Energy efficiency effect on the public street lighting by using LED light replacement and kwh-meter installation at DKI Jakarta Province, Indonesia

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Abstract. Public street lighting consumes large energy for the public interest, but many street lights still do not use energy-saving technologies. In 2014, Provincial Government of DKI Jakarta operated 179,305 units of street lights. Of the number of installed armature, 92 % of them or 166,441 units are HPS (High-Pressure Sodium) armatures which are inefficient. In 2016, the Provincial Government of DKI Jakarta cut down the energy used for street lighting, by implementing the programs of kWh-meter installation in every street lighting panel and use energy-saving lamps equipped with the smart system. The Provincial Government of DKI Jakarta is registered with 6,399 customer IDs in PLN (State Owned Electric Company), and gradually carried out the kWh Meter installation and changes to the contract. The program to use energy-saving lights done by replacing the HPS armature that is not energy efficient to LED armature which is known to be energy efficient. Until the end of 2016, the number of armatures that has been replaced was 89,417 units.

The research results on 25 samples of PLN customer IDs and the replacement of 2,162 units armature, showed that the energy efficiency through kWh meter installation and armature replacement reduce the power consumption from 330,414 kWh to 71,278 kWh or by 78.43%. Generally, there was a decrease in the value of electricity bill compared to the before the replacement. The program of kWh-meter installations and replacement of the armature has a payback period of 2.66 years.

1. Introduction

Public street lighting is street lighting was installed for public interest / shared/is public (www.pln.co.id) Electrical energy sold to public street lighting nationally in 2015 of 3,448.11 GWh with of its installed capacity 1,003.91 MVA (1). Most of the public street lighting lamps installed still use HPS lamps that are not energy efficient (2).

The research of energy saving on street lighting has been done in various places. The various scenario of energy saving in the street lighting has been developed, such us the use of energy saving lamps and the use of the smart system (2,3). In the scale of the pilot project was conducted to determine out the capabilities of LED lamps to replace HPS lamps as street lighting lamps (4–7). In
the other studies has been considering financing scheme that can be done by local government, such us the scheme of ESCO (Energy Service Company)(2,8,9).

This paper, to evaluate the energy efficiency on the street lighting systems by using energy saving lamps and kWh-meter installation at Jakarta. This study based on actual condition of the streets lighting at Jakarta that are currently implemented the program.

Moreover, The Jakarta government follow up the energy-saving program by issuing the Governor Regulation of Jakarta no. 156 the year 2012 about energy saving and water, as for accompanying the implementation of the energy saving and water in Jakarta administration. The regulation it arranged also about the step of electric energy saving in the field of street lighting in accordance with the Minister Energy and Mineral Resources Regulation no. 13 years 2012 about Saving Discharging Electric power namely reduce the power used for street lighting of 50 % in 24 hours up to 5.30 am(10,11).

Provincial Government of DKI Jakarta currently listed as customer category public street lighting in PLN Jakarta Raya and Tangerang. Based on the data PLN 2015, PLN Jakarta Raya and Tangerang recorded customers category street lighting as many as 10,028 connection with a capacity attached 130.59 MVA and energy sold 466.90 GWh worth USD 50,860,328.68\(^1\). If Provincial Government of DKI Jakarta able to perform of electric energy saving in street lighting then there will be the very significant saving, both at the energy consumption and the costs of an electricity bill.

Energy saving programs in street lighting can be done with various strategies, but there are three main strategies that can be implemented namely kWh-meter installation, use energy-saving lamps are equipped with smart system (12,13), which is currently the three step was implemented by the Provincial Government of DKI Jakarta gradually.

1.1. kWh-meter Installation

The installation of kWh-meter to be done at every panel of street lighting and so that the power consumption will be measured. At this time, for the payment of street lighting accounts much of local Government that enforces contract subscription or lump sum without using the kWh-meters. Electricity bill based on the number of lamps installed without kWh meter or un-metered.

In the contract, the lights assumed on 12 hours from hours 6 pm to 6 am for 30 days and assumed as 375 hours. So such as fitted mercury lamps with a capacity of 70 W will be calculated with a capacity of 200 VA and use in 375 an hour a month regardless the condition of the field. So with these contracts, local governments are reluctant to undertake energy efficiency, because even by using the energy-saving light bulb, the cost of electricity bills paid will remain, or absence of tangible benefits for local government.
Table 1. The Classification of The Power Lights on The Street Lighting In Unmetered Tariff

| No. | Lamps type       | Power load (W) | Power load at Bill (VA) |
|-----|------------------|----------------|-------------------------|
| 1.  | Incandescent lamps | 25 – 50        | 50                      |
|     |                  | 51 – 100        | 100                     |
|     |                  | 101 – 200       | 200                     |
|     |                  | 201 – 300       | 300                     |
|     |                  | 301 – 400       | 400                     |
|     |                  | 401 – 500       | 500                     |
|     |                  | 501 – 600       | 600                     |
|     |                  | 601– 700        | 700                     |
|     |                  | 701 – 800       | 800                     |
|     |                  | 801 – 900       | 900                     |
|     |                  | 901 – 1000      | 1000                    |
| 2.  | Gas discharge lamps | 10 – 50        | 100                     |
|     |                  | 51 – 100        | 200                     |
|     |                  | 101 – 250       | 500                     |
|     |                  | 251 – 500       | 1000                    |

1 USD stands for United States Dollars. This research uses exchange rate assumption 1 USD for IDR 13,600.

Therefore, necessary to change the contract and kWh-meter installation, so the number of used measurable and the fee for according to the power usage. The process kWh-meter installation, local governments are required to provide network, panel, time switches, and contactor.

1.2. Use of Energy Saving Lamps

Currently, street lighting lamps commonly use HID (High-intensity discharge) technology type of HPS (High-pressure sodium). This type of lamps produces a yellow light colour, long lifetime 12,000 – 24,000 hours or 2.5 – 5 years, with efficacy at 45 – 130 lm/watt. Currently, HPS lamp technology was mature, so likely to develop no longer significant.

Technology that is currently developing is led light, this type of lights start widely adopted for street lighting. Led lamps have high energy efficiency and the high quality of light. Led light having longer lifetime, 50,000 - 100,000 hours and high efficacy 70 - 150 lm / w.

From a comparison between the HPS lamps and LED lamps for street lighting, HPS lamps can be replaced with LED lamps and can meet the standard set forth (5,6). Jakarta has done the installation of LED lamps in some location, the lighting in the road surface have met SNI (6).

1.3. Smart System

Without the smart system, then the local government will turn off the 1 light between 2 lights, as happened in Jakarta Outer Ring Road (JOR) (12). To be able to turn off the light, then local governments must prepare two networks in a single line, so it requires considerable investment.

The smart system itself is a combination of several types of equipment such as a sensor, lighting fixture, transceiver, measurement and power meter, and some other equipment so that it allows automatic control (14). The lighting of the city which features smart system will be able to control the lighting system at the time of peak hours or times of weather disturbances occur, so will eventually accrue to the energy savings.
2. Research Methodology
The data used in this research is the data on street lighting electricity bills 2016 and data armature replacement 2016.

2.1. Data Analysis
Energy efficiency obtained by comparing data the electric bill before and after the electricity saving programs done. So that would be needed two data electricity bills that in pairs, before and after the electricity saving programs done. With the availability of the data, it can be done statistical tests are t-test: paired two sample for means.

\[ T_0 = \frac{\bar{D} - \Delta_0}{S_D / \sqrt{n}} \]  
(1)

Where:
- \( \bar{D} \): The average of the difference between the sample of observed
- \( \Delta_0 \): The average difference in the population under null hypothesis
- \( S_D \): Standard deviation
- \( n \): Number of samples

2.2. Economic analysis
Economic analysis is used to determine a project feasible or not. The feasibility an investment one of which can be seen from payback period. Payback period is calculated by dividing the total cost of the investment by the savings that occur every year, so it will be known how long will start to get profits from this program. The expected payback period of time equal to or less than the time of product warranty (4,5).

\[ Payback \ period = \frac{C}{R} \]  
(2)

Where:
- \( C \) (Cost): Total cost
- \( R \) (Revenue): Revenue or annual saving

3. Research Result
In 2014, Provincial Government of DKI Jakarta, through the Industry and Energy Agency of the DKI Jakarta operated 179,305 units street lighting lamp in 5 areas of the city administration. The lights still dominated the HPS lamp, which reaches 92% of total the installed lamps, whereas the LED lamp, known as energy-saving lamps only 1.5% of the total the installed lamps.
The programs of kWh meter installation and the lamps replacement with energy saving lamps are done simultaneously, so hopefully it is a significant energy saving. HPS lamps are inefficient replaced with LED lamps that are efficient, E.g. 400 W HPS lamps replaced with LED lamps at maximum 200 W, without reducing the quality of street lighting. Comparison of the specification of the new lamps and old lamps used by Government of DKI Jakarta can be seen Table 2.

In 2016, the Provincial Government of DKI Jakarta carries out kWh meter installation and armature replacement from HPS to LED and until the end of 2016 was installed 89,417 LED lamps. Electricity consumption between un-metered with HPS lamps and metered with LED lamps can be seen in Table 3.

**Table 2.** Comparison of Old Armature and New Armature According to The Road Class

| Parameter          | Arterial road | Collector road | Local Road | Narrow street |
|--------------------|---------------|----------------|------------|---------------|
|                    | Old | New | Old | New | Old | New | Old | New | Old | New |
| Type               | HPS | LED | HPS | LED | HPS | LED | HPS | LED | HPS | LED |
| Power (W)          | 400 | 200 | 250 | 120 | 150 | 40  | 70  | 40  | 70  | 40  |
| Lumen (Lm)         | 48,000 | 20,600 | 25,000 | 13,100 | 15,000 | 90  | 70  | 40  | 70  | 40  |
| Color Temperature (K) | 2,000 | 4,000 | 2,000 | 4,000 | 2,000 | 4,000 | 2,000 | 4,000 |
| Price (USD$)       | 220.59 | 713.38 | 202.21 | 558.82 | 154.41 | 481.18 | 71.91 | 441.18 |

**Table 3.** Data Sample Electricity Consumption Between Un-Metered with HPS Lamps and Metered with LED Lamps

| No. | Customer ID | Power consumption (kWh) | January 2016 | January 2017 |
|-----|-------------|-------------------------|--------------|--------------|
| 1   | 541102453623 | 19.875                  | 2.193        |
| 2   | 541300481235 | 19.875                  | 4.731        |
| 3   | 543104591133 | 12.375                  | 4.950        |
| 4   | 543600109454 | 8.625                   | 2.395        |
| 5   | 543600564608 | 12.375                  | 1.364        |
Table 3 shows the data customer ID who experienced activities kWh meter installation and lamp replacement. From 6,399 customer ID listed in PLN, there are 25 customer ID who experienced activities kWh meter installation and lamp replacement, sample available 25 samples, the amount would be adequate as a sample.

Further analysis conducted an analysis of t-test: Paired two sample for means by using Microsoft Excel 2013. The result of t-test: Paired two sample for means with 25 sample and the α value = 0.5, retrieved the \( t_0 = 11.40727 \), and the \( p \)-value \( 1.77 \times 10^{-11} \). With the value of \( t_{0.05, 25} = 1.708141 \), then the \( t_0 = 11.40727 > 1.708141 \), can be concluded that by kWh meter installation and lamp replacement occurs of difference value of electric power consumption. Electricity consumption on average before kWh meter installation and lamp replacement higher than after kWh meter installation and lamp replacement.
Figure 2 shows a comparison of electric consumption in P3 tariff or subscriptions or without kWh meter by using HPS lamps with a P31 tariff or after kWh meter installation by using LED lamps. Figure 2, can be seen a happening trend of decline in the electrical power consumption on the entire sample. Decline overall power consumption of 330,414 kWh in January 2016 be 71,278 kWh in January 2017 or saving of 78.43 %. The saving is combined saving between kWh-meter installation and lamp replacement.

Cost efficiency obtained from efficiency electricity bill and maintenance cost before and after the energy saving programs. LED armature besides reducing their electricity bill also reduce maintenance cost. LED armature different with HPS armature, where HPS armature consisting of many components that should be replaced periodically.

Table 4. Kwh Meter Installation and Armature Replacement

| No. | Description                  | Volume | Unit price (USD) | cost (USD)   |
|-----|------------------------------|--------|------------------|--------------|
| 1.  | KWh meter installation       |        |                  |              |
|     | Cable (25 location @20m)     | 500    | 183.82           | 4,595.59     |
| 2.  | LED armature installment     |        |                  |              |
|     | LED 40 Watt                  | 1,120  | 441.18           | 494,117.65   |
|     | LED 90 Watt                  | 670    | 481.18           | 322,388.24   |
|     | LED 120 Watt                 | 64     | 558.82           | 35,764.71    |
|     | LED 200 Watt                 | 308    | 713.38           | 219,721.76   |
| 3.  | SS installment               |        |                  |              |
|     | Controller                   | 25     | 177.94           | 4,448.53     |
|     | Total                        |        |                  | 1,081,036.48 |

The cost to the Provincial Government of DKI Jakarta of kWh meter installation is a cable from substation heading the street lighting panel, because the whole customer's ID registered have installed
street lighting panel. While the cost of replacing the armature in form of the cost of purchasing the armature units. In full can be seen in Table 4.

From Table 5 can be seen the value of the cost-saving electricity bill must be paid by the government. That value is monthly saving on 25 samples so that annual saving obtained is USD 322,355.66. The value of the saving comes from 25 samples from total 6,399 customers ID.

| No | Area         | Power consumption (kWh) | Power efficiency (kWh) | Cost efficiencya (USD) |
|----|--------------|-------------------------|------------------------|------------------------|
| 1  | Central Jakarta | 39,750                  | 6,924                  | 32,826                 | 3,402.86               |
| 2  | South Jakarta | 290,664                 | 64,354                 | 226,310                | 23,460.11              |
|    | Total        | 330,414                 | 71,278                 | 259,136                | 26,862.97              |

*) Electricity rates on the average year 2016: USD 0.10 / kWh

In addition, from Figure 3, can be seen the value of saving from the reduced cost of replacing a component of an HPS armature USD 81,815.52 per year, because LED armature unit replacement will be performed in the case of damage. This is one of the weaknesses of the LED armature, because the replacement units needing high cost, while in HPS armature to be done component replacement at a low cost.

Cost saving obtained from HPS armature component replacement USD 81,815.52, and reduced from electricity bill USD 322,355.66, with investment USD 1,076,440.88 obtained the payback period 2.66 year.

4. Discussion

The program kWh meter installation and armature replacement conducted by Provincial Government of DKI Jakarta is able to save 78.43 % power used. Currently, there still 5,102 customer ID without kWh meter or unmetered, with potential saving 3,790,192 kWh.

Payback periods of this programs are 2.66 years when compared with warranty offered by the provider of 5 years, then it can be said this program very reasonable to run. Currently, in South Jakarta and Central Jakarta, the HPS armature have been replaced with LED armature, but not all connected with metered panels, that has not been registered saving electric power. So should be driven the acceleration of the kWh meter installation program so that power saving and costs saving will be can be perceived.
While energy efficiency through dimming using a smart system until now not been made by Provincial Government of DKI Jakarta. This is due to the implementation still need further study, the associated location, so it doesn’t reduce the security and convenience of the society in the work during the night.

5. Conclusions
Energy efficiency of street lighting through kWh meter installation and armature replacement saving 78.43 % power consumption.
Generally, occurs a reduction in the value electricity bills than before energy saving programs. If compared to the investment value, payback period obtained kWh meter installation activities and armature replacement with a payback period of 2.66 years.

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