



Deliverable Report for MECON Project
Task 1.2 Baseline energy consumption of
MECON household in Cambodia

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1. Energy consumption for MECON target group in Cambodia: An overview

MECON is defined in the whole project as New Modern Energy Consumers with low incomes (2-5USD) and access to electricity whether to the public or private systems. It is widely known that, in Cambodia, number of electrified households is very limited compared to the neighboring countries. This makes this country different and identical in terms of energy consumption pattern for MECON target groups. As shown in Table 3, Cambodia’s total population is 15.14 in 2013. Among them, about 53% falls into the group earning from 2 to 5 USD. The growth rate of this group is up to 1.78%. In the MECON data analysis on energy consumption, the Long range Energy Alternative Planning System (LEAP) model structure is designed simply as shown in the following.

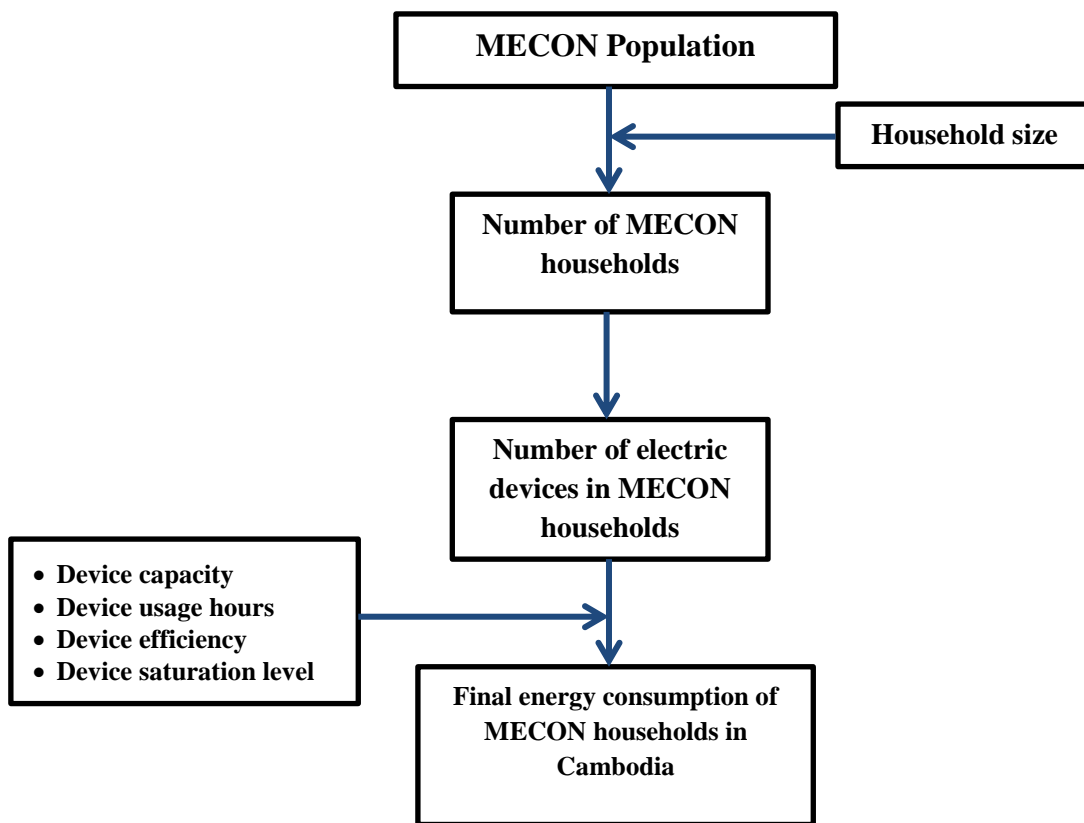


Figure 1: The structure of LEAP model for MECON target groups in Cambodia.

For the LEAP is a widely-used software tool for **energy** policy analysis and climate change mitigation assessment, this application software is chosen for data analysis on energy consumption. Figure 1 shows energy consumption structure designed for the analysis in LEAP software. The designed processes are based mainly in three steps. Firstly, the proportion of MECON target group to total population in Cambodia is estimated. Secondly, a classification is done in the baseline scenario in the LEAP model for MECON target group. Finally, energy

consumption for each specific device employed by MECON households is conducted in order for data to be input into the designed model.

2. MECON target group percent share

To estimate the percentage of the MECON target group, historical data from 1993 to 2012 is used. This series of data include GDP, GDP per capita, total population, percentage of MECON population, number of MECON population, and number of MECON households (HH). The required data is shown in Table 1 below.

Table 1: Historical data required for designed LEAP model

Year	GDP (Million \$US)	GDP (PPP) (Million \$US)	Total Population (Million)	Percentage of MECON Population	Number of MECON Population	Number of MECON HH
1993	2533.73	7799.08	10.08	0.00	0.00	0.00
1994	2791.44	8508.75	10.43	22.03	2.30	0.49
1995	3441.21	9056.96	10.77	0.00	0.00	0.00
1996	3506.70	9547.16	11.09	0.00	0.00	0.00
1997	3443.41	10083.69	11.40	0.00	0.00	0.00
1998	3120.43	10588.78	11.69	0.00	0.00	0.00
1999	3517.24	11849.88	11.96	0.00	0.00	0.00
2000	3654.03	12888.73	12.22	0.00	0.00	0.00
2001	3979.81	13924.81	12.47	0.00	0.00	0.00
2002	4284.03	14856.09	12.71	0.00	0.00	0.00
2003	4658.25	16119.73	12.93	0.00	0.00	0.00
2004	5337.83	17786.59	13.15	31.20	4.10	0.87
2005	6293.05	20143.33	13.36	0.00	0.00	0.00
2006	7274.42	22312.99	13.56	0.00	0.00	0.00
2007	8639.16	24591.72	13.75	33.24	4.57	0.97
2008	10351.83	26237.29	13.94	42.14	5.87	1.25
2009	10401.94	26260.04	14.14	49.11	6.95	1.48
2010	11242.27	27825.95	14.36	50.47	7.25	1.54
2011	12829.54	29793.12	14.61	51.37	7.50	1.60
2012	14061.80	31956.50	14.86	52.29	7.77	1.65
2013	15249.00	34193.45	15.14	53.22	8.06	1.71

The data from 1993 to 2012 leads to an estimation of the growth rate of MECON population to be 1.78%. The following (Table 2) simply illustrates the estimated number of MECON households from 2013 to 2030.

Table 2: Estimated number of Cambodian MECON households from 2013 to 2030

Year	Number of MECON households (million)
2013	1.71
2014	1.86
2015	2.01
2016	2.17
2017	2.34
2018	2.50
2019	2.68
2020	2.85
2021	3.04
2022	3.23
2023	3.42
2024	3.62
2025	3.83
2026	4.04
2027	4.26
2028	4.49
2029	4.72
2030	4.96

3. Structure used for MECON target group

The basic structure designed for the analysis on energy demand applied to Cambodian MECON households in the LEAP model is shown in Figure 2. To simplify, the appliances are divided into 7 categories namely lighting technologies, cooking appliances, cooling appliances, heating appliances, entertainment appliances, cleaning appliances, and other appliances. In the lighting category, five different types of lamps are studied. Those include incandescent light bulb, florescent light bulb, compact florescent light bulb, light emitting diode (LED) lamp, and kerosene light bulb. Second category is named as cooking appliances. This category includes electric cooking stove, rice cooker, microwave-oven, biomass, improved biomass, charcoal, LPG and kerosene stoves. Cooling appliances are in the third category. This category includes air-conditioner, refrigerator, and electric fan. The fourth category which was named as heating includes electric kettle, water heater, solar water heater, and electric heater. It should be noted that in Cambodia, TV is almost a must-have stuff by people for entertaining. In the designed model, TV is put in the fifth category called entertainment. This category includes TV, VDO/DVD, radio, computer, Hifi-system, and mobile phone. Aside from all of the five

categories above, cleaning appliances (washing machine, vacuum cleaner), and other appliances (water pump, electric iron) are the rests.

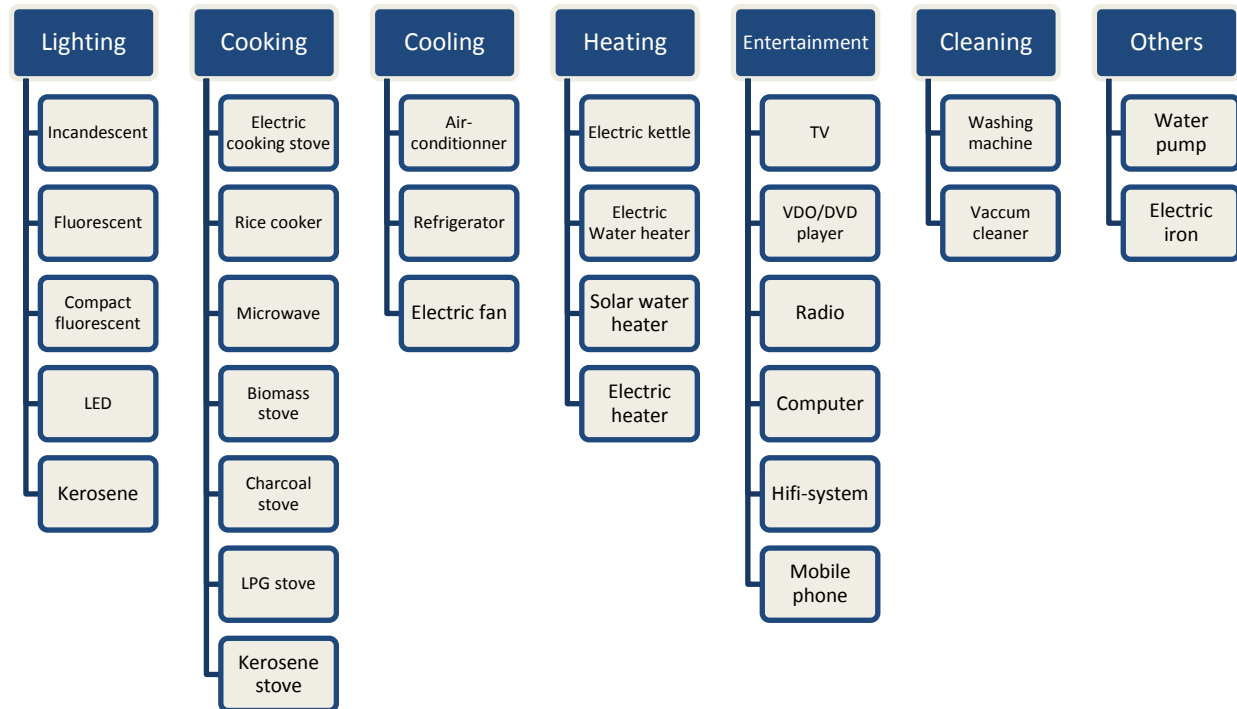


Figure 2: Appliance categories used by MECON households in Cambodia.

4. Key assumptions in the designed LEAP model

Key assumptions for LEAP designed for the energy baseline for MECON target group in Cambodia are shown in Table 3. The base year is set to 2013 while the end year is 2030. The total population in Cambodia is about 15.14 million in 2013 (WorldBank, December 2014) where the rate is about 2.07%. The surveyed data shows that the MECON household size is approximately 4.7. Among the total number of households of 3.22 million, the MECON households contributes 1.71 million with a growth rate of 1.78%.

From household survey in Task 3, 503 samples of MECON target group in urban and rural areas in Cambodia were selected for the study. Based on the data collected in Task 3, the energy consumption can be calculated using the following equation.

$$Consumption \text{ (kWh/yr)} = Power \text{ of appliance (W)} \times Hour \text{ used per year (Hr)} \\ \times Number \text{ of appliances} \times Coefficient$$

It should be noted that among the appliances mentioned, not all of them are estimated in terms of power rate. This is due to the fact that some appliances, for example, refrigerator, usually functions 24 hours per day. Therefore, a specific coefficient is used in the equation

above. Based on the guideline shown in China’s urban households, the coefficient for refrigerator can be set to 0.36.

Table 3: Key assumptions for LEAP model

Parameter	Details
Base year	2013
End year	2030
Population (2013)	15.14 million
Population growth rate	2.07%
Household size	~4.7
Total number of households in Cambodia	3.22 million
MECON population share (2013)	53.22%
MECON population growth rate	1.78%
Number of MECON population (2013)	8.06 million
Number of MECON household (2013)	1.71 million

Table 4 shows the details of different appliances and the corresponding energy consumed by Cambodia’s MECON households. In this table, it is seen that different lighting technologies and cooling appliances together contribute to the highest amount of energy consumed per household per year. This is clear that among the low-income electrified households in Cambodia, the major part of the consumption is for cooling and lighting. Besides, appliances for cooking and entertainment consume more energy compared with the rests. The data from Table 4 will be used in LEAP software as Business As Usual (BAU) scenario in Cambodia.

Table 4: Energy consumption of each device for MECON target group in Cambodia

Appliance	All surveyed households					
	Wattage (Average)	Amount of appliances per household	Hours used (hours/day)	% of households owning the appliance	Energy consumption (kWh/HH/year)	% of household owning the EE appliances
Lighting						
Incandescent light bulb	50.00	2.97	4.64	21.36	251.38	
Fluorescent light bulb	35.84	3.21	5.72	51.19	240.08	
Compact fluorescent light bulb	18.66	2.85	5.34	31.53	103.66	
LED	36.00	2.86	3.60	2.00	135.29	
Kerosene light bulb	0.00	2.92	5.45	3.73	0.00	
Cooking						
Electric cooking stove	1300.00	1.00	0.81	3.05	384.35	

Rice cooker	583.73	1.07	1.11	29.83	252.71	
Microwave oven	850.00	0.06	0.36	0.68	6.70	
Biomass Stove	0.00	0.00	0.00	22.71	0.00	
Improve biomass stove	0.00	0.00	0.00	32.20	0.00	
Charcoal Stove	0.00	0.86	0.00	21.36	0.00	
LPG Stove	0.00	0.12	0.00	35.25	0.00	
Kerosene Stove	0.00	0.00	0.00	4.41	0.00	
Cleaning						
Washing machine	572.02	1.00	0.20	2.03	41.76	5.56
Vacuum cleaner	1000.00	0.05	0.01	0.34	0.18	
Cooling						
AC	1533.33	0.22	2.50	2.37	307.82	1.11
Refrigerator	83.76	1.00	14.00	7.80	214.01	1.07
Electric fan	57.81	1.47	5.95	46.10	184.56	23.49
Heating						
Electric kettle	679.69	0.74	0.30	6.44	55.08	6.09
Electric water heater	945.45	0.09	0.50	0.68	15.53	
Electric Heater	500	0	0	0	0	
Solar water	300	0	0	0	0	
Entertainment						
TV CRT (box TV)	91.92	0.87	5.15	55.93	150.19	5.08
TV LCD (flat screen TV)	147.00	0.32	5.45	5.08	93.57	
Video/DVD player	50.25	0.51	0.06	25.42	0.56	
Radio	31.15	0.12	0.34	29.83	0.46	
Computer	130.36	0.41	0.12	9.15	2.34	
Hi-fi system	50.00	0.03	0.01	5.76	0.01	
Mobile phone	4.81	1.00	4.00	57.97	7.02	
Other						
Water pump	145.83	0.21	1.15	9.15	12.85	
Electric iron	1000.00	0.97	0.27	19.32	95.59	

5. Results

Necessary data are used to run the LEAP model. The following graphs show the results of the analysis using LEAP. It should be noted that LEAP is widely used to analyze the energy demand, environmental and economic assessment, and similar works (Huang, 2011; McPerscen, 2014; Sadri, 2014; & Shin, 2005) in different scenarios by energy researchers. Figure 3 shows the energy consumption of MECON households in Cambodia from 2014 to 2030. This figure illustrates that the consumption increases constantly among the low-income electrified households from about 37.95 thousand tons of oil equivalent (ktoe) in 2014 to 52.50 ktoe in 2030. It should be noted that in 2013, the total population (WorldBank, December 2014) of Cambodia reached 15.14 million with an average of 2.07% of growth rate each year. Among this

population, low-income population who earn between 2 and 5 USD is up to about 1.71 million households with a growth rate of 1.78% per year. In 2030, this low-income group is estimated to reach 4.96 million households with a household size of about 4.7.

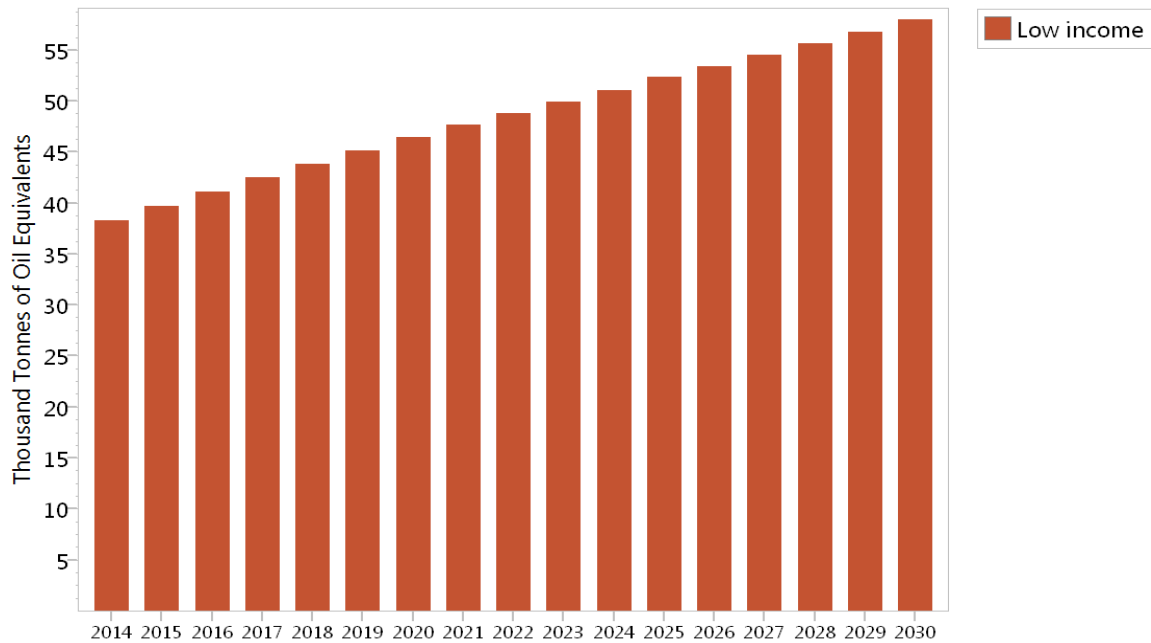


Figure 3: Energy consumption by MECON households in Cambodia in BAU scenario during 2014-2030.

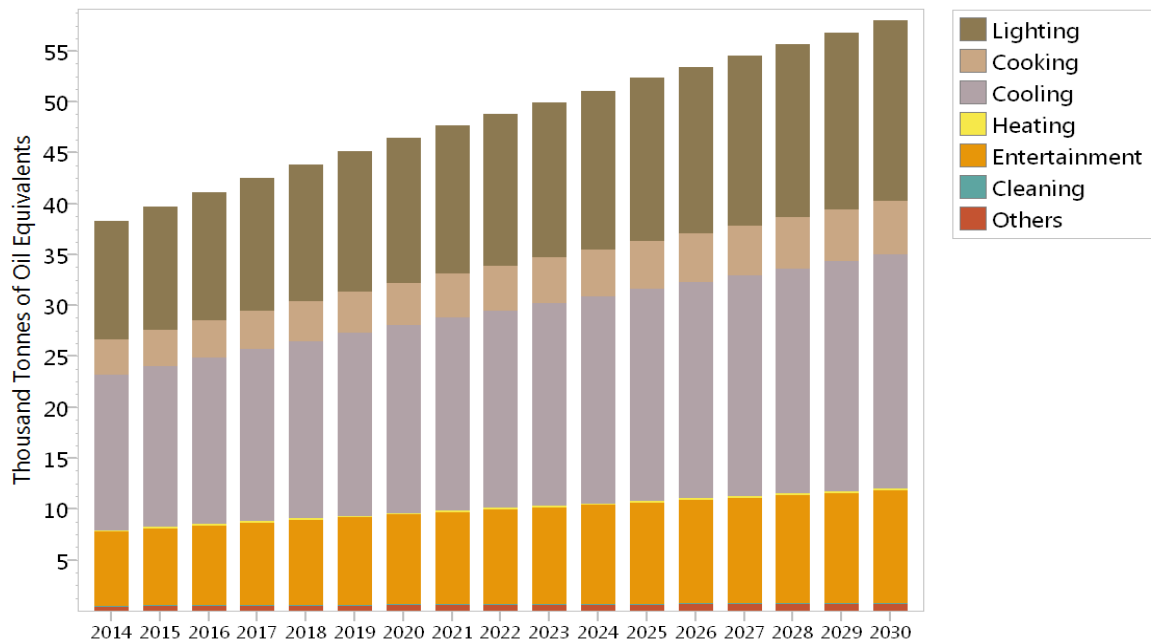


Figure 4: Energy consumption for different categories of appliances used by MECON households in Cambodia based on BAU scenario during 2014-2030.

Figure 4 shows the energy consumption by different categories of appliances used by MECON households in Cambodia. In this analysis, BAU scenario is used to forecast the energy consumption of appliances in terms of lighting, cooking, cooling, heating, entertainment, cleaning, and others from 2014 to 2030. Among these categories, cooling appliances together consume the most energy compared to other appliances while lighting appliances are the second highest consumers. The consumption by cooling appliances increases from about 15.09 ktoe in 2014 to about 20.88 ktoe in 2030. On the other hand, lighting appliances takes up to 11.59 ktoe in 2014. This increases up to approximately 16.03 ktoe in 2030. Aside from these two consumer types, entertainment category is the third highest consumer. The consumption increases from about 7.21 ktoe in 2014 to an approximation of 9.97 ktoe in 2030. Furthermore, cooking category consumes 3.41 ktoe by entertainment category in 2014. The consumption increases constantly to reach about 4.72 ktoe in 2030.

Below are the details of energy consumption by specific type of appliances in different categories obtained by the analysis in LEAP model that is designed for Cambodia’s MECON households using BAU scenario during 2014-2030.

5.1 Lighting

The first category, lighting, it consists of five main appliance types such as incandescent light bulb, fluorescent light bulb, compact fluorescent light bulb, light emitting diode (LED) bulb, and kerosene lamp. The result of the analysis for this category is shown in Figure 5.

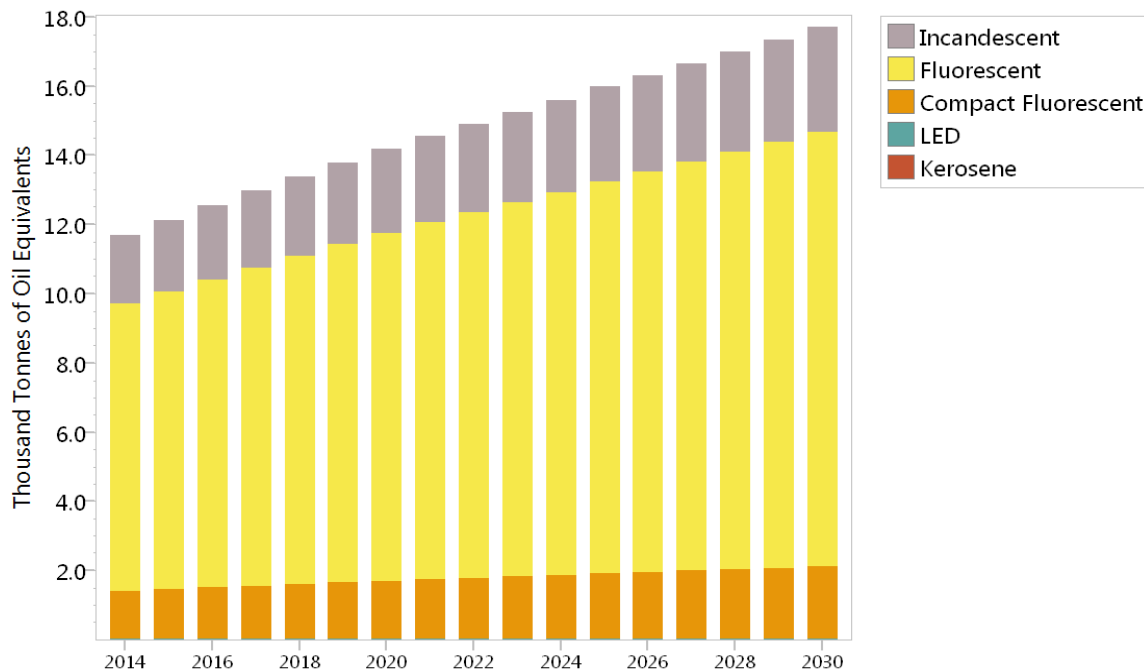


Figure 5: Energy consumption for lighting of MECON group in Cambodia in BAU scenario during 2014-2030.

Figure 5 clearly shows that fluorescent light bulb is the most popular type of light bulb used by Cambodian MECON households leading to the highest amount of energy consumed per year. The result of the analysis indicates that in 2014, the consumption is 8.22 ktoe while in 2030 the increase reaches about 11.37 ktoe. Among them, incandescent light bulb contributes to about 1.98 ktoe of energy consumption in 2014 and increase constantly to approximately 2.74 ktoe in 2030. After incandescent light bulb, compact fluorescent bulb is the third highest energy consumer type where the consumption increases from about 1.36 ktoe in 2014 to approximately 1.88 ktoe in 2030. LED is known as the most energy efficient bulb among bulbs available in the market. However, the results show that this type of bulbs is limitedly used in Cambodia. In 2014, the consumption is estimated to be approximately 0.02 ktoe while in 2030 this amount becomes about 0.028 ktoe. For lighting purpose, kerosene is almost forgotten. This is why the consumption is only about 0.0038 ktoe in 2014 and this goes up to approximately 0.0052 ktoe in 2030.

5.2 Cooking

As shown in Figure 6, cooking is the second highest energy consumer among the defined categories in the LEAP model. In Cambodia, different type of stoves are practical such as electric cooking stove, rice cooker, microwave, biomass stove, charcoal stove, liquefied petroleum gas (LPG) stove, and kerosene stove. Among these types of stoves, the results (Figure 6) show that rice cooker is the highest energy consumed type. In 2014, this type of cooking stove contributes to approximately 1372.95 toe. This constantly increases to about 1899.02 toe in 2030. The second highest type is LPG stoves, which consumes about 1210.72 toe in 2014 increasingly reaches 1674.62 toe in 2030. The third type is charcoal stove. Since this type of stove is historically practical, Cambodian MECON households especially in rural areas tend to widely use it. In 2014, this type of cooking stuffs consumes approximately 632.16 toe. This increases to 874.37 toe in 2030. Biomass is the next type of stoves in terms of energy consumption. In 2014, biomass stoves consume about 154.61 toe and the consumption increasingly becomes 213.86 toe. The rests contributes to about 48.61 toe in 2014 and this amount increases up to 56.17 toe in 2030.

Cookers which are practically used in Cambodia by MECON households in urban and rural areas are in general energy-inefficient. The reason is widely known that the efficient stoves or cookers are expensive and not practical among the low-income population. Figure 7 shows that among 1372.95 toe consumed by the cooking stuffs, the inefficient stoves share up to 1193.68 toe in 2014. Although there is a constant increase of the total consumption by this category, inefficient cookers/stoves share up to 86.94% of the total consumption of 1899.019 toe in 2030.

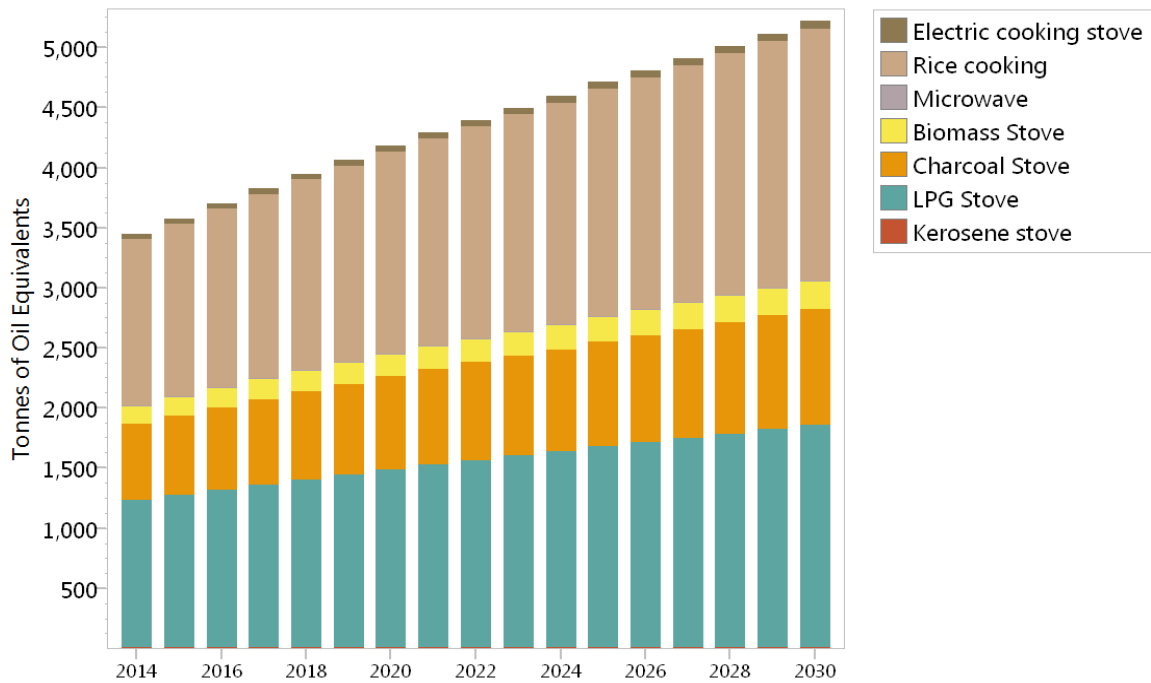


Figure 6: Energy consumption for cooking appliances of MECON group in Cambodia in BAU scenario during 2014-2030.

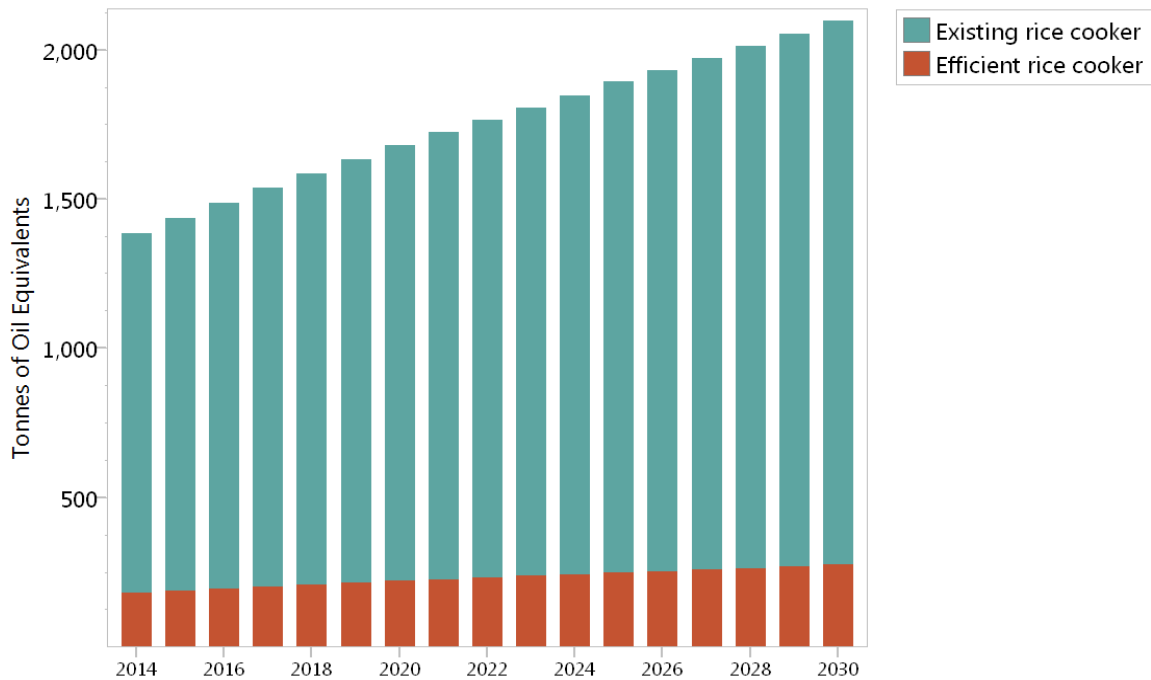


Figure 7: Energy consumption for existing rice cooker and efficient cooker of MECON group in Cambodia in BAU scenario during 2014-2030.

5.3 Cooling

In this category, three main appliances are analyzed for the reason that these three types of appliances share almost 100% of the total energy consumed by cooling appliances. These three types include air conditioner (AC), refrigerator, and electric fan. Among 15.097 toe consumed by these three types in 2014, electric fan, refrigerator, and AC shares 77.3%, 21.96%, and 0.72%, respectively. The consumption by these types increases constantly to 34.06 toe in 2030 but the percentage for each types remain almost the same.

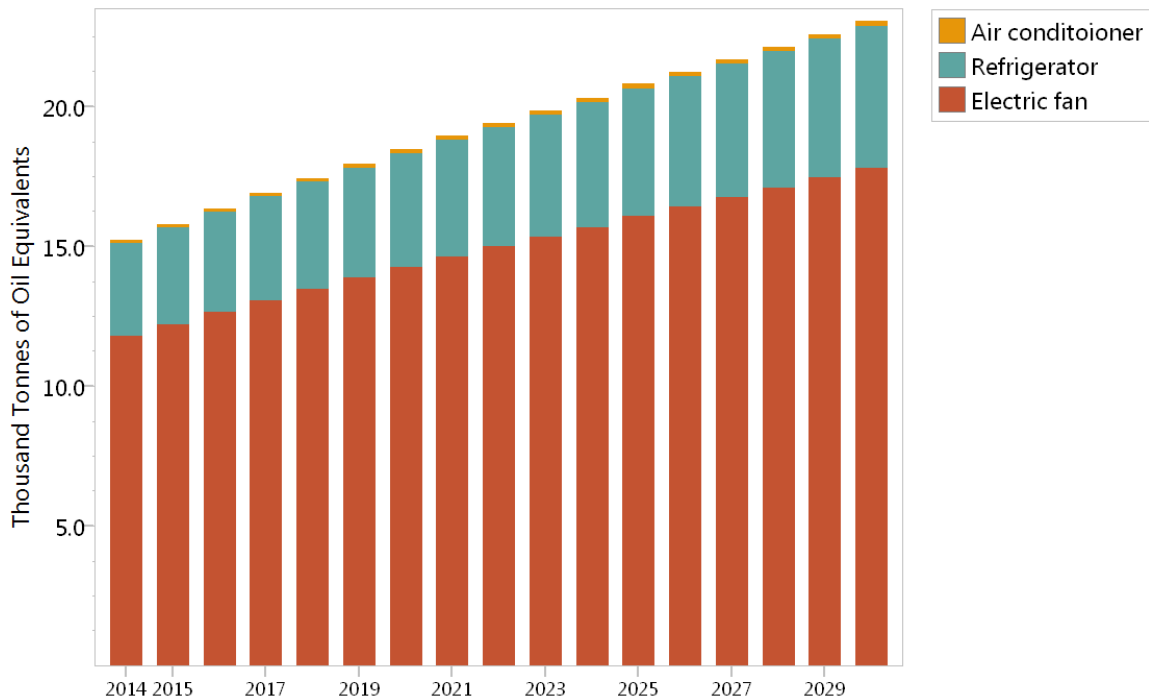


Figure 8: Energy consumption for cooling of MECON group in Cambodia in BAU scenario during 2014-2030.

Figure 9 shows that among the energy consumed by AC, about 74.32% is shared by efficient AC. Oppositely, about 98.92% of energy that is consumed by the refrigerator (Figure 10) is shared by inefficient refrigerator types. Similarly, Figure 11 shows that approximately 82.84% of the energy consumed by the fan is supplied to inefficient fans. It should be noted that different kinds of ventilation fans are practically used by Cambodian populations such as wall-mounted fan, and ceiling mounted fans. Among them, wall-mounted fans are the most popular among households while ceiling-mounted fans are widely used in public buildings.

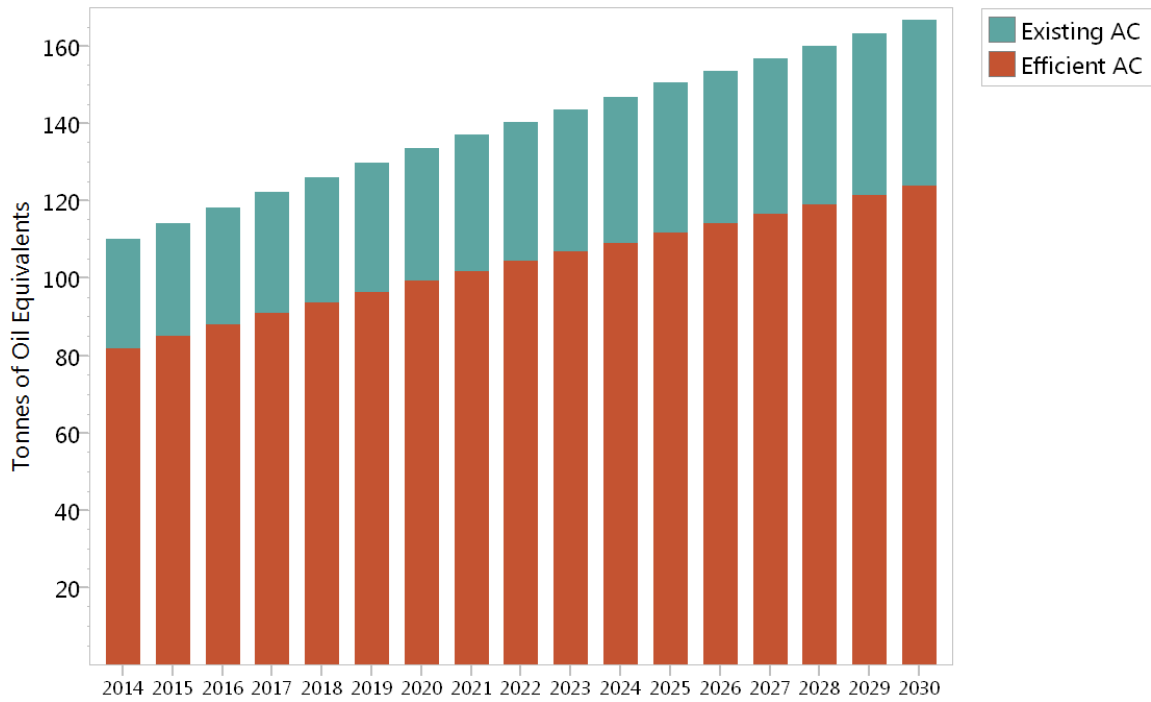


Figure 9: Energy consumption for existing AC and efficient AC used by MECON group in Cambodia in BAU scenario during 2014-2030.

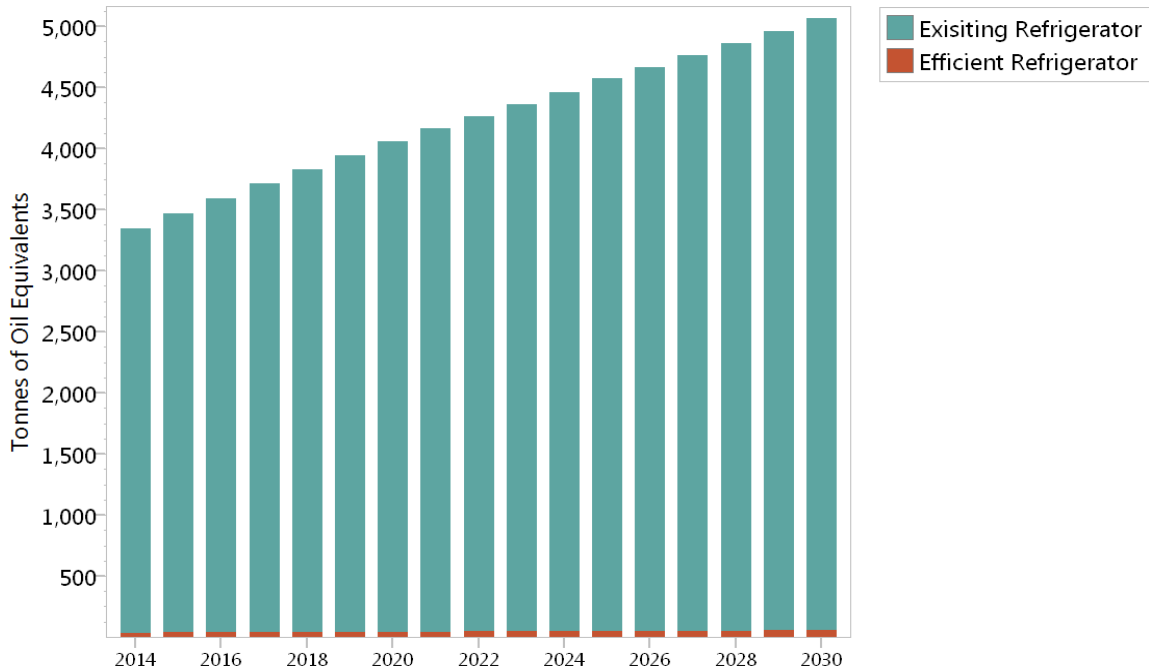


Figure 10: Energy consumption for existing refrigerator and efficient refrigerator of MECON group in Cambodia in BAU scenario during 2014-2030.

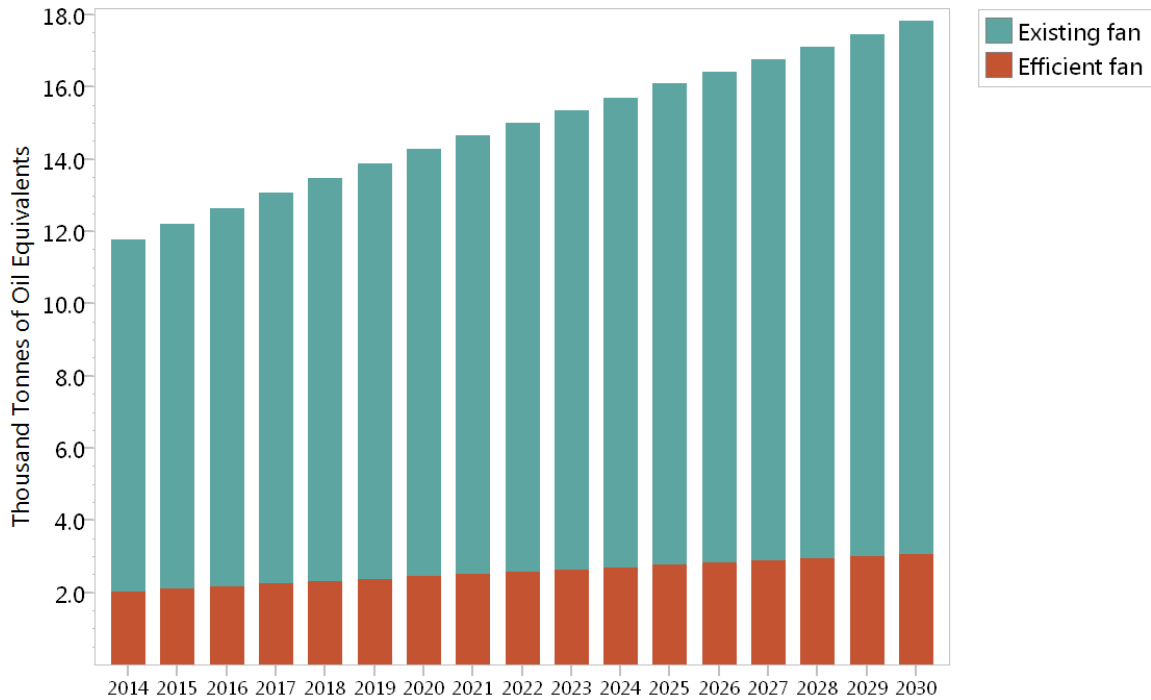


Figure 11: Energy consumption for existing fan and efficient fan of MECON group in Cambodia in BAU scenario during 2014-2030.

5.4 Heating

Heating is the fourth category listed in the designed LEAP model. This category consists of electric kettle, electric water heater, solar water heater, and electric heater. Although water heater, solar water heater and electric heater are included in this category, the percentage shared by these three types of appliances is less than 1% out of 125.80 toe in 2014 and 174.00 toe in 2030. This infers that electric kettle plays the main role in heating. Figure 10 shows that among different types of electric kettles which are practically used by Cambodian MECON households, efficient appliances share up to approximately 43% of the total energy consumed by electric kettle.

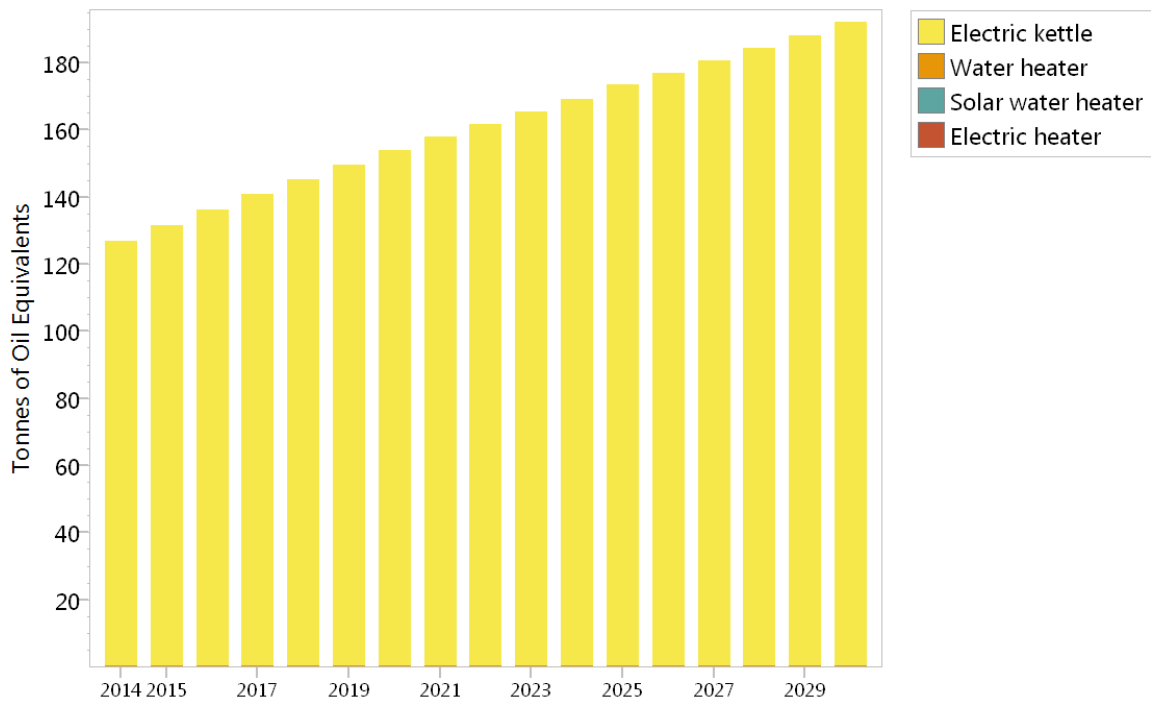


Figure 12: Energy consumption for heating by MECON group in Cambodia in BAU scenario during 2014-2030.

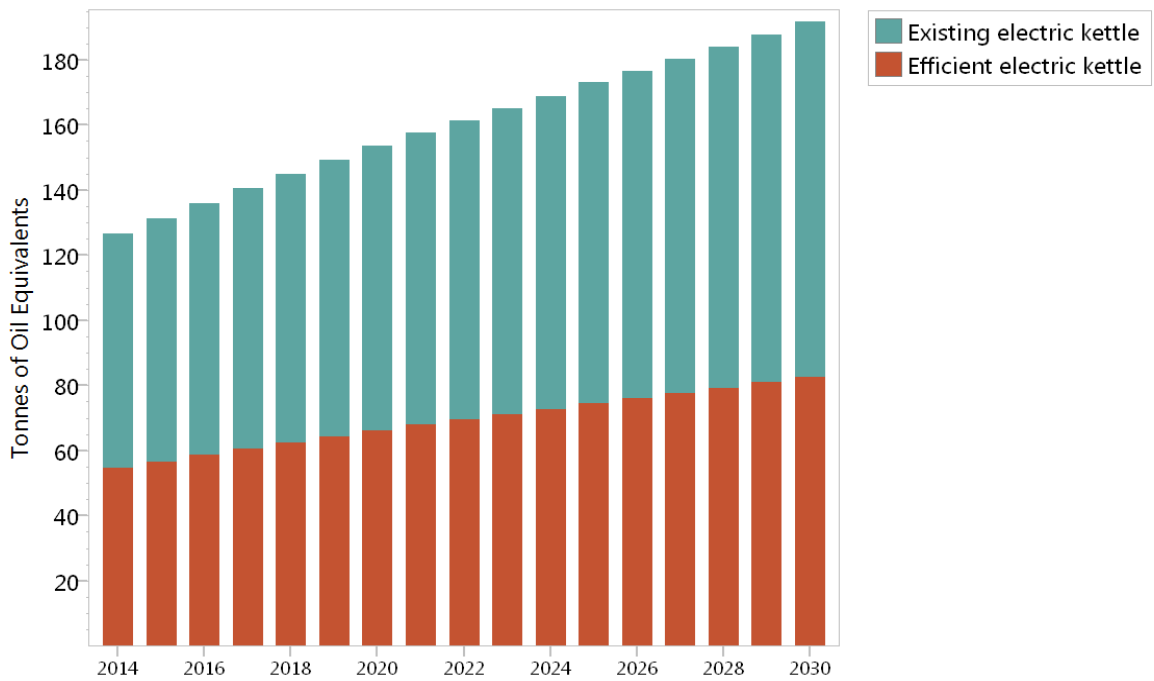


Figure 13: Energy consumption for electric kettle for MECON group in Cambodia in BAU scenario during 2014-2030.

5.5 Entertainment

This category is not the highest energy consuming category but the appliances for entertainment such as TV, radio, VDO/DVD, mobile phone, computer, and hifi-system are usually important for MECON households. This is why it can contribute high consumption to the total energy consumption by the whole MECON households in Cambodia. Figure 14 shows that among different types of entertaining appliances mentioned above TV consumes the highest level of energy consumption in this category. In 2014, among the total of 7212.03 toe consumed in 2014, TV shares 95.73%, while mobile phone shares about 4.09% and computer and VDO/DVD shares less than 1% of the total energy consumed by this category. The amount of energy consumed by this category duplicates in 2030 but the percentage remains almost the same.

Among the TVs used in Cambodia, there are CRT (box) TV, and flat-screen (LED, Plasma, LCD) TV. The first type is well-known to be energy –inefficient type of TVs. However, this type is the most popular type among Cambodian MECON households. As shown in Figure 15, CRT TVs consume up to about 95.82% of the total amount of energy consumed by entertainment category of appliances.

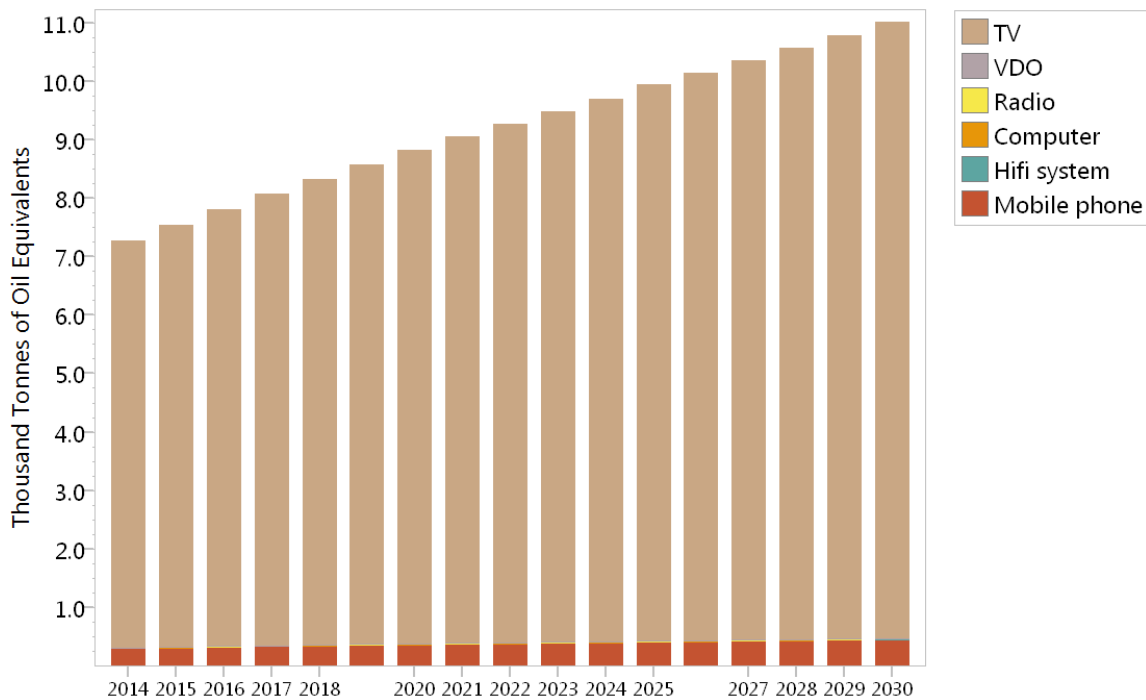


Figure 14: Energy consumption for entertainment appliances used by MECON group in Cambodia in BAU scenario during 2014-2030.

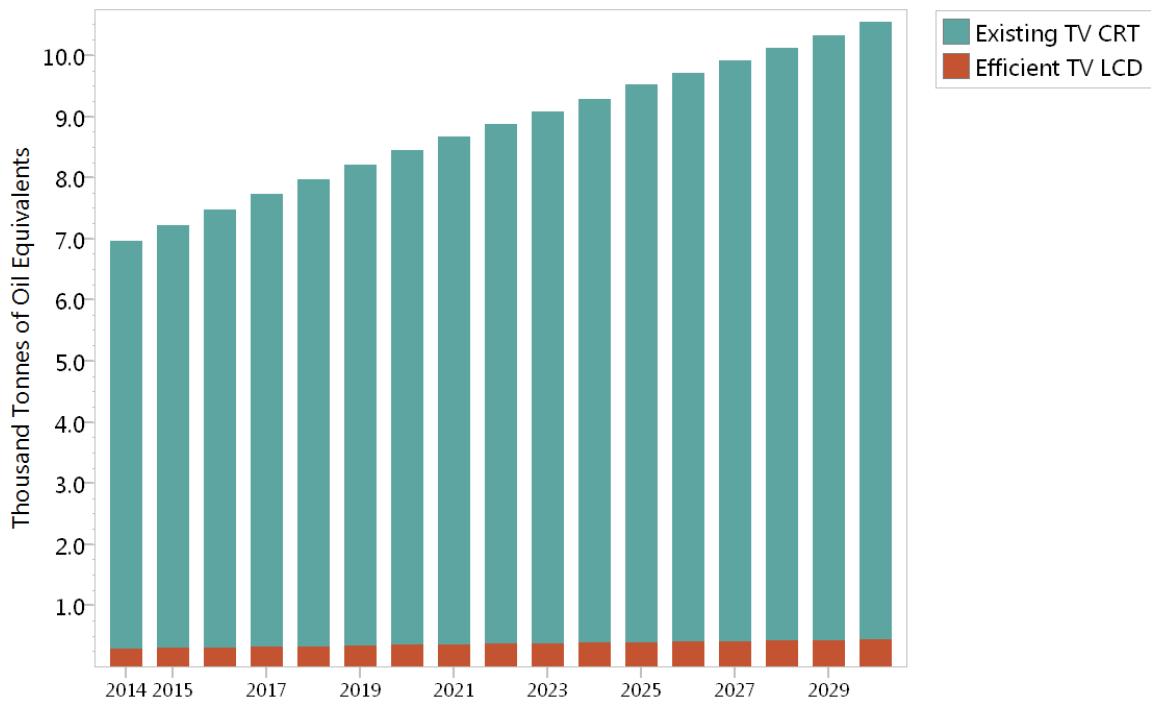


Figure 15: Energy consumption for TV used by MECON group in Cambodia in BAU scenario during 2014-2030.

5.6 Cleaning

In this category, two main appliances are counted such as washing machine and vacuum cleaner. For the reason that vacuum cleaner is not practically used by MECON group, washing machine shares almost 100% of total the energy consumption by this category. In 2014, the total consumption is 49.04 toe where about 99.99% is shared by washing machine. This amount constantly increases to approximately 67.83 toe.

Figure 17 shows that among 49.04 toe consumed by the washing machine in 2014 in the cleaning category, 44.32 toe is contributed by the inefficient types. The percentage remains almost the same for the consumption of 67.83 toe by washing machine in 2030.

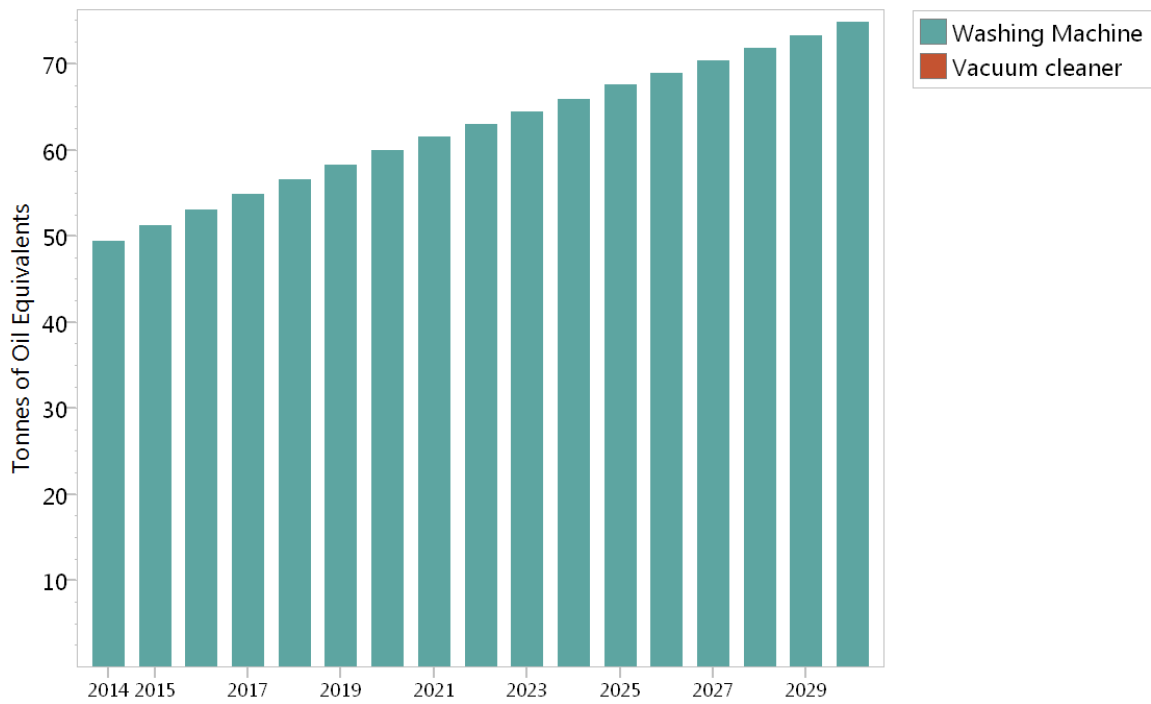


Figure 16: Energy consumption for cleaning of MECON group in Cambodia in BAU scenario during 2014-2030.

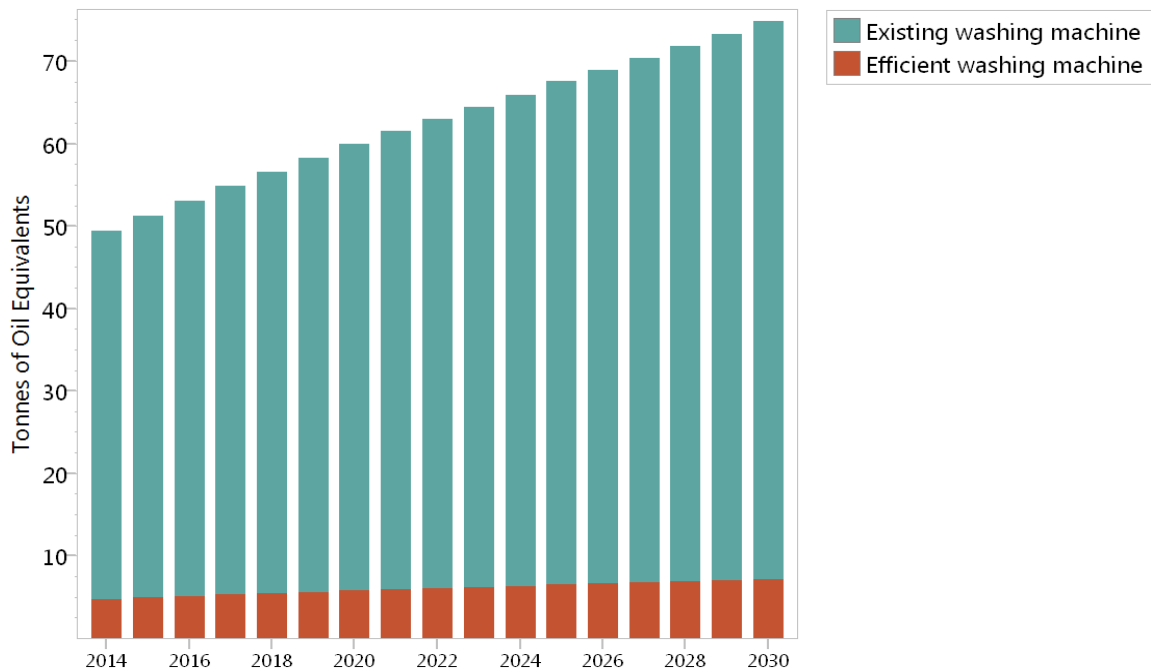


Figure 17: Energy consumption for washing machine used by MECON group in Cambodia in BAU scenario during 2014-2030.

5.7 Others

The seventh category of appliances in LEAP model is named as others. This includes water pump and electric iron. The total amount of energy consumption by this category is 460.17 toe in 2014 and it constantly increases to 636.48 toe in 2030. Out of this total amount, electric iron shares 97.07% in 2014 while in 2030 this percentage is approximately the same.

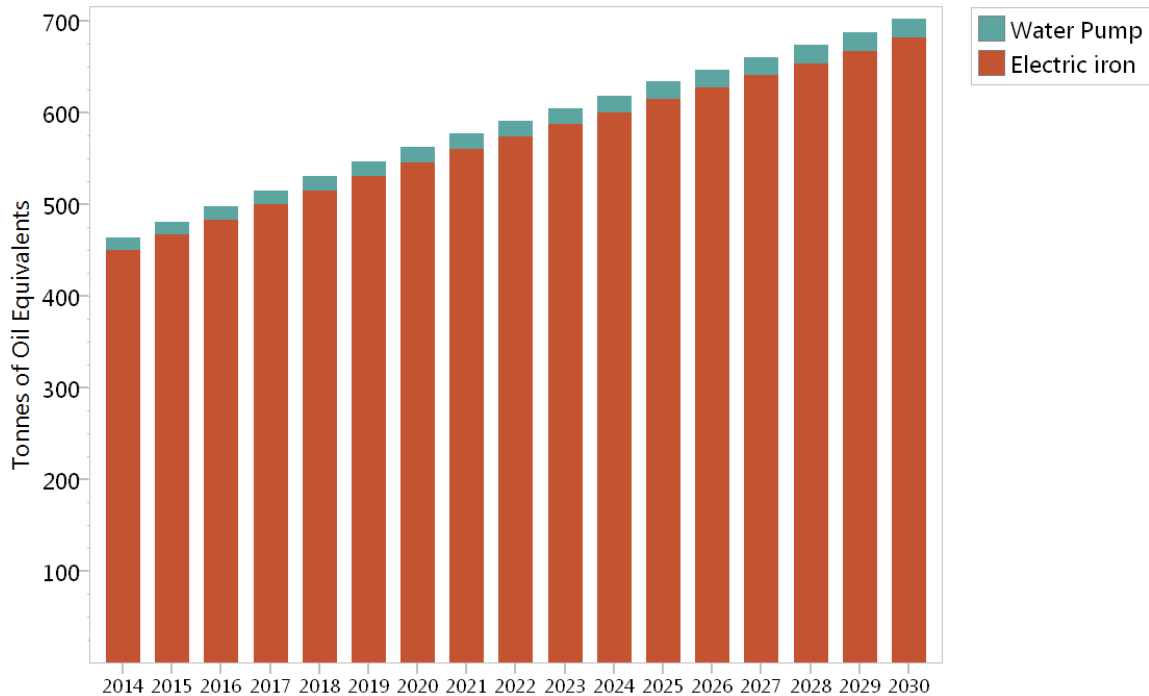


Figure 18: Energy consumption for other appliances used by MECON group in Cambodia in BAU scenario during 2014-2030.

6. Conclusion

In this task, energy consumption by the MECON households in Cambodia is forecasted using LEAP software. The design of the LEAP model is structured to have seven different categories of appliances used by the households who are from rural and urban areas in Cambodia. The BAU scenario is used in the whole analysis in LEAP model. The analysis shows that the consumption in 2030 is duplicated from the consumption level in 2014. This is due to the fact that number of the MECON household also increases constantly over the 25-year period in forecasting.

Among different categories modeled in LEAP, cooling, lighting, and entertainment are the main contributors in terms of energy consumption level. These three categories share almost 89% of the total energy consumed by all appliances. Among this, entertainment appliances takes

up to almost 9% of the total energy consumption. As TV takes the most part of energy consumption by entertainment category, it can be concluded that Cambodian MECON households consider TV as a must-have entertaining appliance for them in daily life. This is how modern lifestyle is practically seen not only in developed countries but also developing countries like Cambodia.

For lighting category, fluorescent light bulb is widely used and this type keeps increasing till 2030. As fluorescent light bulb can normally be considered the most inefficient bulbs among those available in the market, promotion of more efficient bulbs should be considered to change the way MECON households choose electric bulbs for lighting.

In the cooking category, rice cooker and LPG stoves are the most popular cooking appliances for Cambodian MECON households. Since this seems to be a practical way that Cambodian people use for cooking, the inefficient appliances are mostly chosen by MECON household cooks. This is, in addition, a concern that can harm the environment and household economy. Aside from cooking appliances, ventilation fans are similarly another concern in terms of energy inefficiency for household appliances. This requires an attention from energy policy makers, researchers, and the government of Cambodia especially, to work on the promotion of energy efficiency in this country to change the way energy resources and appliances are used to a more efficient way. This Task 1.2 report is therefore expected to contribute to knowledge on the design and implementation of energy efficiency policy in Cambodia.

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