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Exploring Alternative Policies to Reduce Electricity Subsidies in Indonesia

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Abstract. Electricity subsidies in Indonesia remain high and tend to increase. Existing studies generally propose electricity subsidy reform through economic price adjustment; however, this option potentially arises political and social conflicts. The government and the State Electricity Company have also undertaken several measures to decrease electricity supply costs but those measures remain ineffective due to increasing energy prices needed as fuels for power generations. Our study analyses the effectiveness of two alternative grants for LED lamps and rooftop photovoltaic (PV), to reduce electricity subsidies for low-income residential customers with 450 VA and 900 VA electricity capacity limits. The analysis result is that replacing existing lamps with LED lamps for all those customers will cost the government US\$ 313.7 million but potentially decrease electricity subsidies to US\$ 208.7 million/ year for 15 years. On the other hand, installing the rooftop PV system is ineffective to bring down the electricity subsidies. The investment cost of the on-grid rooftop PV system is between US\$ 827.6 and US\$ 1,310.3 per house, while the electricity subsidy savings for 20 years are between US\$ 724.1 and US\$ 744.8.

1 Introduction

Evenly distributed modern energy access, which is affordable, reliable, and sustainable for all people, has been the goal of sustainable development at the global level [1]. To ensure the affordability, developing countries generally provide energy subsidies. For example, electricity subsidies in Indonesia reached US\$ 6,980 million in 2013, but gradual electricity tariff adjustment for several categories of electricity customers brought down the subsidies to US\$ 3,900 million in 2015 [2]. In 2020, the government has allocated electricity subsidies of US\$ 3,778 million divided for various tariff categories [2]. Large shares of the electricity subsidies are allocated for low-income residential customers with tariff category of 450 VA (58.5%) and 900 VA (16.6%) [2]. The two groups on average receive electricity subsidies of US\$ 82.8 to 89.7 per household per year [2].

Increasing the electricity prices of the low-income households always cause political resistances. Alternative policies to reduce the electricity subsidy are through supply and demand sides. In supply side, the State-owned Electricity Company (PLN) may increase the efficiency of power plants, reduce transmission and distribution losses, and minimize the operation of power plants with high fuel costs such as oil-fuelled power plants. In the meantime, demand side policies aim to reduce electricity consumptions, such as through installing rooftop solar photovoltaic (PV) and using energy efficient

equipment. The objective of our study is to compare the feasibility of these two demand side policies in reducing the subsidies. We view that the declining PV prices could be an opportunity to provide low costs of electricity supply during PV lifespan (i.e., 20 years). As the second policy proposal, we evaluate the feasibility of light-emitting diode (LED) lamp grant that has lower costs, but gives smaller reductions of electricity subsidies.

To the best authors' knowledge, there have been no studies comparing the two policies as electricity subsidies reduction measures. Several studies have evaluated the feasibility of PV systems for other purposes, such rural electrification [3], agriculture [4], poverty alleviation policy [5], and emission reductions [6]. In contrast, LED lamp replacement has been recommended as an effective measure to reduce electricity subsidies in residential sector [7] and street lighting systems [8]. Therefore, our study contributes to literature by comparing the effectiveness of rooftop PV grants and LED lamp grants in reducing electricity subsidies.

2 Review of Electrical Subsidies and Rooftop PV

Reducing electricity subsidies in Indonesia is generally undertaken through electricity price adjustment. The price adjustments during 2013 to 2015 have effectively decreased the electricity subsidies. Several studies have estimated the impact of electricity prices on electricity

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demands in Indonesia. A 10% increase in electricity price will reduce residential electricity demands by anywhere between 0.5% and 2.4% [9]. The increase of electricity prices will also increase PLN's investment capacity, improve the economics of renewable energy, and reduce emissions.

However, the main factor affecting electricity demands is urbanization that a 1% increase in urbanization will increase electricity demands by 1.31% in residential sector, 3.03% in commercial sector, and 4.25% in industrial sector [10]. Urbanization is perceived identical to increased possession of appliances. Therefore, setting minimum energy performance standards (MEPS) for electrical appliances can be an effective policy to reduce electricity subsidies. Batih and Sorapipatana [11] recommended to prioritise MEPS mandatory in Indonesia on televisions, refrigerators, air conditioning, and lamps.

Households in Indonesia have generally used energy efficient lamps, i.e., compacted fluorescent lamps (CFLs) and LED lamps. In 2002 to 2008, MEMR and PLN promoted the uses of CFLs (including giving away CFLs) to reduce the uses of incandescent lamps [12]. In 2017, 70% of households did not use incandescent lamps anymore, but there were still 5% of households still using 100% incandescent lamps and 8% of households used incandescent lamps higher than 50% of the number of installed lamps [13].

Compared to CFLs, LED lamps have better efficiency, age, and colour rendering as well as less harmful substances [14]. The efficiency of LED lamps is 25% to 75% higher and the lighting level is still well maintained despite 4,000 hours of usages. In a market survey, Al Irsyad and Sasnofia [15] found that the light output of 9W LED lamps reaches 500 lumens, which was higher than light outputs of several 15W to 20W CFLs circulated in the market. IIEE [16] estimated that the replacement program of CFLs to LED lamps for HH 450 VA and HH 900 VA in North Sumatra – Indonesia could save energy at least 100 GWh/ year.

Apart from energy saving measures, utilizing renewable energy also potentially reduces electricity subsidies. Renewable energy has a relatively lower or zero fuel cost so it can reduce cost of electricity supply. In residential sector, the type of renewable energy that most commonly used is rooftop solar PV [17, 18]. The Ministry of Energy and Mineral Resources (MEMR) has encouraged the utilization of rooftop solar PV through the electricity import - export scheme from and to PLN's grids [19]. This scheme supported by declining investment costs and the presence of financing institutions, will develop rooftop solar PV market in Indonesia rapidly [3]. Yet, most HH 450 VA and HH 900 VA cannot afford the rooftop solar PV. The government needs to give a capital subsidy of rooftop PV to reduce electricity subsidy. Our study aims to assess the feasibility of this policy option.

3 Methodology and Data

3.1. Methodology

The first step for calculating electricity subsidy reductions from lamp replacements is to identify common CFLs wattages used by HH 450 VA and HH 900 VA. The second step is to determine the equivalent wattage on LED lamps. The third step is to calculate the electricity subsidy savings per year per lamp using following formula:

$$Saving = \frac{(W_{LED} - W_{CFL}) \times T}{1000} \times Subsidy \quad (1)$$

Saving = Reduced amount of subsidy (US\$).
 WLED = Wattages of LED lamp (watts).
 WCFL = Wattages of CFLs (watts).
 T = Numbers of lamp operating hours per year (hours).
 Subsidy = Tariff subsidy (US\$/kWh).

The saving is then compared to the investment cost (i.e., the LED price) to conclude the feasibility of the policy. The analysis uses data on the average number of lamps in a household.

The feasibility analysis of rooftop solar PV grant considers technical and economic facets for following scenarios:

- a. 1st scenario: Residential customers use both electricity from rooftop solar PV and PLN. The maximum capacity of rooftop solar PV and the inverter capacity is equal to the installed power capacity as regulated by MEMR [19]. The analysis also needs to consider the patterns of the rooftop solar PV electricity productions and hourly electricity demands. Palaloi [20] conducted a survey of electricity consumed by HH 450 VA and found that the electricity consumptions at 10 am to 2 pm range from 14% to 30% of the total daily electricity consumptions with an average value of 20%. During 7 am to 5 pm, the electricity consumption ranges from 34% to 55% with an average value of 44% of the total daily electricity consumptions [20]. Based on this data, this study uses the average value of 44% as a maximum percentage of daily energy consumptions that can be supplied by the rooftop PV. In other words, HH 450 VA still needs electricity from PLN to meet at least 56% of the daily energy consumptions.
- b. 2nd scenario: Residential customers only use electricity from a rooftop solar PV system equipped with battery.

Designing the rooftop solar PV system should determine the capacities of PV, battery, and inverter as follow:

$$PV \text{ capacity} = \frac{\text{Total electricity demand}}{PSH} \times SF \quad (2)$$

$$\text{Number of PV panel} = \frac{\text{Rooftop PV capacity}}{\text{Capacity of a PV panel}} \quad (3)$$

PSH= Peak sun hours, i.e., the equivalent value of the daily average solar radiation intensity at the site.

SF = Safety Factor, designed by considering the load losses from the PV system and its values range from 1.2 to 1.3.

The calculation of battery capacity is determined by following equation [21]:

$$Battery\ Cap = DoA \times \frac{E_o}{DoD_{maksimum} \times \eta_{disc}} \times Cf \quad (4)$$

- DoA = Days of autonomy, which is the number of days that battery operates without having to be recharged (days).
- E_o = Energy supplied by batteries (kWh).
- DoD = Battery depth of Discharge (%).
- η_{disc} = Discharge efficiency (%).
- C_f = Battery correction factor.

The inverter capacity should be greater than the total load power, calculated by following formula:

$$Inverter\ Cap\ (W) = Total\ load\ power \times Safety\ Factor \quad (5)$$

The calculation of the electricity productions of a rooftop PV system is:

$$EPV = P \times PSH \times RP \quad (6)$$

- EPV = Electricity productions of rooftop PV.
- P = Installed capacity of rooftop PV.
- PSH = Peak sun hours.
- RP = Performance ratios with values range from 75% to 85% as stipulated in IEC 61724-1:2017 [22].

Analysing cost and benefit considers electricity subsidy savings after using rooftop solar PV. The savings for the government are:

$$Government\ savings = Total\ subsidy\ saving - Investment\ costs \quad (7)$$

$$Total\ subsidy\ saving = Electricity\ produced\ by\ PV * Subsidy\ unit \quad (8)$$

Meanwhile, cost savings for residential customers:

$$Customer\ savings = Electricity\ produced\ by\ PV * electricity\ tariff \quad (9)$$

3.2. Data

Required data for the feasibility analysis of the LED replacement program are number, type, and wattages of lamps commonly used by HH 450 VA and 900 VA. IIEE [16] provided these data for case studies in North Sumatra. The number of lamps used by HH 450 VA was between 2 to 15 units with an average of 6 units. The number of lamps owned by HH 900 VA was between 3 to 12 units with an average number of 7 units [16]. Therefore, this study assumes that the average number of CFLs used by HH 450 VA and HH 900 VA are 6 lamps and 7 lamps correspondingly. Another assumption is the CFL wattages, which are 11 W for HH 450 VA and 16 W for HH 900 VA. CFL with these wattages have the same light outputs with LED lamps of 6 W and 9 W [16]. The assumption for LED lamp price uses the cheapest price for the best brands available on an online store in Indonesia, i.e., US\$ 1.59 for a 6 W LED lamp and US\$ 1.72 for a 9 W LED lamp.

The feasibility analysis of the rooftop solar PV uses data of daily electricity consumptions, electricity tariffs, electricity subsidies, and PV specifications. The Directorate General of Electricity [23] provides

electricity consumption data in 2019. The PV specifications is used to estimate investment costs and operational costs. Investment costs include the costs of components (modules, inverters, batteries, SCC, balanced of systems), installation costs, and other costs borne by the government. The operational costs include costs borne by residential customers such as for maintenance and component replacements.

4 Analysis Results

4.1. LED Lamp Grants

Table 1 shows the analysis results of electricity subsidy reductions from the LED lamp grant. The electricity consumption reductions per household are 76.7 kWh/year for HH 450 VA and 125.2 kWh/year for HH 900 VA. The electricity consumption reductions are equivalent to electricity bill savings for US\$ 2.21 and US\$ 5.24 per year. The estimated subsidy reductions are US\$ 6.21/year and US\$ 8.48/year for each HH 450 VA and HH 900 VA correspondingly. The investment cost is US\$ 9.52 per HH 450 VA and US\$ 12.07 per HH 900 VA. Therefore, electricity subsidy reductions will return the investment between 1.3 and 1.5 years. For all HH 450 VA and 900 VA, the LED lamp grant will cost of US\$ 310.03 million while electricity subsidy reductions reach US\$ 206.89 million per year for 15 years assuming 40,000 hours' lifespan of LED lamps with 7 operational hours per day.

Table 1. Electricity subsidy reductions from LED lamp program

Parameters	HH 450 VA	HH 900 VA
Number of lamps	6	7
Number of HH	23,786,546	7,232,527
Lamp wattages (W)		
Old CFL lamp	11	16
New LED lamp	6	9
Difference	5	7
Savings per year		
Electricity (kWh)	76.7	125.2
Bill savings (US\$)	2.21	5.24
Subsidy savings (US\$)	6.21	8.48
Financial analysis		
LED price (US\$/ unit)	1.59	1.72
Costs per HH (US\$)	9.52	12.07
Payback period (year)	1.5	1.3
Total investments (US\$)	226,384,203	87,290,326
Subsidy savings (US\$/year)	145,231,823	60,556,105

4.2. Rooftop PV Grants

Residential customers require PV capacity that could meet their electricity demands, i.e., on average 2.8 kWh per day for HH 450 VA and 3.43 kWh per day for HH 900 VA [23]. For the first scenario, the capacities of the rooftop PV system and inverters for HH 450 VA and 900 VA are limited to 450 W and 900 W respectively. Available capacity of PV module is 250 Wp so the capacities of the rooftop PV system become 500 Wp for HH 450 VA and 1,000 Wp for HH 900VA. The second scenario requires larger capacities of rooftop solar PV and inverter, i.e., 1 kW for HH 450 VA and 1.25 kW for HH

900 VA. The capacities may serve the electricity demands for 3 days without recharging. The required battery capacities for HH 450 VA and 900 VA are 14.4 kWh and 19.2 kWh respectively.

The investment costs of the first scenario for HH 450 VA and HH 900 VA are US\$ 827.59 and US\$ 1,310.34 as shown in Table 2. The PV system will reduce PLN's electricity usage from 7 am to 5 pm as much as 44% of daily electricity demands. The reduction of PLN's electricity usage is equivalent to 1.2 kWh for HH 450 VA and 1.5 kWh for HH 900 VA. The PV system will reduce the annual electricity subsidy around US\$ 36.34 per HH 450 VA or equivalent to US\$ 724.14 during 20 years PV lifespans. The electricity subsidy reduction for each HH 900 VA is quite similar, i.e., US\$ 37.24/year or US\$ 744.83 for the PV lifespans. These savings are lower than the investment costs so the benefits to the government are negative as shown in Table 2. In the second scenario, the installed rooftop solar PV capacity produces 3.2 kWh/day on HH 450VA and 4 kWh/day on HH 900 VA as seen in Table 2. The electricity production is higher than the daily electricity consumption of the two classes of HH customers. The estimated investment costs are US\$ 2931 for HH 450 VA and US\$ 3634.5 for HH 900 VA. The subsidy savings for each of HH 450 VA and HH 900 VA are US\$ 82.76/year and US\$ 89.66/year, or equivalent to US\$ 1,655.17 and US\$ 1,793.1 during PV lifespan successively. These savings are lower than the investment costs so that the government loss per year is equivalent to US\$ 63.87 per HH 450 VA and US\$ 97.17 per HH 900 VA.

Residential customers benefit from electricity bill savings. The PV system will reduce the electricity bill of HH 450 VA by US\$ 12.90/year for the first scenario and US\$ 29.24/year for the second scenario. Likewise, electricity bill savings for the HH 900 VA is amounted to US\$ 22.97/year for the first scenario and US\$ 52.14/year for the second scenario.

Yet, giving rooftop PV for free also confronts various technical challenges. Many those poor households have a rooftop made from vulnerable bamboo wooden and live-in dense neighbourhoods. Consequently, the investment cost may increase to renovate the rooftop first while electricity production is lower than expected due to the shading effects from surrounding houses. Moreover, those households also cannot afford the maintenance and service costs, which is relatively expensive compared to pay monthly electricity bills.

5 Conclusion and Policy Implications

The Indonesian government still subsidizes electricity tariffs for low-income electricity customers, i.e., HH 450 VA and HH 900 VA. Transforming the subsidized electricity tariffs requires political negotiations and may lead to social unrest. PLN and the government have made various efforts to reduce the electricity production costs, but these efforts have become ineffective due to the increase of primary energy prices. This leads to higher gap between the electricity production cost and electricity's tariffs to subsidized customers. Potential alternative

policies are to reduce electricity consumptions and to diversify energy sources for those customers.

The most nationally successful energy-saving measure is inefficient lamp replacement. During 2007 to 2009, Indonesia promoted CFLs to replace incandescent lamps by providing free CFLs to reduce electricity supply crisis at that time. The government can repeat the success of this measure by also providing free LED lamps that have higher efficiency, lifespan, and lumen maintenance than CFLs [14]. The estimated investment costs of the LED lamp grant for all HH 450 VA and HH 900 VA is US\$ 310.34 million. This measure will reduce electricity subsidies by US\$ 206.9 million per year for 15.7 years. It means that the simple payback period of the LED lamp grant is 1.5 years.

Another alternative measure is by giving a free rooftop PV. The investment costs needed for the on-grid system are US\$ 827.59 for each HH 450 VA and US\$ 1310.34 for each HH 900 VA. The electricity subsidy reductions over the lifespan of the PV panel (i.e., 20 years) are around US\$ 724, so this program suffer a loss anywhere between US\$ 5 to US\$ 28.21 per year. The losses for the on-grid system are greater at around US\$ 63.87/year per HH 450 VA and US\$ 97.17/year per HH 900 VA due to higher investments of additional battery systems and higher PV capacities.

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Table 2. Benefits of rooftop PV grants to government

Scenario	<i>1st scenario</i>		<i>2nd scenario</i>	
	HH 450 VA	HH 900 VA	HH 450 VA	HH 900 VA
Electricity consumptions				
24 hours (kWh)	2.8	3.4	2.8	3.4
7 am to 5 pm (kWh)	1.2	1.5	1.2	1.5
Without rooftop PV				
Subsidy (US\$/year)	82.76	89.66	82.76	89.66
Subsidy (US\$/20 year)	1655.17	1793.10	1655.17	1793.10
With rooftop PV				
Investment costs (US\$)	827.59	1310.34	2965.52	3655.17
PV electricity production (kWh/day)	1.6	3.2	3.2	4.0
PLN electricity reductions (kWh/day)	1.2	1.5	2.8	3.4
Subsidy reductions (US\$/year)	36.38	37.28	82.76	89.66
Subsidy reductions (US\$/20 year)	724.14	744.83	1655.17	1813.79
Benefits to government (US\$/year)	-5.00	-28.21	-63.87	-97.17