Potency of energy saving and emission reduction from lighting system in residential sector of Indonesia

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Abstract. The Government of Indonesia (GoI) has a strong commitment to the target of decreasing energy intensity and reducing Greenhouse gas emissions. One of the significant solutions to reach the target is increasing energy efficiency in the lighting system in the residential sector. The objective of this paper is twofold, to estimate the potency of energy saving and emission reduction from lighting in the residential sector. Literature related to the lighting system in Indonesia has been reviewed to provide sufficient data for the estimation of the energy saving and emission reduction. The results show that the in the year 2016, a total of 95.33 TWh of nationally produced electricity is used in the residential sector. This is equal to 44% of total produced electricity. The number of costumers is 64.78 million houses. The average number of lamps and average wattage of lamps used in Indonesia are 8.35 points and 13.8 W, respectively. The number of lighting and percentage of electricity used for lighting in the residential sector in Indonesia are 20.03 TWh (21.02 %) and 497 million lamps, respectively. The projection shows that in the year 2026 the total energy for lighting and number of lamps in the residential sector are 25.05 TWh and 619 million, respectively. By promoting the present technology of high efficient lamps (LED), the potency of energy saving and emission reduction in 2026 are 2.6 TWh and 2.1 million tons CO_{2eq}, respectively.

1. Introduction

The Government of Indonesia (GoI) has a strong commitment to reducing energy elasticity and emission reduction [1]. In the energy elasticity, the GoI has released a target on reducing the value of energy elasticity from the value of 1.54 in the year 2015 to 1.1, 1.04, and to 0.71 in the year 2020, 2025 and 2030, respectively. In the emission reduction, Indonesia has released its target on reducing Greenhouse gas (GHG) emission by 26% from condition Business as usual (BAU) using own budget and up to 41% with support from international by 2020 [2]. The new target is released in 2016 with a target emission reduction up to 29% from BAU by 2030 [3]. The targets on energy elasticity and emission reduction targets can be reached by penetrating energy efficient technologies in all sectors. One of the potential sectors of implementation high efficient technology is electricity consumption in the residential sector. The electricity in residential typically used to power lighting, air conditioning system, entertainment, laundry, and others. In this study, the author focuses on the energy saving and emission reduction from residential sector in Indonesia.

Study on the electricity consumption in the residential sector and its relation to energy saving and GHG emission has come under scrutiny in recent years. Liao et al. [4] reported their study on the

forecasting residential electricity demand in provincial China. The results showed that growth rates are different in the developed and the less developed provinces. In the developed one will slow down and fast growing in the less developed provinces. Hu et al. [5] reported their survey on the energy consumption and energy usage behavior of households and residential building in urban China. The results show that the average electricity consumption of the urban residential building is 1690 kWh per year per household in the year 2015 and it continuous to grow as home electronics become more widespread and the demand for higher quality of life increases. The characteristics of the urban residential building in China are steady growth in size and energy consumption of the buildings associated with rapid urbanization, decentralized and individual equipment with diversified energy usage behavior. Harris et al. [6] reported residential emissions reductions through the variable timing of electricity consumption. Locational Marginal Price Emissions Estimated Method (LEEM), a real-time electricity emission estimating tool, is used in the study area of Michigan, USA. The result showed that theoretically 21-35% annually emission reduction can be reached. Nilsson et al. [7] assessed the impact of real-time price visualization on residential electricity consumption, cost, and carbon emissions. The test was performed in Swedish using 12 households as a sample. The results suggest that, on average, the test household shifted roughly 5% of their total daily electricity consumption from peak hours (of high electricity price) to off-peak hours (of low electricity price) as an effort of real-time price visualization. Boogen [8] estimated the potential for electricity savings in households in Swiss. The finding was an average inefficiency in electricity use by Swiss households of around 20 to 25%. The bottom-up economic-engineering models estimated the potential in Switzerland to be around 15%.

The above literature shows the characteristics and saving potency of electricity in households in general. Several researchers have reported their work in electricity consumption in specific for lighting in residential. Ahemen et al. [9] reported a survey of the power supply and lighting patterns in North Central Nigeria as well as the energy saving potentials through efficient lighting systems. It was reported that the major electric lighting source is the 60W and 100W incandescent bulbs, but a significant population uses both incandescent and energy efficient lamps CFLs. About 70% of power generated in Nigeria or equal to annual USD 4.98 billion can be saved if efficient lighting source such as CFLs and solid-state lighting are urgently adapted. Khorasanizadeh et al. [10] reported their study on energy and economic benefits of LED adoption in Malaysia. It was reported that majority of residential lamps in Malaysia are incandescent lamps. By replacement of incandescent with LED, a significant reduction in annual energy use, electricity bill, CO2 and other GHG emissions can be accomplished by each household in Malaysia. It was suggested government provide financial support and regulation on assisting in adopting the efficient technology penetration. In specific in Indonesia case, Batih and Sorapipatana [11] surveyed seven big cities in Indonesia to explore characteristics of urban households' electrical energy consumption and its saving potentials. It was shown that the electricity consumption in the houses in those seven big cities varies from 13.83% to 19.98% and depend on the income.

The above literature shows that there is no study reported the saving potency and emission reduction from lighting system in the residential sector of Indonesia. This paper attempts to explore the potency of energy saving and emission reduction from the lighting system in the residential sector in Indonesia. Also, the characteristics of lamps, electrical energy consumption as well as the projections are investigated. The objective is twofold, to estimate the potency of energy saving and emission reduction from lighting in the residential sector. The results are expected to supply the necessary information in the development of a friendly city.

2. Method

As a note, there are several projects related to lighting have been executed in Indonesia by Ministry of Energy and Mineral Resources of Indonesia in collaboration with international agencies. Those projects include ASIAN SHINE, Pilot LED project, UNEP en. Lighten initiative, etc. Several surveys have been conducted by those projects. The data from those surveys will be used in this study. Data of the

electricity consumption and number of residential that use electricity will be drawn from government owned electricity company (PLN).

The total electricity consumption (E) by lamps in household sector is calculated by using the following equation:

$$E = N\sum_{i=1}^{n} L_i P_i t \quad (1)$$

Where, N is number of households, L number of lamps at capacity of i, P [Watt] is the capacity of lamp and t [hours] the average operational lamp operated in a year. As a note, percent shares of accumulative high efficiency appliances, includes lamps, usually follows S-curve logistic function. The percent share of high efficient technology varies as a function of time and denoted by $PH(y)$. The equation to calculate the percent share is given by

$$PH(y) = \frac{1}{1 + a \times e^{-b \times y}} \quad (2)$$

Where y is time in year, a and b are the coefficient of the logistic function. Since, there is no report on implementation of high efficient appliance, Batih and Sorapipatana [11] suggested to use Thailand experience. Thus, the coefficient $a = 46.51$ and $b = 0.31$ are used.

3. Results and Discussions

3.1. Indonesian Electricity

In Indonesia, electricity can only be sold to the costumers by government-owned electricity company named as PLN. On the other hand, the electricity can be produced by PLN power generation and also the private sector, Independent power producers. The sold electricity by PLN to costumers in the last five years has been growing 8.1% per year. The average number of customer in every year is 3.5 million new costumers per year. As a note, the total electricity sold by PLN in the year 2015 was 202.84 TWh.

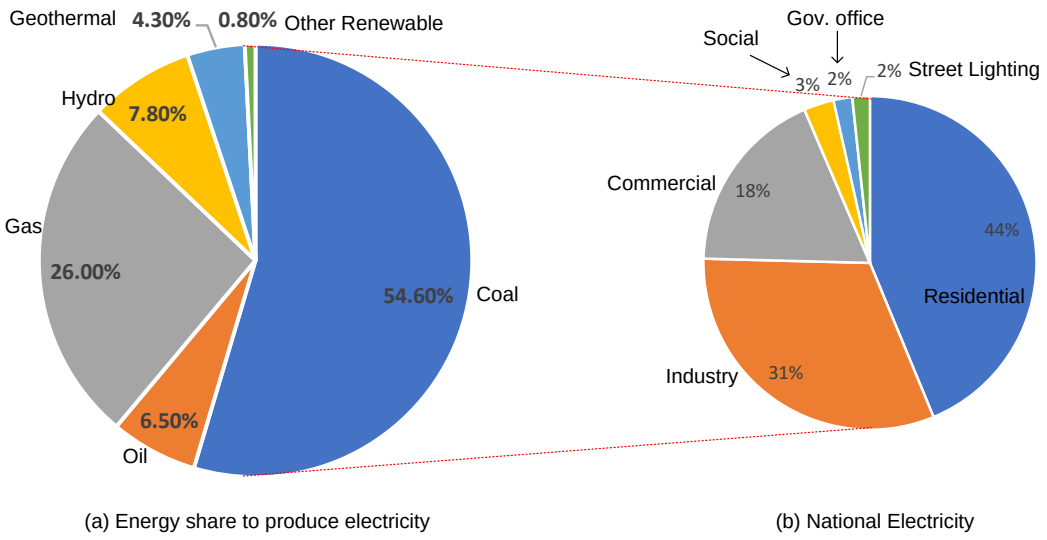

Figure 1 National electricity consumption and urban electricity consumption in the year 2015

Figure 1a shows the source of energy used to produce electricity in the year 2015. The figure shows that the main energy source is coal (54.60%) and followed by gas (26%) and hydro (7.8%). It can be seen clearly that the oil fuel is only 6.5% due to the regulation released the government that oil should

be used for the transportation sector. The oil consumption only for power generation in the remote area or needed additional power. The figure reveals that the renewable energies contribute 12.9% in producing electricity in the year 2015. Based on this energy resource the emission factor is calculated. The result reveals that emission factor of the electricity generation in 2015 is 0.808 tons CO2eq/MWh. It means for each MWh of electricity produced, 0.808 tons of CO2eq is emitted to the atmosphere.

Figure 1b shows the consumers of the electricity sold. The figure shows that the electricity consumers in Indonesia are divided into residential, industry, commercial, social, government office, and street lighting. The figure shows that the biggest consumer is the residential sector. This sector consumes up to 44% percent of the electricity produced and followed by industrial and commercial sectors with consumption of 31% and 18%, respectively. The social buildings, government office, and street lighting consume the electricity 3%, 1.8%, and 1.6%, respectively. This fact suggests that the residential sector will give significant impact on energy saving and emission reduction. This is because it consumes significant electric energy.

Figure 2 shows history and projection of electricity consumption and the number of costumer in the residential sector in Indonesia. The history of electricity consumption during 2008 to 2016 shows significant growth. The average growth is 8.3% annually. This growth is bigger the growth of national electricity consumption. The number of costumer in the residential sector is also shown in the figure. The average growth of costumer in the residential sector is 6.5% annually. The specific energy consumption for each household increased from 1393 kWh/household/year in 2008 to 1601 kWh/household/kWh in 2016. The average growth of the specific energy consumption is 1.7% yearly. This is because increasing the number of home appliances and quality life in Indonesia. In comparison with another study [5], the specific energy consumption in the household in Indonesia is lower than in China. In the year 2015, the specific energy consumption in the household in China is 1690 kWh per household per year. The projection of the energy in the residential sector and the number of costomers are also shown in Figure 2. The figure shows that the energy consumption will grow from 95.33 TWh in 2016 to 189.23 TWh in 2026. At the same time, the customer will grow from 59.5 million to 74.1 million.

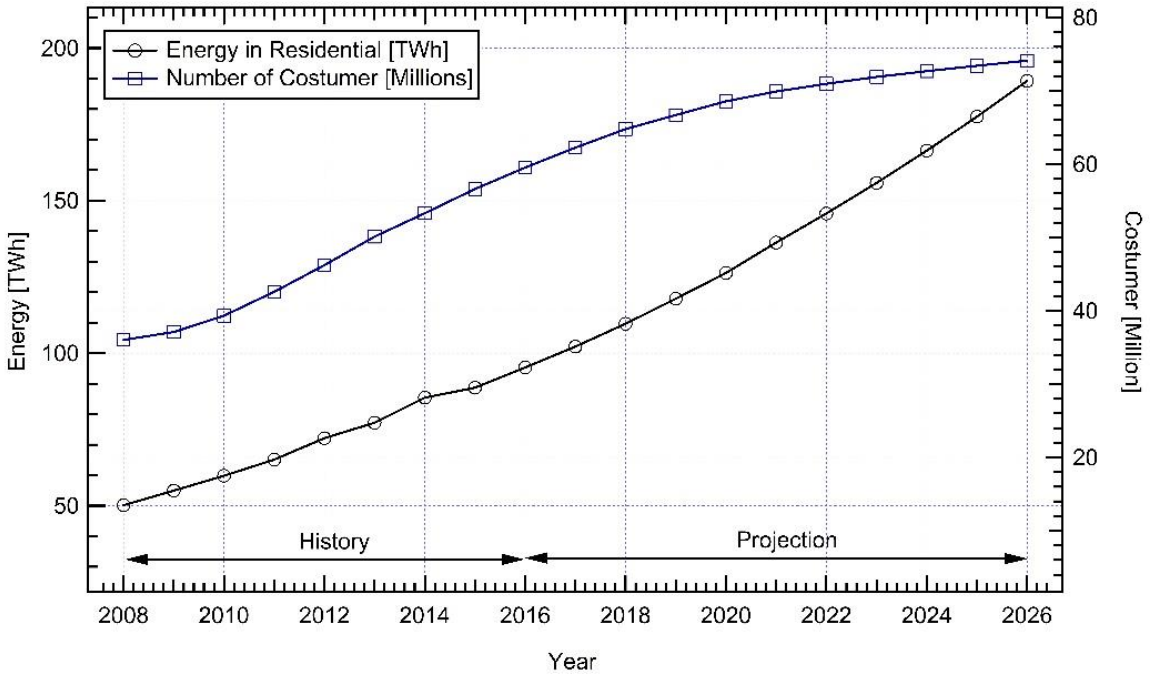

Figure 2. History and projection electricity consumption and costumer in residential sector

3.2. Energy for lighting in residential sector

Literature related to the lighting system in Indonesia has been reviewed to provide sufficient data for the estimation of the energy saving and emission reduction. The surveys were performed by ASIAN SHINE in 2015. The average lighting point per house in Indonesia is 8.35. The majority of lamps found in Indonesia market is CFL. Typical distribution of lamps found in Indonesia is presented in Figure 3. The figure shows that 8 W lamp is the most used lamps in the residential sector it is 15%. Followed by 5W, 14W, and 18W. The average wattage of lamps used in Indonesia is 13.8 W.

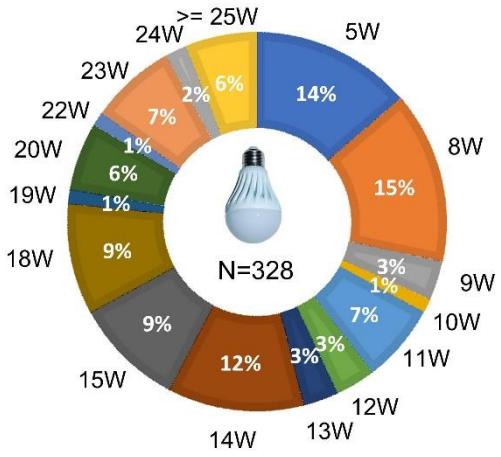

Figure 3 Lamps found in Indonesia market

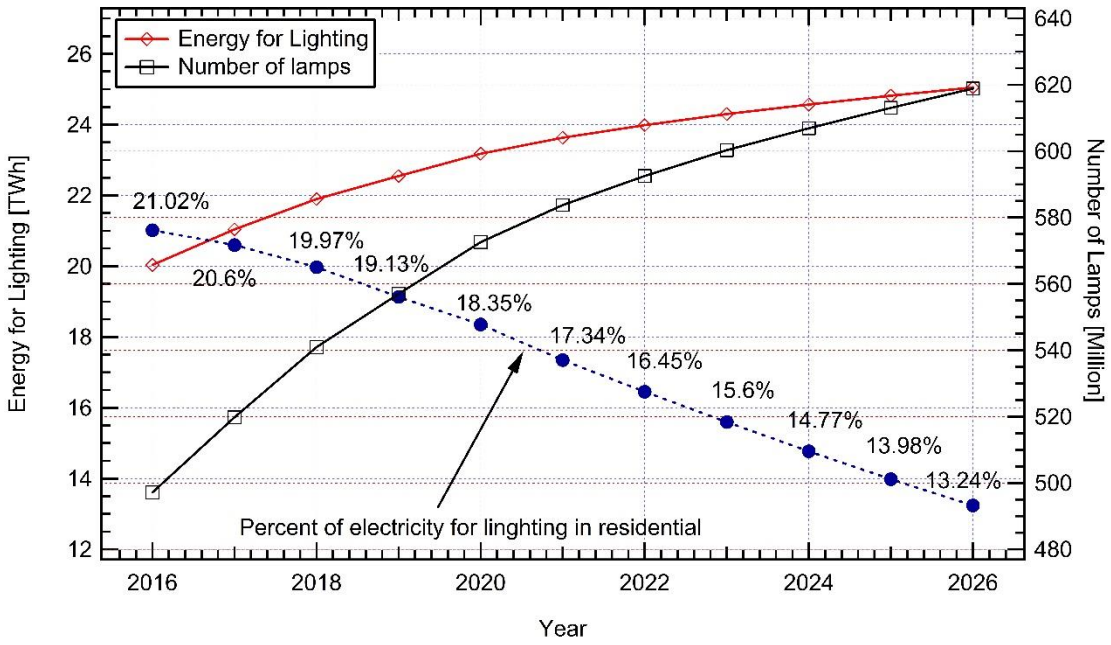

Figure 4. National electricity consumption and urban

By using those data presented in the above paragraph, the total electrical energy used for lighting in Indonesia is calculated using equation (1), and the results are presented in Figure 4. The figure shows

that the energy for the lighting system in Indonesia will grow from 20.03 TWh in 2016 to 25.05 TWh in the year 2026. The number of lamps also will grow from 497 million in 2016 to 616 million in 2026. The percentage of electricity for lighting in the residential sector is also shown in the figure. It can be seen, the percentage of electricity in the household will decrease from 21.02% to only 13.24% in 2026. The study reported by Batih and Sorapipatana [11] revealed that electricity for the household in the biggest city in Indonesia varies from 13.83% to 19.98% and depend on the income. The present finding shows a good agreement with the previous finding. In this study, all household in the urban and remote area are counted. In the previous study [11] only households in the urban area were counted. This suggests that in the next year, the percent of the electricity for lighting decrease as time increase. This is because the energy consumption of household will be dominated by other appliance such as air conditioning system, refrigerator, etc as income increases.

3.3. Energy Saving and Emission reduction from lighting in Indonesia

As a note, the objective of this work is to estimate the potency of energy saving and emission reduction from lighting in the residential sector. The above results will be used to estimate energy saving in the lighting system in the residential sector. Several assumptions are made. The first assumption is that all of the lamps in service no in the residential sector is CFL lamps. This is a very gentle assumption. In fact, the incandescent lamps and even a lower efficiency lamps are still found in service in the households in Indonesia. The bigger energy saving can be reached. But those lamps below the CFLs are not taken into consideration. The second assumption is the average percentage saving by retrofitting from CFL to LED is 40%. The present CFLs efficiency varies from 50 to 70 lumen/Watt. On the other hand, the present technology for LED in Indonesia market varies from 90 to 110 lumen/Watt. By using the average value, replacing CFL to LED, the energy saving of 40% can be reached. The third assumption is that LED lamps now in service are not taken into account. By using those assumptions, and it starts from 2018, the penetration of LED lamps and energy saving are shown in Table 1. The table shows that the penetration ratio in percent increase from 2.85% in the year 2018 to 5.17% in 2020 and 25.93% in the year 2026. The number of LED lamps in service will start with 2.85 million lamps in 2018 increase to 160 million of LEDs in service in residential in 2026. It is suggested the government support local manufacture to supply this number of LED lamps. By installing the LEDs and replacing the lower efficiency lamps, significant energy savings will be gained. The energy saving in 2018 is 0.25 TWh will grow to 0.48 TWh in 2020. At the end of 2026, the energy saving will be 2.6 TWh.

Table 1. Penetration of LED lamps in residential sector in in Indonesia

Parameter	Year								
	2018	2019	2020	2021	2022	2023	2024	2025	2026
Percent penetration [%]	2.85	3.84	5.17	6.92	9.20	12.14	15.85	20.43	25.93
LED lamps in service [million]	15	21	30	40	55	73	96	125	160
Energy saving [TWh]	0.25	0.35	0.48	0.65	0.88	1.18	1.56	2.03	2.60
GHG emission reduction [million tons CO_{2eq}]	0.20	0.28	0.39	0.53	0.71	0.95	1.26	1.64	2.10

Figure 5 shows the Business as usual (BAU) energy consumption from lighting system and energy consumption after technology intervention. It can be seen that the BAU energy consumption will grow to 25 TWh in the year 2026. By extracting the total energy saving from the BAU, the total energy consumption from lighting is plotted. The figure shows that the technology penetration will affect the energy consumption. The energy consumption will grow by the year 2021. The growth will decrease from 3.75% per year in 2018 and almost 0 in the year 2023 and become negative after 2023. Since the growth is negative, the energy consumption will be decreased since the year 2023. This fact is shown in the figure.

By using the total energy saving, GHGs emission can be estimated. As a note, the emission factor of 0.808 tons CO2eq/MWh is used for all calculation. Even though this factor is released by PLN for the year 2015, during the projection, the emission factor is assumed to be constant.

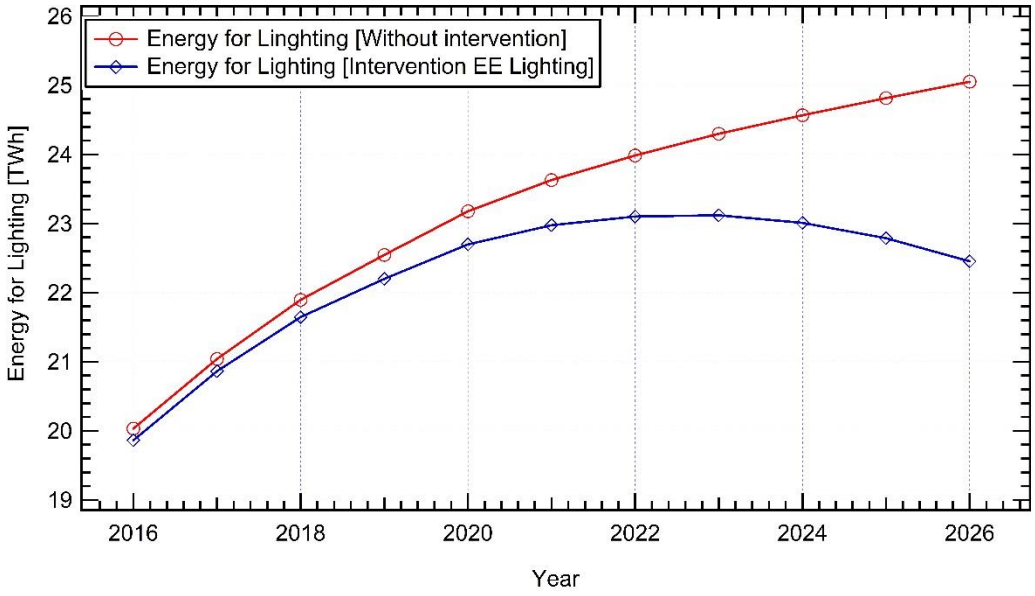

Figure 5. National electricity consumption and urban

4. Conclusions

The characteristic of the electricity for the lighting system in the residential sector of Indonesia has been investigated. Using the data, the potency of the energy saving and emission reduction from the lighting system have been estimated. The conclusions can be drawn here are as follows. The residential sector is the major consumer of national electricity. In the year 2015, it is up to 44%. The electricity in this sector consumed by lighting system up to 21.03% in the year 2016. The percentage of electricity consumption for lighting decreases as time increases. In the year 2026, only 13.24% of the electricity in residential goes to the lighting system. By using technology intervention since 2017 the potency of energy saving in 2026 is 2.6 TWh or 10% from the energy consumption in the same year. The potency of emission reduction is 2.1 million tons CO2eq in the year 2026. The energy saving and emission reduction will grow significantly after 2026.

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