User Guide for Household Sector

Indonesia 2050 Pathway Calculator

Table of Contents

1. Overview and Determining Factor of Energy Consumption in Household Sector

Indonesia is the fourth largest population nation in the world. As reported in 2010 census conducted by Statistics Indonesia (BPS), the population of Indonesia was 237.5 million peoples. In 2011, Indonesian households sector is the second largest final energy consumption after industrial sector that account for 319.28 million boe or 37.5 % of total final energy consumption. Biomass was the most consumed energy form in this sector. 73.3 % final energy consumption this sector in consumed in the form of biomass followed by 12.5 % , 11.0 %, 3.1 %, 0.04% for electricity, LPG, and city gas, respectively[1].

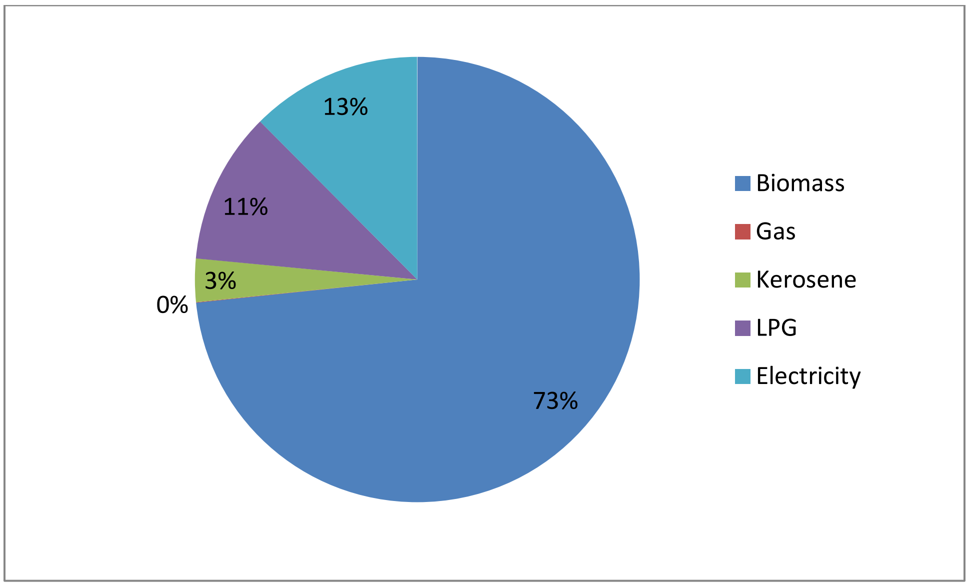


Figure 1 Energy consumption of household sector in Indonesia (urban and rural) in 2011 [1]

Disparity of energy consumption and accessibility to energy resources are two main problems of energy consumption in Indonesia's household sector [2]. These problems are attributed to the characteristics of energy consumption in Indonesian household sector which is dominated by non-commercial energy consumption, and the domination of high-income household groups in commercial energy consumption. Figure 2 and 3 present monthly energy consumption of urban household and share of urban household energy consumption by type of energy. Figure 1, 2 and 3 clearly show that the use of biomass is dominant in rural household.

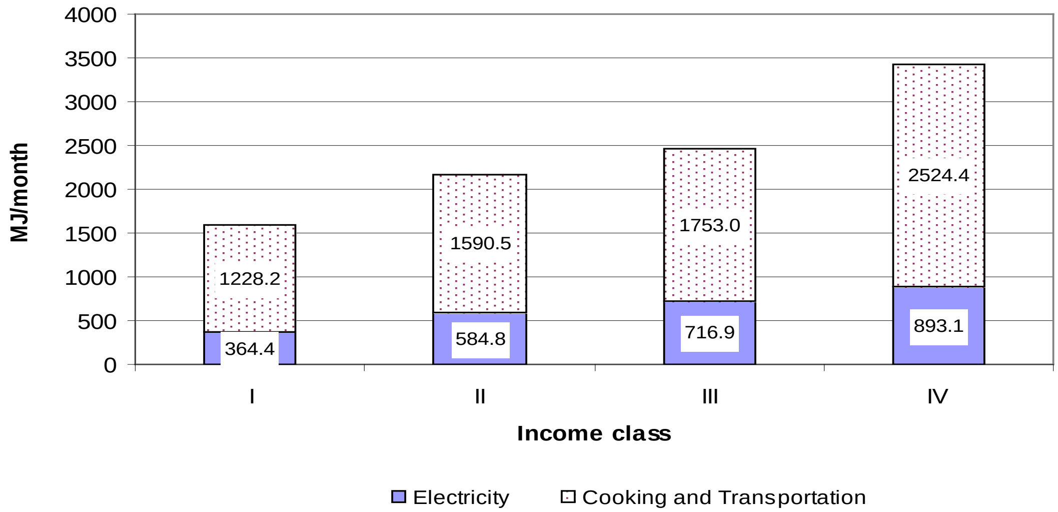


Figure 2 Monthly energy consumption of urban household [3]

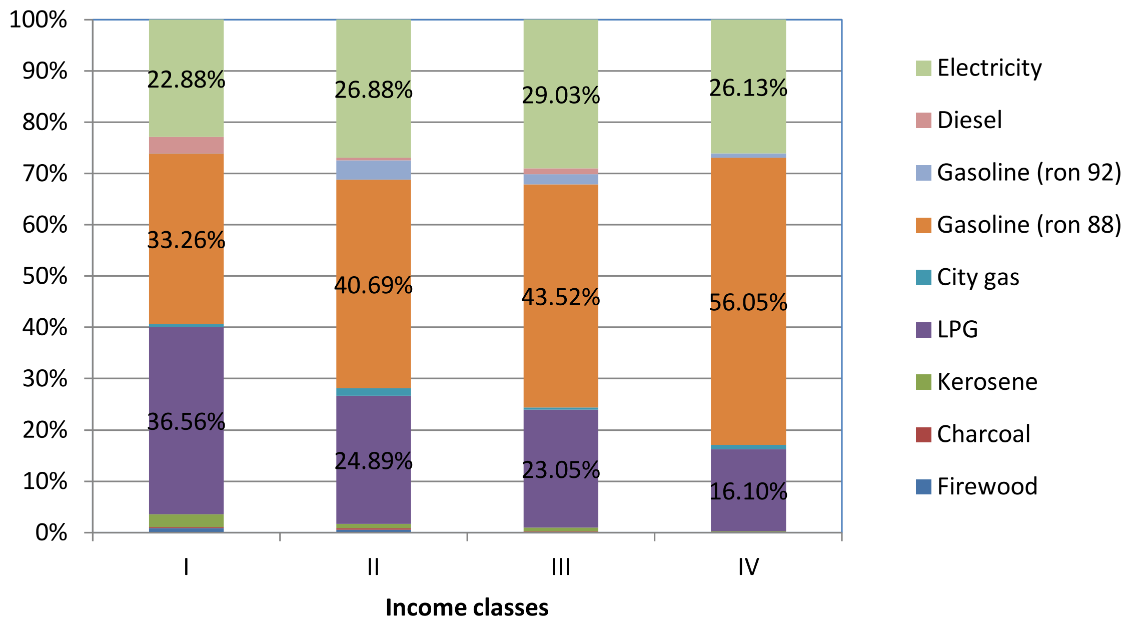


Figure 3 Composition of urban household's energy consumption by type of energy [3]

Many factors determine energy consumption in household sector. Those factors fall under some categories: demographic, economy, technical, and even life style. As population increase, the number of household will increase which in turn increasing household energy consumption. Household energy consumption is also determined by the household income. Higher income class generally consumes more energy as compared to the lower ones. Income stratification as shown in the above figure 2 and 3 is based on the distribution of respondent's income per capita provided in the survey [3]. First class (class 1) refers to those with per capita income that is lower than Rp 412,000, second class (Class II) refers to those with per capita income between Rp 412,000 and Rp 978,000, third class (Class III) refers to those with per capita income between Rp 978,000 and Rp 1,543,000, and the fourth class (Class IV) refers to those with per capita income that is higher than Rp. 1,453,000.

2. Methodology

Household energy consumption is calculated by using the end-use model. This approach is adopted in order to accommodate the decreasing energy intensity in the future due to technological change. By using this approach, energy consumption is the multiplication of activity level and energy intensity (see Eq.1)

$$Energy\ Consumption = Activity\ Level\ \times Intensity \quad (1)$$

In household sector, the activity level is number of household while the intensity is divided into four type of utilization in household, among others: lighting, cooking, cooling, and other uses such as television, water dispenser, ironing activity, fan and etc. Number of household can be calculated by dividing the population by the household size. Table 1 shows the trajectory of population and number of household from 2011 to 2050.

Table 1 Projection of population and household number [4]

Year	Population (Million)	Number of household (Thousand)
2011	242.0	62200
2015	255.5	65600
2020	271.1	69400
2025	282.1	74352
2030	293.6	79658
2035	305.5	85342
2040	317.9	91431
2045	330.9	97955
2050	344.3	104945

Projection of population from 2011 to 2020 is obtained from the presentation of the Statistic Agency (BPS) during stakeholder consultation [4]. Historical data of Indonesian population from 1990 to 2008 shows that the size of household declined at the rate of 0.58% per year [5, 6]. This model uses this number to project the household size from base year (2011) to 2050. Table 2 presents the model structure of household sector.

Table 2 Model Structure of Household Sector

Structure	Activity	Unit of intensity
Lighting	Number of household	*boe/hh/year*
Cooking		*boe/hh/year*
Air conditioning		*boe/hh/year*
Others		*boe/hh/year*

Remark: boe stands for barrel of oil equivalent

The base year data of energy intensity for each utilization (lighting, cooking, cooling, and others) derives from the *Handbook of Energy & Economic Statistics of Indonesia* 2012 and the judgement of the core team modeler [1]. The judgement is based on various research paper and govermnet's documents. The energy intensity for each type of utilization is different between urban and rural household. This model use the core team modeler judgement in determining the the intensity difference between rural household and urban household (in percentage) (See Table 5).

Technology is an important factor that determines the energy intensity for each household activity. In order to project the energy intensity from base year to 2050, stakeholder consultation has been conducted. The objective of stakeholder consultation is to get the insight from the stakeholders related to the energy intensity reduction for each household activity (lighting, cooking, air conditioning, and others). Energy intensity reduction is not only attributed to technology of appliances but also other factors such as passive design of building (insulation, natural lighting, etc.).

3. Assumption

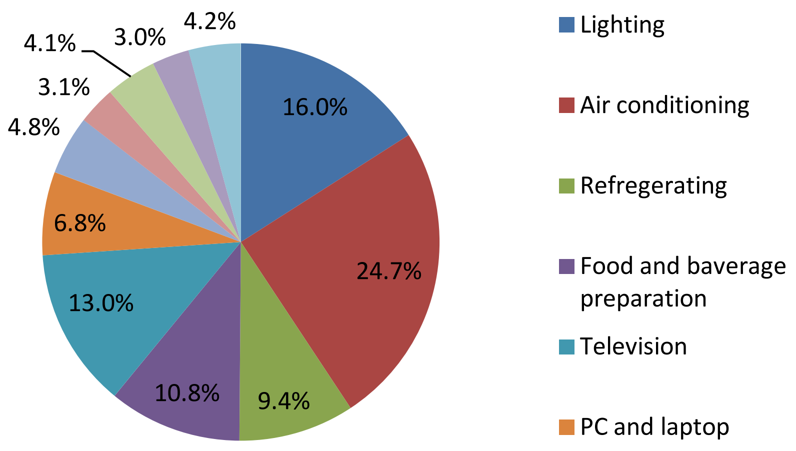
3.1 Expert Judgment on Energy Intensity by Household Activity

Since the structure of energy consumption of household sector in *Handbook of Energy & Economic Statistics of Indonesia*. 2012 [1] is different from the structure in this model, the expert judgment is needed in order to find the energy intensity of each household activity in base year. Table 3 presents the core team modeler's assumption in determining the energy consumption for each household activity by its type of fuel.

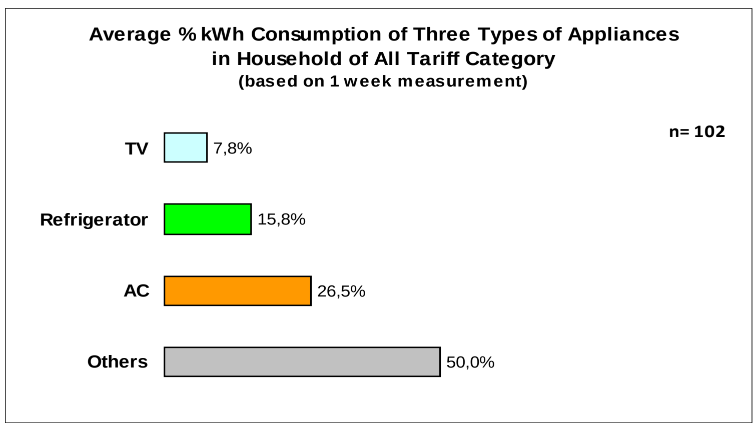
Table 3 Assumption of energy consumption for each household activity by type of fuel [7]

	Biomass	Kerosene	LPG	Electricity
Lighting		1%		19%
Cooking	100%	99%	100%	9%
Air conditioning				24%
Others				48%

For electricity consumption, consensus among the core team modeler in Table 3 is based on some studies on household energy consumption survey in Indonesia [8, 9]. The survey result is shown in Figure 4 below:



(a)



(b)

Figure 4. (a) Share of urban household's electricity consumption in Indonesia based on household activity [8] (b) Share of household's electricity consumption for all tariff groups (based on 1 week meter reading) [9]

3.2 Assumption of energy intensity per period

Energy intensity of each household is affected by some factors such as economic growth, technology efficiency, and even lifestyle. Economic growth leads to an increase in per capita income, which ultimately improves the living standard as well as energy consumption in household sector. Although the number of household appliances continues to grow, the energy consumption of each appliance is predicted to be lower due the improvement in efficiency. Awareness on energy efficiency will also play a significant role in reducing the energy consumption in household sector.

In general, economic growth and high efficiency technology penetration will not be similar over time, thus the core team modeler agreed to divide the period of energy intensity reduction into three periods:

2011-2025, 2026-2035, and 2036-2050. Intensity for each period is calculated by using interpolation method. Details of energy intensity reduction can be viewed in Table 4. Figures in table 4 are based on some factors, namely increase in electrification ratio, improvement of living standard, and high efficiency technology penetration including passive design such as insulation improvement and natural lighting. Contribution of the above factors will be discussed later in section 3.3 (Leveling logic).

Table 4. Energy intensity assumption by period

Structure	Trajectory/Leveling	Addition (reduction) of energy intensity relative to base year (2011)		
		2025	2035	2050
Lighting	Level 1	30%	35%	25%
	Level 2	20%	25%	5%
	Level 3	10%	15%	(10%)
	Level 4	5%	8%	(25%)
Cooking	Level 1	30%	35%	25%
	Level 2	20%	25%	15%
	Level 3	10%	15%	0%
	Level 4	5%	8%	(10%)
Air conditioning	Level 1	30%	35%	25%
	Level 2	20%	25%	10%
	Level 3	10%	15%	(5%)
	Level 4	5%	8%	(20%)
Others	Level 1	30%	35%	25%
	Level 2	20%	25%	10%
	Level 3	10%	15%	0%
	Level 4	5%	8%	(10%)

The table shows the increase or decline of energy intensity in certain years (2025, 2035, and 2050) relative to base year (2011). The above table shows that the energy intensity of household sector increases from base year to 2025, the energy intensity continues to increase yet with lower pace until 2035, and then the intensity decreases until 2050. Increase in energy intensity from base year to 2025 is triggered by the increase in living standard and electrification ratio, it is supported by the data on waiting list household for electricity connection in PLN Statistics [10]. The fact shows that there is a higher energy consumption potential in household sector than the figure written in the Handbook of Energy and Economic Statistics of Indonesia 2012 [1]. Between 2026 and 2035, the energy intensity is assumed to still progress yet with lower pace. Albeit there are additional households with access to energy and additional energy consuming appliances due to living standard improvement, there is an energy intensity reduction owing to the penetration of high efficiency technology. Between 2036 and 2050, household sector's access to energy reaches its saturation stage and the penetration of high efficiency technology occurs, leading to a reduction in energy intensity.

3.3 Leveling Logic

As stated above, changes in intensity as shown Table 4 for each level are attributed by some factors, namely (1) economic growth that affects living standard, (2) technology efficiency, (3) electrification ratio, (4) electricity subsidy, (5) lifestyle, including the efforts to save energy that is incorporated into the house design. The extent of high efficiency technology penetration and the impacts of passive design might occur as a business as usual or as the effects of binding government policy. Government instruments to improve high efficiency technology penetration may consist of implementation of standard policy, energy labeling for household appliances.

The Minimum Energy Performance Standard (MEPS) is a specification containing a number of minimum energy performance conditions for certain circumstances that is aimed for limiting the maximum energy consumption based on permissible energy consumption of household appliances. [11]. Meanwhile save energy labeling states that the product has met certain energy saving requirements [11].

For all levels, it is assumed that in 2035, 100% household in Indonesia will have access to electricity. With 77% electrification ratio in 2011 and disregarding other factors, the total national household energy consumption divided by number of households in 2035 will be 30% higher than those of 2011.

In general, the level of household energy consumption will be affected by the level of income. The higher the income, the people tend to purchase appliances for household pleasure purpose. It will lead an increase in household's energy consumption. Referring to the survey [8], the relationship between household income and electricity consumption is described in Figure 5.

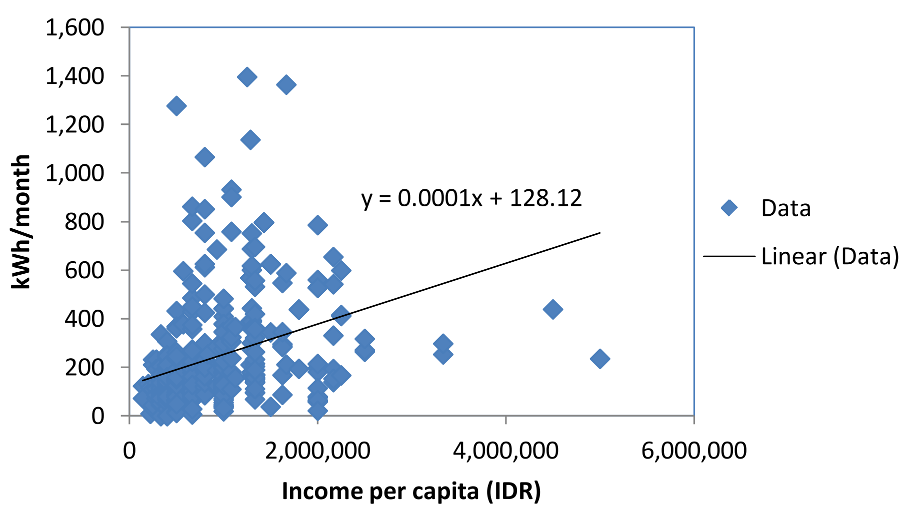


Figure 5. Relationship between household's income and electricity consumption in Indonesia

The equation in Figure 5 shows that 10% increase of income will increase the energy consumption by 4%.

Electricity subsidy also affects the energy consumption pattern in Indonesia. The lower the subsidy the higher the electricity cost, which causes decrease in electricity intensity triggered by the raised awareness of saving energy. At level 1, it is assumed that the electricity subsidy situation will be similar from base year to 2010. In level 2, it is assumed that the subsidy is only provided for certain groups. Level 3 assumes that the subsidy to certain groups is provided only until 2025, and it is assumed that there would be no more subsidies from 2026 to 2050. For level 4, it is assumed that the subsidy is not provided from base year to 2050.

The logic behind the intensity changes for each household activity in each level is elaborated as follow:

1. Lighting

In general, factor attributing to the lighting intensity is the composition of lighting technology which comprises: bulb, Compact Fluorescent Lamp (CFL), Light Emitting Diode (LED), Lighting Sensor, and natural lighting. LED technology truly affects lighting consumption in household sector because when LED is compared to bulb and CFL, LED consumes 12% and 41% less respectively. Figure 6 shows the prediction of LED penetration in United States by the National Lighting Bureau (NLB).

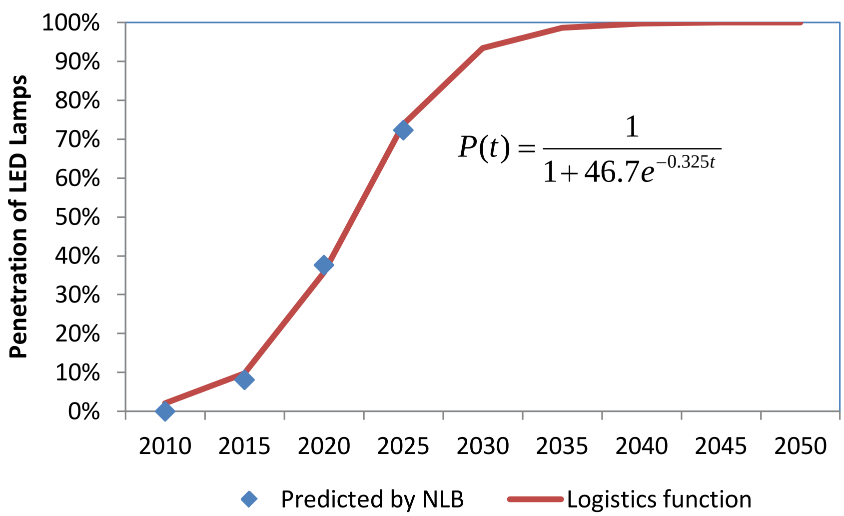


Figure 6. Prediction of LED penetration in the United States [12]

For each level, the energy consumption of lighting activity in household is given as follow:

Level 1

Between 2011 and 2025, the number of lightings per household is predicted to increase owing to the improvement of living standard and government's endeavor to increase electrification ratio. Standard policy instrument and save energy labeling are not binding, LED penetration is still below the prediction in Figure 6, it is estimated that LED penetration is only 20%. The combination of the above factors contributes to the increase in lighting consumption intensity in 2025 as much as 30% compare to base year.

Between 2026 and 2035, energy intensity will still increase yet with lower pace. Electrification ratio will be 100% by 2035, yet the growth is slower than the previous period. LED penetration is only 30% out of total lighting technology. Combination of the above factors contributes toward the increase in lighting consumption intensity in 2035 as much as 30% compare to base year.

Between 2035 and 2050, composition of lighting in household is still dominated by CFL, bulb technology is no longer in use, and LED penetration is 40% out of total lighting technology. In this period, the most determining factor of energy consumption in household sector is the more efficient technology penetration considering that the electrification ratio has reached 100% and the economic growth is lower than the previous period. Such conditions cause a decline in energy consumption per household compare to the previous period; however the energy consumption is still 25% higher than the consumption in base year.

Level 2

Between 2011 and 2025, the number of lightings per household is predicted to increase owing to the improvement of living standard and government's endeavor to increase electrification ratio. 35% households have used LED, although the penetration is below the LED prediction for developed countries (Figure 6) the above factors contributes to the increase in household's lighting consumption intensity in 2025 as much as 20% compare to base year.

Between 2026 and 2035, energy intensity will still increase yet with lower pace. Electrification ratio will be 100% by 2035, yet the growth is slower than the previous period. LED penetration is only 40% out of total lighting technology. Combination of the above factors contributes toward the increase in lighting consumption intensity in 2035 as much as 25% compare to base year.

In 2050, lighting technology for household will be dominated by CFL and LED, with 50% share each; bulb technology will not be utilized anymore. Standard policy instrument and save energy labeling are not binding. The energy intensity is lower compare to previous period; however the energy consumption is still 5% higher than the consumption in base year.

Level 3

Between 2011 and 2025, the number of lightings per household is predicted to increase owing to the improvement of living standard and government's endeavor to increase electrification ratio. LED penetration is similar to developed countries' level of LED penetration (see Figure 6). Energy intensity in 2025 is predicted to be 10% higher than base year.

Between 2026 and 2035, energy intensity will still increase yet with lower pace, energy intensity is predicted 15% higher than base year. In 2050, lighting technology will be dominated by LED. This situation is achieved due to the mandatory implementation of Minimum Energy Performance Standard

(MEPS) and voluntary labeling policy. These measures cause the energy intensity in 2050 become 10% lower than base year.

Level 4

Between 2011 and 2025, the number of lightings per household is predicted to increase owing to the improvement of living standard and government's endeavor to increase electrification ratio. LED has been adopted widely, thus the LED penetration is higher than those in developed countries (see Figure 6). LED penetration is predicted to be 90% in 2025. Energy intensity of lighting activity in 2025 is predicted to be 5% higher than base year.

Between 2026 and 2035, energy intensity will still increase yet with lower pace, energy intensity is predicted 8% higher than base year. In 2050, energy intensity is assumed to be 25% lower than the base year due to high LED penetration, massive adoption of natural lighting and lighting sensor. This situation is triggered by the implementation of mandatory MEPS and labeling for lighting. There is also high community awareness on the importance of natural lighting and lighting sensor in reducing energy consumption.

2. Cooking

In general, factors contributing to energy intensity in cooking activity are type of stove, type of fuel, type of appliance used for cooking, and habits developed in cooking. Biomass, kerosene, natural gas, LPG, biogas, and electricity are type of energy that is used generally for cooking in Indonesia. Stove efficiency is one of important factors that determine the amount of energy consumed for cooking activity. Conventional LPG stove has 53% efficiency and high efficiency product could have 68% efficiency [8]. It is not easy to obtain specific data on study related to the use of efficient cooking equipment to replace the conventional ones. With such hurdle, the model will utilize the data on average penetration of household appliances in Thailand, published by the Joint Graduate School of Energy and Environment (JGSEE) [13] as the basis to determine the penetration of cooking equipment in Indonesia. Figure 7 shows the prediction of efficient technology penetration of household appliances in Thailand.

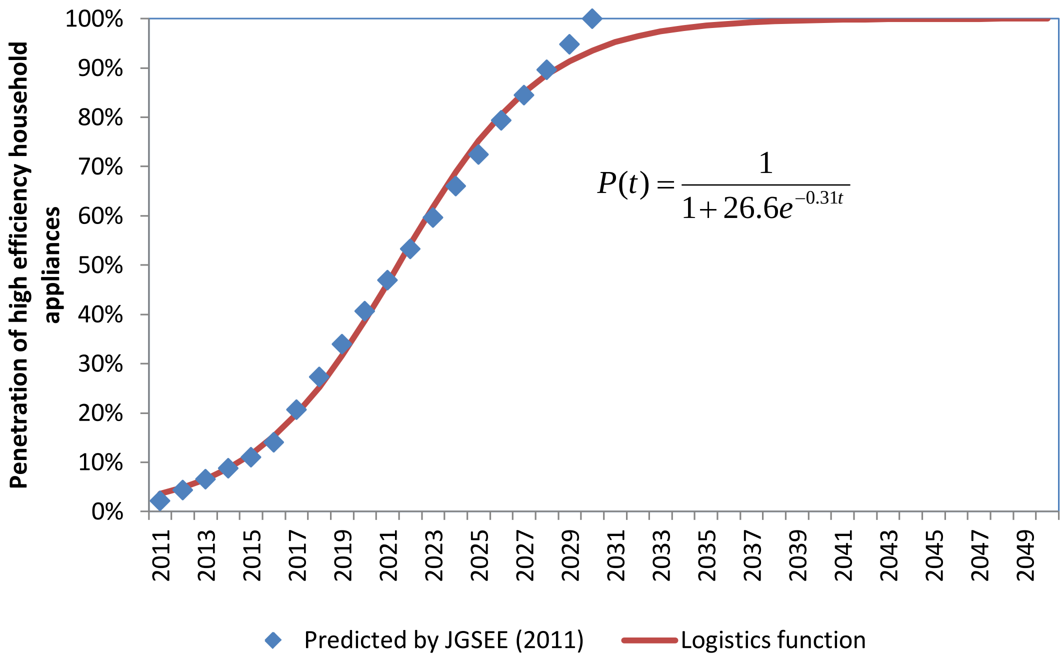


Figure 7. Prediction of high efficiency household appliances penetration in Thailand [13]

Government applies the policy to reduce the consumption of biomass and kerosene for cooking in order to reduce our dependency on imported fuel and to improve people's living standard.

Level 1

Between 2011 and 2025, the number of household with access to LPG is predicted to increase. However, kerosene and fuel wood are still widely used, particularly in rural areas. Penetration of high efficiency stove is still below the target as shown in Figure 7. Penetration of efficient LPG stove is only 20% by 2025. Those factors contribute to 30% increase in energy consumption for cooking in 2025 compare to base year.

Between 2026 and 2035, number of household with access to LPG increases yet with slower pace compare to the previous period. The share of efficient stove and cooking appliances in 2035 is only 35%. Thus, the energy consumption for cooking in this period is predicted to be 35% higher than the base year.

In 2050, there is no significant government policy yet in changing the fuel composition for cooking. Efficient stove and cooking appliances have not been used widely and are far below the penetration target shown in Figure 7. The share of efficient LPG stove is only 40% out of total LPG stove population. Standard policy instrument and save energy labeling for cooking appliances are still not binding. Energy intensity for cooking is lower than the previous period, but still 25% higher than the base year's figure.

Level 2

Between 2011 and 2025, the number of household with access to LPG is predicted to increase. It is predicted that 30% household would have used high efficiency LPG stove. The condition leads to an increase in energy consumption for cooking by 20% compare to the base year.

Between 2026 and 2035, number of household with access to LPG increases yet with slower pace compare to the previous period. The share of efficient stove and cooking appliances in 2035 is only 40%. Thus, the energy consumption for cooking in this period is predicted to increase with slower pace, it is predicted to be 25% higher than the base year.

In 2050, LPG starts to be the fuel preference to replace fuel wood and kerosene in rural area. Although standard policy instrument and save energy labeling for cooking appliances are still not binding yet, the high efficiency stove and cooking appliances have been adopted due to economic reason. 50% household would have used the efficient LPG stove by then. These factors cause the energy consumption for cooking to be 15% higher than the base year

Level 3

Between 2011 and 2025, the number of household with access to LPG is predicted to increase in both urban and rural areas; natural gas infrastructure has been built in big cities. Biogas is introduced in rural areas to substitute the use of fuel wood and kerosene. The number of household that uses efficient stove will be in accordance with the prediction in Figure 7 (70%) by 2025. The condition leads to an increase in energy consumption for cooking by 10% compare to the base year.

Between 2026 and 2035, number of household with access to LPG, natural gas, and biogas increases yet with slower pace compare to the previous period. The number of households that uses efficient stove would be similar to the prediction shown in Figure 7. High efficiency LPG stove has been adopted by 95% household in Indonesia by 2035. Energy consumption for cooking is predicted to be 15% higher than the base year.

In 2050, LPG would be the fuel preference to replace fuel wood and kerosene in rural area. Efficient stove has been widely used because the MEPS for stove and cooking appliances becomes mandatory, thus the stove producers only produces the high efficiency stove. The energy consumption for cooking activity in each household is predicted to be similar with the base year.

.

Level 4

Between 2011 and 2025, the number of household with access to LPG is predicted to increase, natural gas infrastructure has been built massively in big cities, and so has biogas installation in rural area. The number of household that uses efficient stove will be higher than the prediction in Figure 7 (70%) by 2025. The condition leads to an increase in energy consumption for cooking by 5% compare to the base year.

Between 2026 and 2035, all household would have used the efficient stove and cooking appliances. The energy consumption of household will increase compare to the previous period yet with slower pace. Energy consumption for cooking is predicted to be 8% higher than the base year.

In 2050, the standard policy instrument and energy save labeling for stove and cooking appliances are binding. LPG is considered as the main source of energy in urban and rural area. In addition, natural gas would become the alternative energy in urban area, and biogas in rural area. In the future, the household in Indonesia would prefer to purchase meals outside due to practical reason. These situations cause the energy intensity for cooking to be 10% lower than the base year.

3. Cooling

Energy consumption for cooling is affected by the penetration of efficient air conditioning (for instance inverter technology), insulation and building design. Low wattage technology (Coeeficient of Performance, COP=3.8) and inverter (COP=4.2) are expected to significantly reduce electricity consumption in cooling sub-sector because both technologies only consume electricity as much as 74% and 40% of the energy consumed by the conventional technology. Study [8] reveals that in 2011, only 20% air conditioning in household sector in Indonesia that fall under low wattage category (more efficient compressor, evaporator and insulation) and it is very rare to find a household that uses air conditioning with inverter technology, most households still use conventional technology. Study [8] also predicts the future of air conditioning technology (see Figure 8). Prediction in this study utilizes stock turn-over analysis by considering: the average air conditioning age used by household sector, estimated age of air conditioning and prediction of efficient air conditioning penetration to replace conventional air conditioning

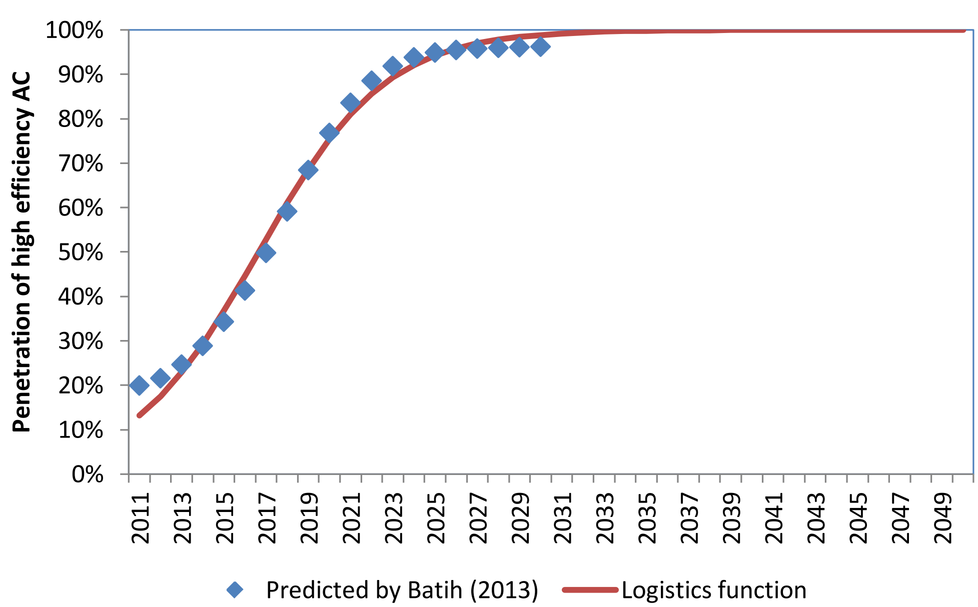


Figure 8. Prediction of high efficiency air conditioning penetration [8]

For each level, the factors that determine the amount of energy consumption for cooling activity in household sector are described below:

Level 1

Between 2011 and 2025, there would be an improvement of living standard and government efforts to increase electrification ratio, thus the energy intensity for cooling activity is predicted to be 30% higher than the base year. Penetration of air conditioning with low wattage is still far below the prediction shown in Figure 8. By 2025, the share of air conditioning with low wattage technology is estimated 40% out of total air conditioning used by household in Indonesia.

Between 2026 and 2035, the use of air conditioning with low wattage technology causes an increase in energy intensity, yet with lower pace. Energy intensity is estimated to be 35% higher than the base year. The penetration of air conditioning with low wattage technology is predicted to be 70% out of total air conditioning used by household in Indonesia.

In 2050, the air conditioning with low wattage technology is widely used by the household sector in Indonesia due to economic reason. Energy intensity for cooling activity decreases, yet still 25% higher than the base year. For all periods, the standard policy instrument and save energy labeling for air conditioning are still not binding. MEPS and labeling are still voluntary.

Level 2

Between 2011 and 2025, there would be an improvement of living standard and government efforts to increase electrification ratio, thus the energy intensity for cooling activity is predicted to increase. By 2025, the share of air conditioning with low wattage technology is estimated 70% out of total air conditioning used by household in Indonesia. The above factors lead to an increase in energy consumption for each household by 20% compare to the base year.

Between 2026 and 2035, the use of air conditioning with low wattage technology causes an increase in energy intensity, yet with lower pace, the energy intensity is predicted to be 25% higher than the base year. In 2050, the Air Handling Unit (AHU) and inverter technology start to be adopted due to economic reason. MEPS and labeling are still voluntary. Energy intensity decreases will still be 10% higher than the base year.

Level 3

Between 2011 and 2025, there would be an improvement of living standard and government efforts to increase electrification ratio. The penetration of air conditioning with low wattage technology and inverter technology is 70% and 20% respectively, thus the energy intensity for cooling activity is predicted to be 10% higher than the baseline.

Between 2026 and 2035, the share of air conditioning with low wattage technology and inverter technology would be 50% each. Air conditioning with inverter system will be widely adopted in 2050 owing to the government policy on MEPS and labeling for air conditioning. At this level, it is assumed that the community has realized the importance of insulation to reduce the cooling load. These efforts contribute to reduce the energy intensity for cooling, thus the intensity of 5% lower than the base year.

Level 4

Between 2011 and 2025, there would be an improvement of living standard and government efforts to increase electrification ratio. The penetration of air conditioning with low wattage technology and inverter technology is 80% and 30% respectively, thus the energy intensity for cooling activity is predicted to be 5% higher than the baseline.

Between 2026 and 2035, the share of air conditioning with low wattage technology and inverter technology would be 30% and 70% respectively. The energy consumption per household for cooling will be 15% higher than the base year. Air conditioning with inverter system will be widely adopted in 2050 owing to the government policy on MEPS and labeling for air conditioning. In addition, the design of new building has considered the air circulation principal in order to reduce demand for cooling. Energy intensity for cooling activity will be 20% lower than the base year.

4. Other Appliances

It is assumed that other appliances in household sector also use electricity. Other appliances refer to household appliances, apart from the appliances used for lighting, cooking and cooling. Other appliances are television, iron, vacuum cleaner and etc. Considering that van, water pump, vacuum cleaner, compressor and other household appliances utilize electric motor, an efficient motor technology is one important factor that determines the amount of energy consumption in this sub-sector. Variable Frequency Drive (VFD) technology is an electric motor technology that could adjust the speed and torsion based on the frequency and voltage inputs. This technology is expected to save the energy significantly. For instance, at 63% of its maximum speed, VFD technology only consumes 25% power at that maximum speed. [14]. Since the sub-sector covers many household appliances, the prediction of efficient appliances penetration will use the prediction in Figure 7.

Level 1

Between 2011 and 2025, there would be an improvement of living standard and government efforts to increase electrification ratio, thereby the number of appliances in each household would increase. In 2025, the penetration of high efficiency household appliances will be far below the prediction given in Figure 7. The penetration in 2025 will be just 25%. It will lead to an increase in energy consumption for other household appliances sub-sector. The increase is predicted to be 30% higher than the base year.

Between 2026 and 2035, there would be an increase in electrification ratio yet with slower pace. There are 30% household that would have used the efficient appliances in 2030. This condition trigger an increase in energy consumption of each household for other appliances sub-sector as much as 35% higher than the base year. MEPS and labeling are introduced yet not binding, the decrease in energy intensity is caused more by economic reason. In 2050, the energy intensity will still be 25% higher than the base year because there are only 40% households that use efficient appliances.

Level 2

Between 2011 and 2025, there would be an improvement of living standard and government efforts to increase electrification ratio, thereby the number of appliances in each household would increase. In 2025, the penetration of high efficiency household appliances will be higher than level 1 but still below the prediction given in Figure 7. The penetration of efficient appliances in 2025 will be 30%. It will lead to an increase in energy consumption for other household appliances sub-sector. The increase is predicted to be 20% higher than the base year.

The determining factor for energy consumption this sub-sector during this period would be the penetration of efficient appliances, instead of increasing electrification ratio. At this period, the electrification ratio would only increase at a slow pace, thus it would not significantly affect the energy consumption. There are 40% household that would have used the efficient appliances in 2030. This condition trigger an increase in energy consumption of each household for other appliances sub-sector as much as 25% higher than the base year.

In 2050, MEPS and labeling are introduced yet still not binding, the decrease in energy intensity is caused more by economic reason. Efficient appliances are easy to find in the market. There would be 50% households that use efficient appliances. These factors will contribute to increase the energy intensity of this sub-sector to be 10% higher than the base year.

Level 3

Between 2011 and 2025, there would be an improvement of living standard; thereby the number of appliances in each household would increase. The number of household with access to electricity increases following the government efforts to increase electrification ratio. In 2025, the penetration of high efficiency household appliances will be close to the prediction given in Figure 7 (65%). It will lead to an increase in energy consumption for other household appliances sub-sector. The increase is predicted to be 10% higher than the base year.

Between 2026 and 2035, there would be an increase in electrification ratio but the pace is slower. There are 95% household that would have used the efficient appliances. This condition trigger an increase in energy consumption of each household for other appliances sub-sector as much as 15% higher than the base year.

In 2050, high efficiency appliances have been used widely. MEPS is mandatory but labeling is still not binding. These factors will cause the energy intensity to be similar to the base year.

Level 4

Between 2011 and 2025, there would be an improvement of living standard; thereby the number of appliances in each household would increase. The number of household with access to electricity increases following the government efforts to increase electrification ratio. In 2025, the penetration of high efficiency household appliances will be higher than the prediction given in Figure 7; the penetration is expected to be 80%. It will lead to an increase in energy consumption for other household appliances sub-sector. The increase is predicted to be 5% higher than the base year.

Between 2026 and 2035, all household would have used the efficient appliances, and the energy intensity is predicted to be 8% higher than the base year. In 2050, MEPS and labeling are mandatory for all appliances. At this level, community awareness on energy saving is high, the energy saving habits have been adopted massively. The above measures reduce the energy consumption in this sub-sector as much as 10% lower than the base year.

Energy intensity in each household activity is different between urban household and rural household. The core team has agreed that the energy intensity of rural household is 18.5% lower than the energy intensity of urban household. Table 5 presents the energy intensity of urban and rural households for each household activity in the base year (2011).

Table 5 Energy intensity of urban and rural households for each household activity in the base year

Level	Lighting			Cooking			Cooling			Other appliances		
	Urban	Rural	Average	Urban	Rural	Average	Urban	Rural	Average	Urban	Rural	Average
Level 1	0.17	0.14	0.15	6.28	5.12	5.71	0.38	0.31	0.19	0.42	0.35	0.39
Level 2	0.14	0.12	0.13	5.78	4.71	5.25	0.33	0.27	0.17	0.37	0.30	0.34
Level 3	0.12	0.10	0.11	5.03	4.10	4.57	0.29	0.23	0.15	0.34	0.28	0.31
Level 4	0.10	0.08	0.09	4.52	3.69	4.11	0.24	0.20	0.12	0.31	0.25	0.28

4. Calculation Result

By referring to the above methodology and assumptions, the energy consumption of household sector is presented as follow:

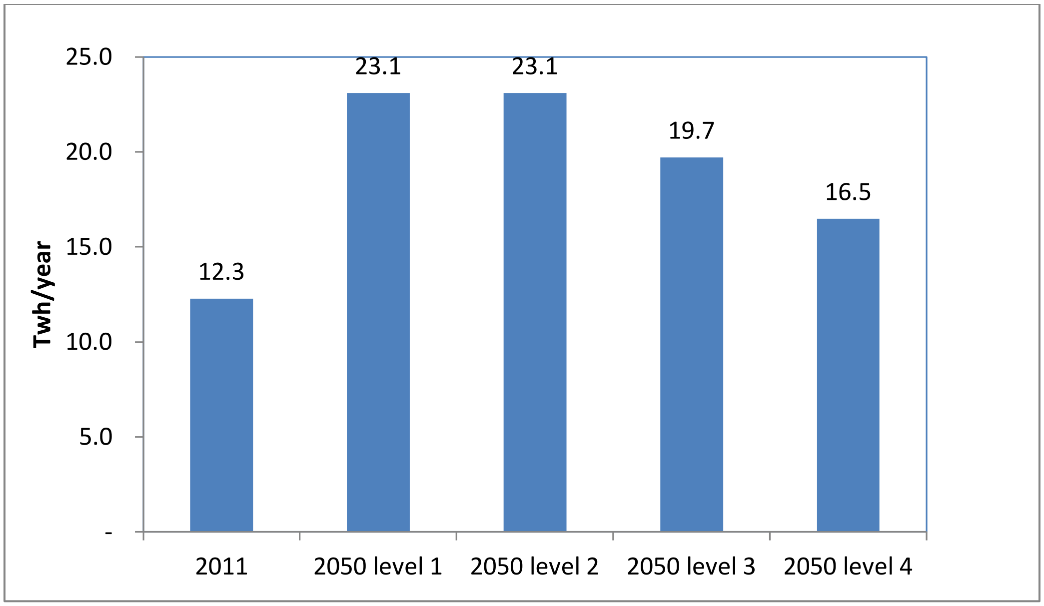


Figure 9 Household energy consumption for lighting

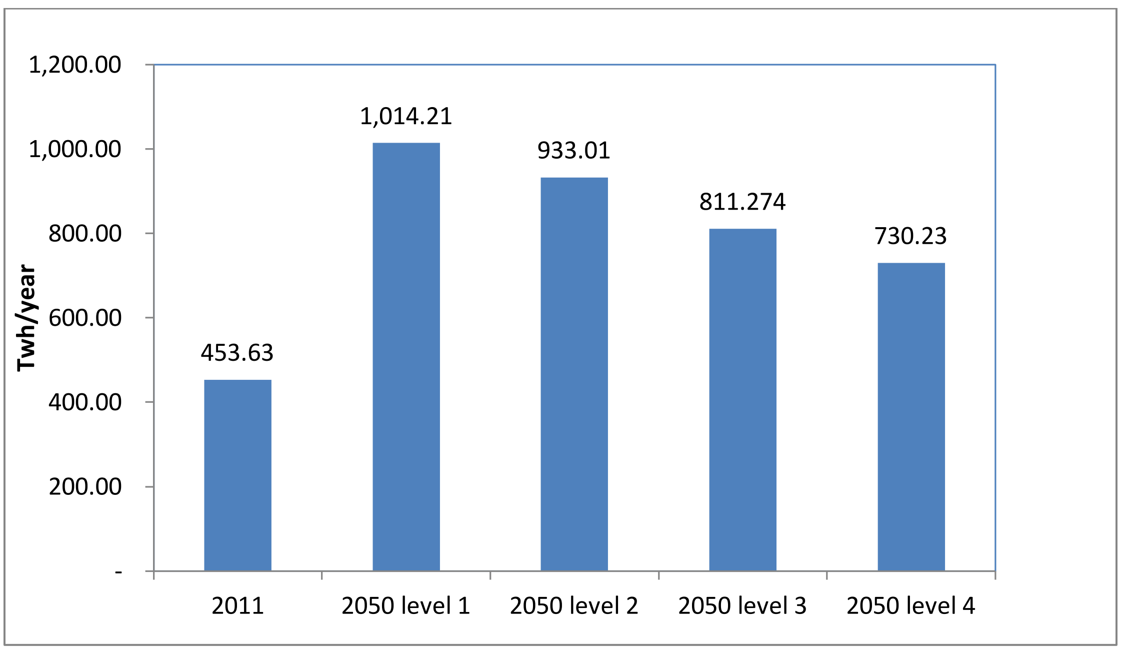


Figure 10 Household energy consumption for cooking

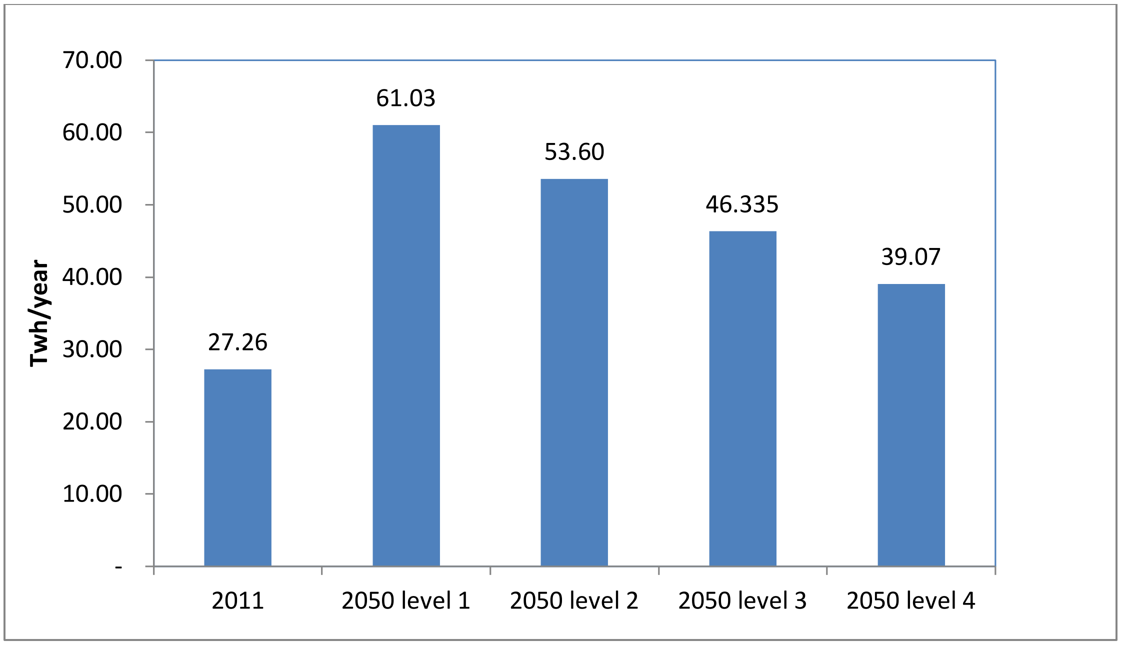


Figure 11 Household energy consumption for cooling

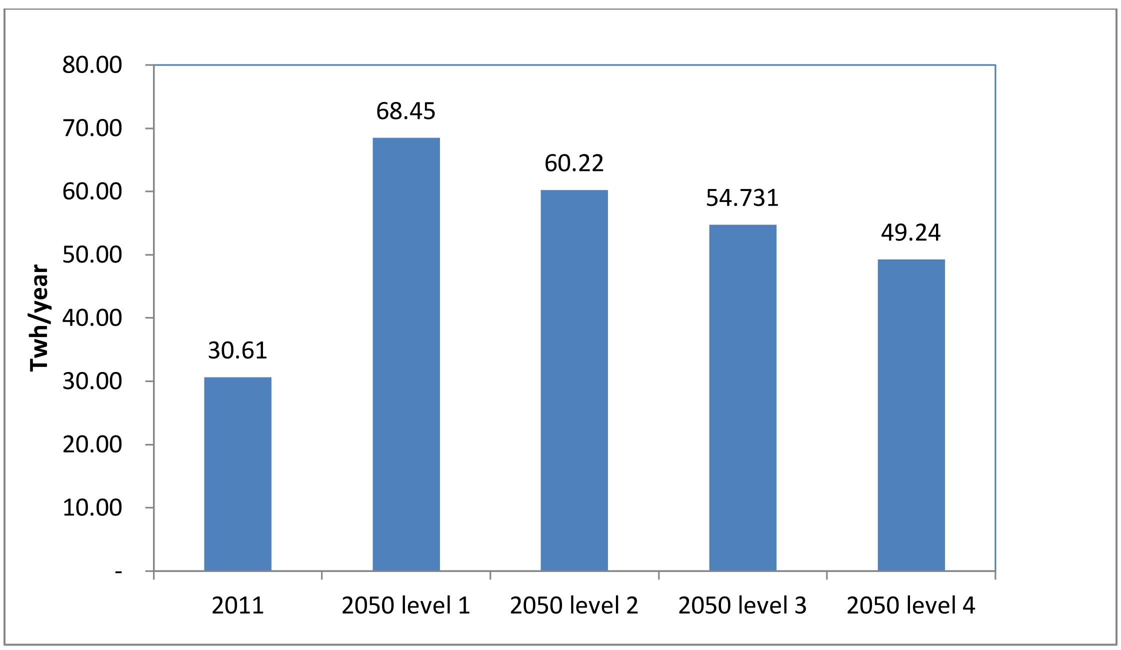


Figure 12 Household energy consumption for other appliances

5. Reference

1. Ministry of Energy and Mineral Resources (MEMR), *Handbook of Energy & Economic Statistics of Indonesia*. 2012.
2. Nuryanti and S.S. Herdinie, *The characteristic analysis of energy consumption in household sector*, in *National seminar III human resources of nuclear technology*. 2007: Yogyakarta.
3. Batih, H., *Improvement of Indonesia's Energy Security and Co2 Emission Reduction By Energy Conservation of Household Sector in Urbanized Area*, in *Joint Graduate School of Energy and Environment*. 2011, King Mongkuts University of Technology Thonburi, Bangkok, Thailand.
4. BPS, *Perkembangan Jumlah Penduduk dan Rumah Tangga*. 2014.
5. Ministry of Energy and Mineral Resources (MEMR), *Handbook of Energy and Economics Statistics of Indonesia*. 2005.
6. Ministry of Energy and Mineral Resources (MEMR), *Handbook of Energy and Economics Statistics of Indonesia.* 2009.
7. Core team modeler, *Core team modeler meeting*. 2014: Bandung.
8. Batih, H., *Improvement of Indonesia's Energy Security and Co2 Emission Reduction By Energy Conservation of Household Sector in Urbanized Area*, in *Joint Graduate School of Energy and Environment (JGSEE)*. 2013, King Mongkut's University of Technology Thonburi.
9. JICA, *JICA Study for Promoting Practical Demand Side Management in Indonesia*. 2011, PT. Energy Management Indonesia (Persero).
10. (Persero), P.P., *Satistik PLN 2012*. 2012.
11. KESDM, *Draft Peraturan Menteri Skem & Label Pengkondisi Udara dan Lemari Pendingin*. 2014, KESDM.
12. (NLB), T.N.L.B. *74% Market Penetration Predicted for White-Light LED*. 2015 15 January 2015].
13. Joint Graduate School of Energy and Environment, *Development of the 20-Year Energy Efficiency Development Plan for Thailand*. 2011, Joint Graduate School of Energy and Environment.
14. Wikipedia. *Variable Frequency Drive*. [cited 2015 22 January 2015]; Available from: http://en.wikipedia.org/wiki/Variable-frequency_drive.