Rooftop PV System Policy and Implementation Study for a Household in Indonesia

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ABSTRACT
This paper discusses the recent solar rooftop photovoltaic (PV) system policies in Indonesia, particularly for the implementation of the residential sector. The aim of this study is to demonstrate the rooftop PV system for a household based on the current related policies. The study is conducted by literature reviews and computer simulation for a typical rooftop PV system for residential in Surabaya, Indonesia. The most recent solar energy policy in Indonesia is the Ministry of Energy and Mineral Resources Regulation No. 49, the year 2018, which establishes net metering for the residential, commercial and industrial National Grid (PLN) customers that have excess power from solar rooftop installations. The simulation shows the average values global solar irradiation on a horizontal surface in Surabaya vary between 6.81 kWh/m² and 4.82 kWh/m² with an average of 5.54 kWh/m²/day. Energy output by 3 kWp rooftop PV system in Surabaya is found about 4,200 kWh/year, with an average of 11.67 kWh/day. Economically, under present conditions, rooftop on-grid PV system investment would give about 9-10 years of the payback period.

Keywords: Rooftop, PV System, Solar Energy, Residential, Indonesia

1. INTRODUCTION
Solar energy is one of the most promising of renewable energies in attempting to reduce fossil-based fuel consumption due to its limited reserved and the greenhouse gas (GHG) emissions from the combustion process. Indonesia is located around the equator line, which fortunate to have relatively high and stable daily solar energy throughout most of the year. Statistically, the daily solar irradiation in Indonesia would provide more than 500 GW of potential solar sources (Dang, 2017; UNEP DTU Partnership, 2016). However, the solar photovoltaic (PV) sector has not been well tracked in Indonesia. By the time of writing this paper, based on various sources (Hamdi, 2019; Tarigan, 2018; Tarigan et al., 2015), it is estimated that there are approximately 14.7 MW of solar PV system running on-grid, 48 MW under construction, and an estimated 326 MW in the pipeline. This capacity is relatively small in comparing to the neighboring South East Asian countries such as Thailand (2.6 GW) and the Philippines (868 MW) (Hamdi, 2019).

The success of the implementation of the rooftop PV system in a country might be affected by many factors such as technical and policy or regulation. It is important for electricity consumers to consider the factors to ensure the beneficial use of the PV system. A number of studies for different countries were found in the literature regarding the policies that regulate the rooftop PV systems in particular countries. Goel (2016) studied and reported the policies, challenges, and outlook of solar rooftop in India. It is reported that with a strong commitment to increasing the renewable sources based energy capacity to 175 GW by 2022, India has a target to install 100 GW of solar energy capacity. Of this 40 GW would be the share of grid-connected solar PV rooftop (Goel, 2016). Xin-Gang and Yi-Min (2019) studied the economic performance of industrial and commercial rooftop PV in China.
It was reported that for a small rooftop PV investment payback period is short and the risk is low. The levelized cost of electricity is reported at about 0.2727 - 0.5573 CNY/kWh. The techno-economic impact of the rooftop PV system for schools in Palestine schools as the study cases. It is reported that the application of the rooftop PV systems was experiencing a significant increase and expanding vastly as an alternative source of energy provider for different buildings.

The Government of Indonesian under the Ministry of Energy and Mineral Resources (MEMR) has set a target of 23% of renewable energy of total national energy needs by 2025 (ESDM, 2016). In this connection, the PV rooftop system regulation has recently been introduced (Government of Indonesia, 2018), i.e Permen ESDM or MEMR Regulation No 49/2018. The regulation allows and encourages users, including residents, public, and commercial buildings to generate electricity by using PV system installed on the building roofs. The produced energy can be exported or fed into the utility grid.

The present paper discusses the current solar rooftop PV system policies in Indonesia, particularly for implementation for the residential sector. The available previous related policies on solar energy are compared, and the electricity Feed-in Tariffs (Fit) per are identified. In addition, simulation for a 3 kWp rooftop PV system for residential is done using solar PVSpot (SolarGis, 2017). The objective of this study is to demonstrate the rooftop PV system for households based on the current related policies and to figure out the opportunity benefits from the user’s perspective. The information and the results from this work are expected to be useful for the development of solar rooftop PV system applications for a larger scale in Indonesia, particularly for residential sectors.

2. METHOD

The study in this present work is carried out by literature reviews and computer simulation. The related solar PV policies documents and literature were retrieved through the internet, and then they were reviewed and discussed. Implementation of solar rooftop PV system for a typical household is simulated by taking Surabaya as object location.

3. RESULTS

3.1. Solar Energy Policies in Indonesia

Since 2013, the government of Indonesia, through the Directorate General of New and Renewable Energy and Energy Conservation (DGNREEC) of the MEMR has started to regulate solar energy sectors in Indonesia. The first policy was introduced with MEMR Regulation Number 17/2013. In the early years, solar technology was still perceived as expensive and unreliable relative to conventional technologies. This has made the lack of a market for solar energy.

In the course of time, there have been the regulation changes in Indonesia as shown in the road map solar energy policies in Figure 2. Table 1 presents the comparison of solar regulations ever issued in Indonesia. The important issues of regulations are mainly concerning: requirement of local content, feed-in tariffs, procurement method, residential application, the build own operate transfer (boot) rules, and deemed dispatch in case of force majeure. It can be seen that none of the regulations specifically regulate the rooftop PV system until the latest MEMR Regulation Number 49/2018 was introduced.

3.2. Rooftop PV System Policy

The most recent solar energy policy is in Indonesia is MEMR Regulation No. 49 the year 2018 which establishes a net metering...
scheme for the customers of PLN, including the residential, commercial and industrial customers that have excess power from solar rooftop installations. Under the regulation, the installation and construction of a rooftop PV system require prior approval and verification from PLN. The process of approval and verification involves application submission to office of relevant PLN distribution unit, along with the required technical information and administrative matters, such as the PLN customer identification number, the capacity of the rooftop PV system planned to install, one-line diagram of the planned PV system, and the specifications of the equipment to be installed.

Upon customer application, PLN will make the evaluation on the application and notify the decision within 15 business days. The decision can be either approved or rejected. The installation work for the PV system can only be started after a customer gets formal approval.

With the rooftop PV system, the electricity bill for PLN customers will be calculated monthly using the export-import energy meter. The calculation is based on the energy used (kWh import) value minus energy produced by the rooftop PV system (kWh export) value. Under MEMR Regulation No 49 the year 2018, the price of electricity by rooftop PV customers that exported to the grid will be valued at 65% for compensation. If the export is higher, the balance can be accumulated for up to 3 months before it expires.

Table 1: Solar energy policies in Indonesia

<table>
<thead>
<tr>
<th>Regulation</th>
<th>MEMR Regulation No. 12/2017 Updated by No. 50/2017</th>
<th>MEMR Regulation No. 49/2018 – (Solar Rooftop)</th>
<th>Regulation No. 17 the Year 2013</th>
<th>Regulation No. 19 the Year 2016</th>
<th>Regulation No. 12 the Year 2017, Updated by Regulation No. 50 the Year 2017</th>
<th>Regulation No. 49 the Year 2018 – (Solar Rooftop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The requirement of local content</td>
<td>Feed-in tariffs</td>
<td>Yes</td>
<td>Yes US$ 0.30/kWh (using modules with &gt;40% local content) US$ 0.25/kWh (using modules with &lt;40% local content)</td>
<td>Yes</td>
<td>Yes The range between US$ 0.145 – 0.25/kWh depending on the project location</td>
<td>Yes The tariff should be lower than the National supply cost of electricity (National BPP) or no more than 85% of local electricity supply cost (regional BPP) which ranges from US$ 0.048 – 0.144/kWh depending on the location</td>
</tr>
<tr>
<td>Procurement method</td>
<td></td>
<td>Auction based on quota per annum Direct appointment allowed if only 1 company bids</td>
<td>Auction based on quota for certain pre-determined regions Project size per developer is subject to a limit based on the available quota in the region</td>
<td>Direct selection based on quota capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOOT</td>
<td></td>
<td>Not regulated</td>
<td></td>
<td></td>
<td>Not regulated</td>
<td></td>
</tr>
<tr>
<td>Deemed Dispatch in case of force majeure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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- The allowed capacity of the rooftop PV system is limited at a maximum of 100% of the PLN customer’s installed capacity.
exemption of emergency energy charge and capacity charge for rooftop PV systems;
• The industrial users can install rooftop PV systems either off-grid on an on-grid installation. For the off-grid installations, capacity charge and emergency energy charge are exempted, while for on-grid installation will be subject to both charges.

There have been some questions raised related to the latest MEMR Regulation 49/2018, including how the electricity that exported from rooftop PV systems valued by the government, and what is the additional requirements to obtain approval prior to system installation. The multiplier of 65% applied to exported energy is considered unfavorable to rooftop PV users (Hamdi, 2019).

3.3. Implementation Study for Household
The conversion process of solar energy into electricity is affected by many factors, including materials properties and operating environment conditions. The material properties have been fixed during the manufacturing process of solar cells, while environmental operating conditions factors can be simulated to find optimum conditions. The Solar GIS PV planner simulation results showed the potential of the site solar irradiation presented in the form daily sum of global irradiation.

The result from the simulation shows that the average values global solar irradiation on a horizontal surface in Surabaya vary between 6.81 kWh/m² and 4.82 kWh/m² with an average of 5.54 kWh/m²/day. The global solar irradiation consists of direct, diffuse, and reflected components. The diffuse component of radiation is quite significant especially during March – October, while reflected radiation relatively small throughout the year. The monthly global from simulation results is shown in Figure 3. The global radiation in the past time was usually higher during month April – October than the other months due to dry season, meanwhile low radiation during December – March due to rainy season. However, in the present time, the season period is likely unpredictable, and further investigation should be done. Daily air temperature showed that the ambient temperature in Surabaya varies about 26-30°C.

The results of the simulation on energy output by 3 kWp PV system presented in Figure 4. Total annual energy production from the system is found at about 4200 kWh. The lowest energy production was in December and January which is about 190 kWh. Further specific studies are recommended to investigate the main factors such as dust, shading, weather, etc to optimize the energy output.

3.4. Economic Analysis
A quick market survey on the retail price of PV system components in Surabaya was conducted using the internets. There was a variation of the price for each of the components by different brands, types and vendors or suppliers. The average prizes among all surveyed data are used for economic analysis. The retail price of components and cost for installing 3kWP rooftop on-grid PV is presented in Table 2.

A financial simulation was carried out with RETScreen software with financial parameters as presented in Table 3. Assuming that the price of one kWh of exported electricity from rooftop PV

<table>
<thead>
<tr>
<th>Components</th>
<th>Retail price or cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 kWp PV modules</td>
<td>2400</td>
</tr>
<tr>
<td>Inverters 3000 W</td>
<td>350</td>
</tr>
<tr>
<td>Cabling</td>
<td>100</td>
</tr>
<tr>
<td>Construction cost</td>
<td>250</td>
</tr>
<tr>
<td>Total</td>
<td>3100</td>
</tr>
</tbody>
</table>

Table 2: Cost component for 3 kWp PV system

Figure 3: Global irradiation and air temperature in Surabaya
system to the grid is 0.09 (USD/kWh), then during 1 year, based current situation above, the system will be generated earning: 4.200 (kWh/year) × 0.09 (USD/kWh) × 1 (year) = 378 (USD/year). Lifetime for PV panels is considered about 20 years, while for inverters are 6-7 years.

Table 3: Simulation parameters for financial simulation

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt ratio</td>
<td>50%</td>
</tr>
<tr>
<td>Debt interest rate</td>
<td>6%</td>
</tr>
<tr>
<td>Inflation rate</td>
<td>5%</td>
</tr>
<tr>
<td>Project life</td>
<td>20 year</td>
</tr>
<tr>
<td>Electricity export rate</td>
<td>1.2 USD/kWh</td>
</tr>
<tr>
<td>GHG emission factor</td>
<td>0.709 tCO₂/MWh</td>
</tr>
<tr>
<td>debt term</td>
<td>10 year</td>
</tr>
<tr>
<td>Capacity factor</td>
<td>14%</td>
</tr>
</tbody>
</table>

The annual cumulative cash flows are presented in Figure 5. The cumulative cash flow in the figure is from the accumulation of money value of electricity produced by the PV system in comparison to system incremental of installation cost. It can be seen that under present conditions, rooftop on-grid PV system investment would give about 9-10 years of the payback period.

3.5. Environmental Analysis
Replacing fossil fuel with renewable ones for power generation would give a positive impact on the environment. It has been known that the combustion process of fossil fuels in power plants would realize GHG such as Sulphur dioxide (SO₂), nitrogen oxide (NOx), and Carbon dioxide (CO₂) to the atmosphere. Besides, it also produces a large amount of ash that needs particular handling. Mathematically, reducing GHG emissions from using 3 kWp solar panels in Surabaya (due to replace the burning of fossil fuel...
with the equivalent of produced energy) (RETScreen, 2019) is presented in Table 4.

GHG reduction as shown in Table 4 is just representing by applying the PV system by a household. If the number of the house installing PV increases then the amount of reduction GHG should be multiplied by the number of houses with PV systems.

| Table 4: Greenhouse gasses reduction by 3 kWp PV system |
|-------------------------------|-----------------|-----------------|
| Greenhouse gasses from the coal power plant | Per kWh (g) | For annual energy production of E=4200 kWh (kg) |
| SO₂ | 1.24 | 5.21 |
| NOₓ | 2.59 | 10.88 |
| CO₂ | 970 | 4075.00 |
| Ash | 68 | 285.6 |

4. CONCLUSIONS

The regulation on solar energy application in Indonesia has been reviewed, and the simulation of the rooftop PV system a typical household in Surabaya Indonesia has been conducted. The most recent solar energy policy in Indonesia is MEMR Regulation No. 49 the year 2018 which establishes a net metering scheme for the customers of PLN, including the residential, commercial and industrial customers that have excess power from solar rooftop installations. Under the current regulation, the electricity bill for PLN customers will be calculated monthly using the export-import energy meter. The calculation is based on the energy used (kWh import) value minus energy produced by the rooftop PV system (kWh export) value.

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