bangkok (urban) and Nakorn Ratchasima (rural)

	Households in Bangkok (76 households)			Households in Nakorn Ratchasima (78 households)		
	Type of expense	Expense (USD)	%	Type of expense	Expense (USD)	%
1	**Food**	**164**	**40.8%**	**Food**	**136**	**32.1%**
2	**Housing**	**67**	**16.8%**	**Housing**	**113**	**26.5%**
3	**Education**	**37**	**9.3%**	**Education**	**45**	**10.5%**
4	Savings & investment	30	7.5%	Transportation	24	5.5%

	Households in Bangkok (76 households)			Households in Nakorn Ratchasima (78 households)		
	Type of expense	Expense (USD)	%	Type of expense	Expense (USD)	%
5	Electricity bills	30	7.4%	Other	22	5.1%
6	Transportation	20	5.0%	Clothing & furniture	20	4.6%
7	Clothing & furniture	20	4.9%	Healthcare	18	4.2%
8	Cooking fuels	16	4.0%	Savings & investment	17	4.0%
9	Water bills	11	2.8%	Electricity bills	17	3.9%
10	Healthcare	6	1.5%	Cooking fuels	11	2.5%
11	Other	0	0.0%	Water bills	4	1.0%
	Sum	400	100.0%	Sum	425	100.0%

Table 4E: Comparison of monthly expenses between male and female respondents

	Male respondents (67 households)			Female respondents (87 households)		
	Type of expense	Expense (USD)	%	Type of expense	Expense (USD)	%
1	**Food**	**149**	**40.5%**	**Food**	**150**	**35.5%**
2	**Housing**	**52**	**14.1%**	**Housing**	**78**	**18.5%**
3	**Education**	**43**	**11.8%**	**Education**	**40**	**9.5%**
4	Savings & investment	25	6.8%	Clothing & furniture	31	7.3%
5	Transportation	25	6.7%	Other	29	6.8%
6	Electricity bills	21	5.8%	Electricity bills	25	5.9%
7	Healthcare	15	4.2%	Transportation	19	4.5%
8	Cooking fuels	11	3.0%	Cooking fuels	15	3.5%
9	Clothing & furniture	11	2.9%	Savings & investment	14	3.3%
10	Other	9	2.5%	Healthcare	13	3.1%
11	Water bills	6	1.7%	Water bills	9	2.1%
	Sum	368	100.0%	Sum	423	100.0%

Table 5E: Comparison of additional spending from reduced electricity bills between the households in category (b) and (c)

	Category (b) (16 households)		Category (c) (134 households)	
	Type of expense	Percentage of increased expense	Type of expense	Percentage of increased expense
1	**Food**	**35.6%**	**Food**	**53.0%**
2	**Don't know**	**31.3%**	**Savings & investment**	**18.1%**
3	**Savings & investment**	**18.1%**	**Education**	**8.3%**
4	Other	6.3%	Don't know	4.5%
5	Transportation	3.8%	Transportation	3.4%
6	Healthcare	1.9%	Other	3.4%
7	Electrical appliances	1.3%	Healthcare	3.1%
8	Education	1.3%	Cooking fuels	2.5%
9	Clothing & furniture	0.6%	Housing	1.9%
10	Housing	0.0%	Electrical appliances	1.4%
11	Cooking fuels	0.0%	Clothing & furniture	0.5%

Table 6E: Comparison of additional spending from reduced electricity bills between the households with monthly income between 100-267 USD and 267-500 USD

	Households with monthly income between 100-267 USD (41 households)		Households with monthly income between 267-500 USD (101 households)	
	Type of expense	Percentage of increased expense	Type of expense	Percentage of increased expense
1	**Food**	**64.6%**	**Food**	**45.2%**
2	**Savings & investment**	**14.9%**	**Savings & investment**	**20.8%**
3	**Don't know**	**4.9%**	**Education**	**9.9%**
4	Healthcare	3.7%	Don't know	6.9%
5	Education	3.2%	Other	4.5%
6	Transportation	2.9%	Transportation	4.0%
7	Other	2.4%	Healthcare	2.9%
8	Cooking fuels	1.5%	Housing	2.2%
9	Housing	1.0%	Cooking fuels	2.0%
10	Electrical appliances	1.0%	Electrical appliances	0.9%
11	Clothing & furniture	0.0%	Clothing & furniture	0.7%

Table 7E: Comparison of additional spending from reduced electricity bills between the households in Bangkok and Nakorn Ratchasima

	Bangkok (74 households)		Nakorn Ratchasima (76 households)	
	Type of expense	Percentage of increased expense	Type of expense	Percentage of increased expense
1	**Food**	**39.2%**	**Food**	**62.8%**
2	**Savings & investment**	**23.5%**	**Savings & investment**	**12.8%**
3	**Don't know**	**12.2%**	**Education**	**5.9%**
4	Education	9.2%	Cooking fuels	4.3%
5	Other	6.8%	Transportation	3.3%
6	Healthcare	3.9%	Don't know	2.6%
7	Transportation	3.6%	Electrical appliances	2.5%
8	Housing	1.4%	Housing	2.1%
9	Electrical appliances	0.3%	Healthcare	2.0%
10	Cooking fuels	0.0%	Clothing & furniture	1.0%
11	Clothing & furniture	0.0%	Other	0.7%

Table 8E: Comparison of additional spending from reduced electricity bills between male and female respondents

	Male respondents (63 households)		Female Respondents (87 households)	
	Type of expense	Percentage of increased expense	Type of expense	Percentage of increased expense
1	**Food**	**56.5%**	**Food**	**47.2%**
2	**Savings & investment**	**16.2%**	**Savings & investment**	**19.4%**
3	**Education**	**9.0%**	**Don't know**	**8.0%**
4	Don't know	6.3%	Education	6.4%
5	Transportation	3.7%	Other	6.3%

	Male respondents (63 households)		Female Respondents (87 households)	
	Type of expense	Percentage of increased expense	Type of expense	Percentage of increased expense
6	Housing	3.5%	Healthcare	4.1%
7	Cooking fuels	2.1%	Transportation	3.3%
8	Healthcare	1.4%	Cooking fuels	2.3%
9	Electrical appliances	0.8%	Electrical appliances	1.8%
10	Clothing & furniture	0.5%	Clothing & furniture	0.5%
11	Other	0.0%	Housing	0.5%

Table 9E: Comparison of ranking between the surveyed households in category (b) and (c)

	Category (b) (16 households)		Category (c) (136 households)	
Rank	Category	Score	Category	Score
1	**Food**	**8.88**	**Food**	**9.17**
2	**Savings & investments**	**7.94**	**Cooking fuels**	**6.90**
3	**Housing**	**6.69**	**Housing**	**6.71**
4	Cooking fuels	6.13	Savings & investments	6.15
5	Transportation	5.88	Electrical appliances	5.91
6	Electrical appliances	5.56	Transportation	5.63
7	Education	4.94	Education	5.30
8	Healthcare	4.06	Healthcare	4.17
9	Clothing & furniture	3.88	Clothing & furniture	3.74
10	Other	1.06	Other	1.30

Table 10E: Comparison of ranking between the surveyed households with monthly income between 100-267 USD and 267-500 USD

	Households with monthly income between 100-267 USD (41 households)		Households with monthly income between 267-500 USD (103 households)	
Rank	Category	Score	Category	Score
1	**Food**	**9.29**	**Food**	**9.09**
2	**Cooking fuels**	**6.76**	**Housing**	**7.31**
3	**Savings & investments**	**6.61**	**Cooking fuels**	**6.85**
4	Transportation	5.66	Savings & investments	6.37
5	Education	5.63	Electrical appliances	5.97
6	Electrical appliances	5.44	Transportation	5.62
7	Healthcare	5.39	Education	5.19
8	Housing	5.15	Clothing & furniture	3.70
9	Clothing & furniture	3.83	Healthcare	3.66
10	Other	1.24	Other	1.23

Table 11E: Comparison of ranking between the surveyed households in Bangkok and Nakorn Ratchasima

	Bangkok (75 households)		Nakorn Ratchasima (78 households)	
Rank	Category	Score	Category	Score
1	**Food**	**8.91**	**Food**	**9.36**
2	**Housing**	**8.03**	**Cooking fuels**	**6.97**
3	**Savings & investments**	**7.31**	**Electrical appliances**	**5.84**
4	Cooking fuels	6.67	Transportation	5.79
5	Electrical appliances	5.91	Education	5.61
6	Transportation	5.52	Housing	5.43
7	Education	4.91	Savings & investments	5.40
8	Clothing & furniture	3.41	Healthcare	5.06
9	Healthcare	3.23	Clothing & furniture	4.09
10	Other	1.12	Other	1.43

Table 12E: Comparison of ranking between the male and female respondents

	Male respondents (67 households)		Female Respondents (87 households)	
Rank	Category	Score	Category	Score
1	**Food**	**9.20**	**Food**	**9.09**
2	**Cooking fuels**	**7.14**	**Housing**	**6.95**
3	**Housing**	**6.38**	**Cooking fuels**	**6.59**
4	Savings & investments	6.03	Savings & investments	6.57
5	Electrical appliances	5.68	Electrical appliances	6.02
6	Transportation	5.58	Transportation	5.71
7	Education	5.54	Education	5.06
8	Healthcare	4.74	Clothing & furniture	3.80
9	Clothing & furniture	3.69	Healthcare	3.72
10	Other	1.02	Other	1.47

Figure 1E: Comparison of behaviour in responds to lower electricity bills between the households in category (b) and (c)

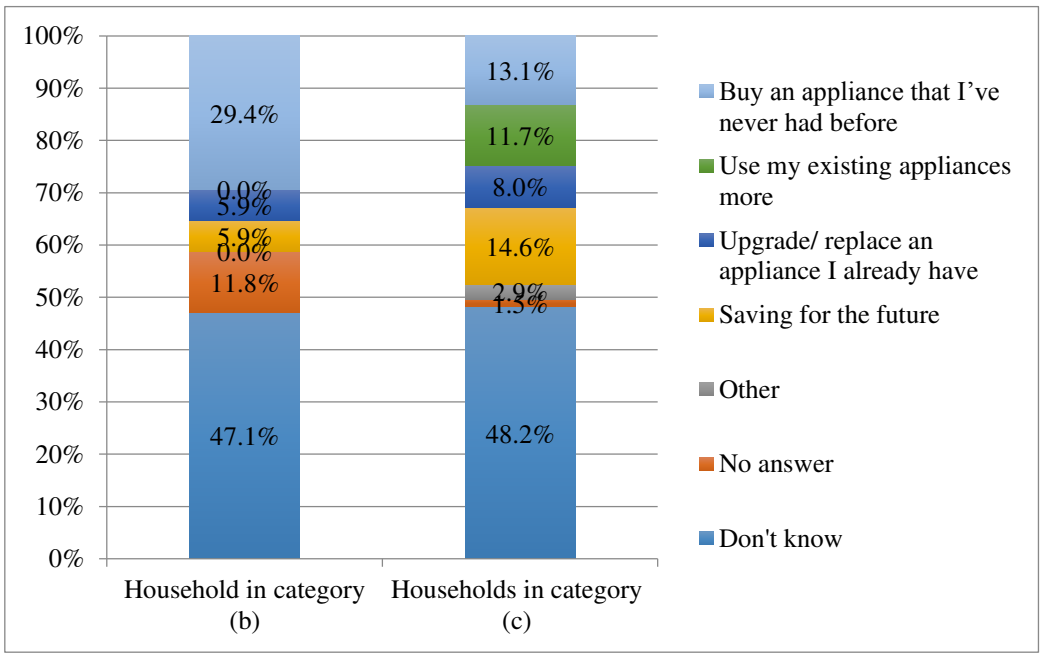

Figure 2E: Comparison of behaviour in responds to lower electricity bills between the households with monthly income between 100-267 USD and 267-500 USD

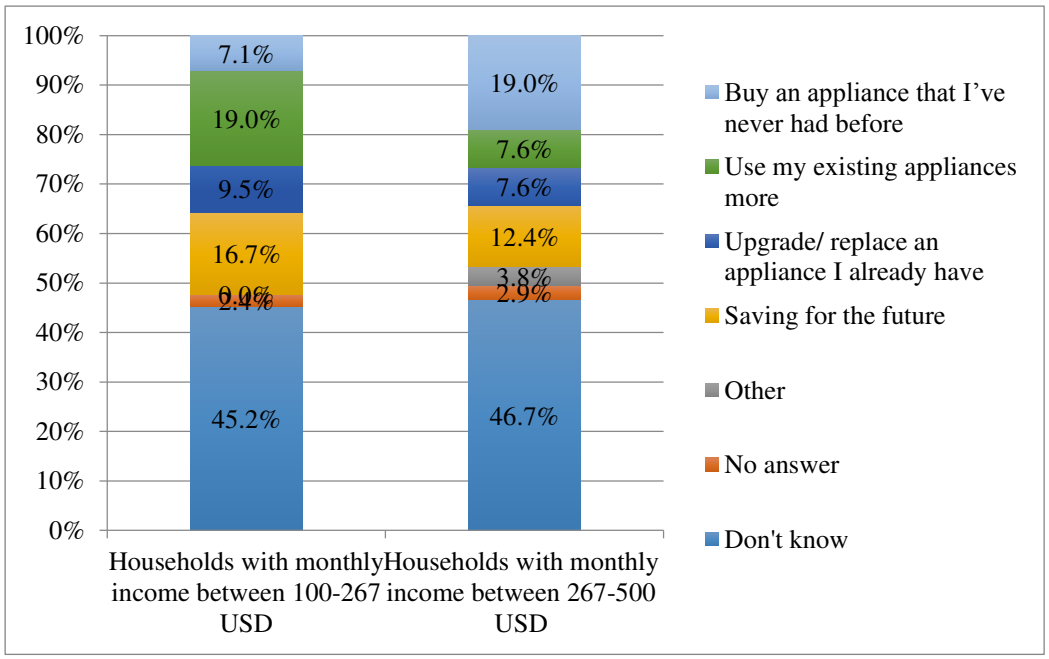

Figure 3E: Comparison of behaviour in responds to lower electricity bills between the households in Bangkok and Nakorn Ratchasima

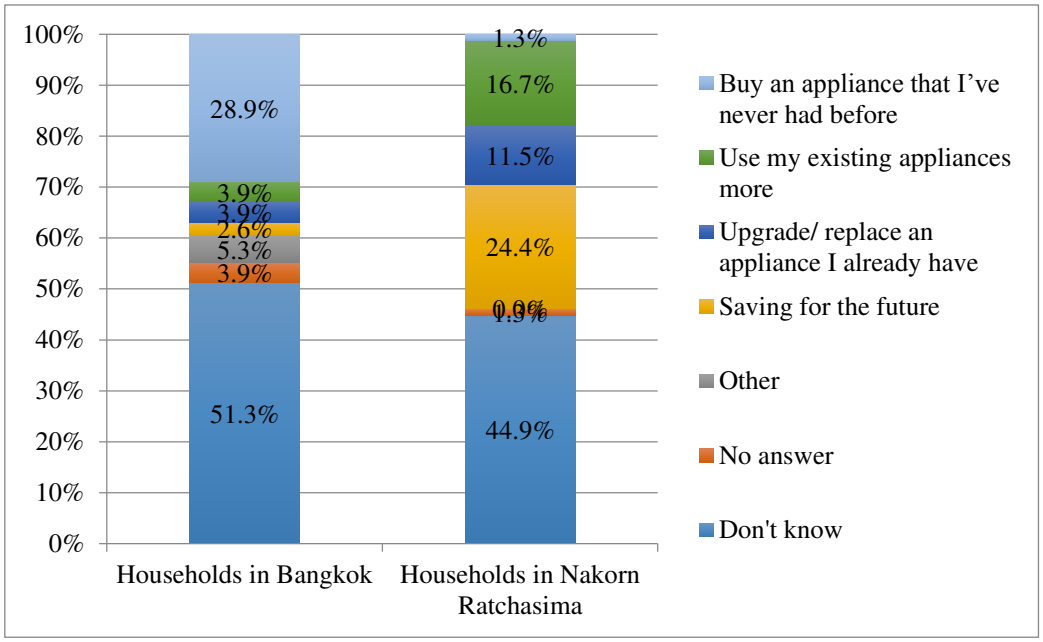

Figure 4E: Comparison of behavior in responds to lower electricity bills between male and female respondents