Solar energy as natural resource utilization in urban areas: Solar energy efficiency literature review

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Abstract. Solar power plant is a power generator that utilizes solar cells to transform solar radiation into electrical energy. Solar cells are a direct energy technology. Electrical energy can be produced without the assistance of moving fluids such as vapour or gas. If it is compared with wind, water and biomasses powers, solar cells utilization tend to be much easier and simpler. The aim of this research is to evaluate urban areas potentials to utilize solar cells as solar power plant. The energy of the sun as a stable electricity source would never be damaged and environmental friendly. A solar power plant system is divided into several sections. Solar cells will transform solar energy into electricity. The electricity produced by solar panels will be stored in an accumulator through a charger controller. This charger controller will act as voltage and current regulator in the accumulator. Rooftop solar power plant utilization has improved as much as 170%. At this moment, there are numerous buildings and housings in urban areas that have already installed rooftop solar panels as electricity generator. Jakarta and Surabaya are two major cities that have already implement rooftop solar power plant on top of office buildings, universities, and housings. Rooftop solar power plant is an environmental friendly and a potential electricity generator to be implemented.

1. Introduction
Nowadays, numerous power plants are built to produce various alternative energy sources. Energy utilization efficiency can be measured by conducting technology audit by checking air conditioner, lighting, and other electricity utilizations in a certain place or area. Energy efficiency can be defined as a situation of certain level energy utilization that produces optimum result. There are numerous challenges faced to achieve a target of solving energy efficiency and alternative energy procurement problems for the nation [1]. Basically, any renewable energy can be chosen if it can be presented as an alternative that would be able to minimize limited natural resources and negative impact on the environment. Suitable energy options for a certain area are always depend on geographical condition and climate. In this situation, Indonesia can be said as a suitable area to establish solar power plants. Suitable areas to build solar power plant are areas located around the equator. Solar power plant is an electricity generator that utilizes Photovoltaic (PV) solar cells to transform solar radiation into electrical energy. Solar cells are a direct energy technology. Electrical energy can be produced without the assistance of moving fluids such as vapour or gas. Solar cells are also does not require mechanic motion generators such as Rankine cycle or Brayton cycle. Solar power plant can also applied in urban areas such as on office buildings, malls, hotels, apartments, or flats; in residential areas; industrial areas such as factories; and in other places such as recreational park, museums, schools, universities, hospitals,
airports, bus or train stations, libraries, and other buildings [2]. The roof of a building is an open, flat area, located at the highest part of a building without any covers. Urban areas are mostly filled by tall buildings possess great potentials to be developed into solar power plant. The utilization of solar energy as power plant, actually have already known for quite a long period, but the application is still limited on a rather small scale or as known as solar home system (SHS) [3]. Urban scale solar power plant is a power generator system that commonly able to produce enough power capacity to fulfill the needs of housings in urban and semi urban areas.

2. Literature review

Urban society is a quite large group which act as a quite significant component that forms Indonesian population composition. This group of society is majorly located inside National Electricity Company’s (PLN) electricity network coverage area, which possesses better characteristics to utilize solar power plant than rural society such as buying power, education level, and environmental awareness and preservation knowledge [4]. The role of electricity is highly related with the life of urban society, where the inability of this energy will produce a direct impact on urban life’s productivity and comfort. The ability of solar cells to absorb sun rays is highly varied. This situation is caused by different intensities of sun rays in the afternoon and in the morning [5].

Generally, there are 3 ways to utilize solar energy based on the utilization type, namely the utilization of (1) solar radiation by using photovoltaic solar cells that transform solar radiation into electricity by using photovoltaic solar cells technology; (2) solar thermal utilization by using heat collector technology that transform solar thermal into electricity by collecting solar thermal in a centralized medium; (3) direct solar light and thermal by utilizing them as they are without converting the energy into electricity.

The general concept of solar energy utilization is to transform heat energy of the sun into electricity by utilizing solar panel. Heat energy of the sun that contacted photovoltaic cells will be absorbed by solar panel, which will convert the energy into electricity and further channel the energy into conservation battery or directly to the inverter. The inverter has the ability to transform direct course (DC) electricity into alternative course (AC) that can be utilized as electrical power source.

Based on Indonesian National Standard (SNI) 8395:2017, Solar Power Plant is a power plant that utilizes solar radiation as energy source that uses photovoltaic cells conversion. Photovoltaic system transforms solar radiation into electricity. The higher the solar radiation intensity that contacted photovoltaic cells, the higher the electricity produced. Because electricity is always needed, excess electricity generated is stored in batteries so it would be ready to use at any time for any electrical tools [7]. The working system of a photovoltaic system can also be pictured as rain collecting system. The
rate of water collection is highly affected by the weather, which also affects the level of water collection ability, which sometimes produces nothing. In photovoltaic system, the amount of electricity collected is highly dependent on the weather condition. On bright days the system can produce high level of electricity, meanwhile on cloudy days the system can only produce minimum level of electricity.

Power plant that utilizes solar heat energy does not directly produce electricity. The process to transform solar heat energy into electricity requires a rather complex process. There are two ways utilized by solar power plant to produce electricity. The first way is Solar Thermal Power Plant that collects solar energy to heat liquid substance. The vapour of the liquid substance is then utilized to move generator that would produce electricity. The other way is by utilizing Photovoltaic Solar Power Plant that collect solar heat energy as its main material that would be directly converted into electricity [6].

Photovoltaic is proven as an effective and faster way to produce electricity if compared with Solar Thermal Power Plant. In this universe, there are two kinds of solar energy systems, which are passive and active solar energy. On passive system, special tools are not required to collect solar energy. For example if we park a motorcycle under the sun, the seat will be heated and automatically reach high temperature. Meanwhile for active solar energy system, it requires certain methods and tools to collect the energy and reserve it.

Both Thermal Solar Power Plant and Photovoltaic Solar Power Plant are utilizing active solar energy system as their energy source. Solar Power Plant surely require special tools to absorb solar energy, which also able to minimize energy reflection to optimally collect and process solar energy to be processed and converted into electricity. The application of Solar Power Plant can be implemented in urban areas where the buildings are generally possesses potential roofs that can be utilized as solar energy collection centre. Rooftop Solar Power Plant application is highly popular in the present time because of its simple utilization and adjustable capacity according to roof availability. Rooftop Solar Power Plant has become one of national priority programs in 2020. Not only to ensure national energy security by helping to decrease fossil energy utilization, but also to achieve energy mix target especially on the scope of new and renewable energy (EBT) as mentioned in Indonesian law and to actualize One Million Solar Rooftop program.

3. Results and discussion
Sunlight is an energy source of solar cells series. The aim of energy source measurement on a location is to predict the possibility of available energy supply that can be produced by a planned Solar Power Plant centre. Energy source measurement and the effort to convert and predict its production capacity for at least twenty years, is surely depending on the right data and modelling technique. There are two available data verification methods which are primary and secondary data measurement. Primary data measurement can be conducted by applying a direct solar radiation potential measurement in the area where Solar Power Plant is planned to be built, at least for one year time. On the other hand, secondary data can be obtained from authorized institutions appointed to publish radiation data. If the previous sunlight data is unavailable or cannot be obtained from the Meteorology, Climatology and Geophysics Council (BMKG), we can utilize data published by NASA, NREL, or Solargis.

Solar roof has become a familiar sight in capital cities. Skyscrapers have installed numbers of photovoltaic modules in their rooftops to support their electrical needs. The solar panels lined up on rooftop, walls, or other outside parts of the buildings are known as Rooftop Solar Power Plant.

Almost every building in the Ministry of Energy and Human Resources area has already fitted with rooftop solar power plant. One of which is the building of Directorate General of New Renewable Energy and Energy Conservation (Ditjen EBTKE) in the Ministry of Energy and Human Resources area located at Pegangsaan Timur Street in Central Jakarta. The rooftop solar power plant with a capacity of 20 kilo Watt peak (kWp), which was installed in 2015, is able to produce 20,160 Watt of electricity at its top capacity with 4 hours of battery recharging rate. By utilizing 40 meters square of rooftop area, the 20 kWp solar power plant on top of Directorate General of New Renewable Energy and Energy Conservation building is able to provide energy consumption for all of its 8 floors. The Directorate General of Electricity as a part of Ministry of Energy and Human Resources located in Rasuna Said
Street in South Jakarta has also installed rooftop solar power plant since 2010. Nowadays, the power plant has 130 kWp of total capacity and can help to save at least 10 Million Rupiahs of electricity budget each month. Residential areas can also install a rooftop solar power plant on-grid with the electricity network of PT Perusahaan Listrik Negara (PLN) Persero, as regulated in Ministry of Energy and Human Resource Regulation Number 49 Year 2018 about Solar Power Plant System Utilization by PLN Customers.

With the issuance of this regulation, the people can also have access on low cost electricity through electricity “export-import” with PLN. The amount of savings is varied and highly depending on the whole electricity production capacity and utilization. The capacity produced by rooftop solar power plant will automatically deduct customer electricity bill up to 65% of total power generated by rooftop solar power plant. It means that 1 Watt of electricity produced by rooftop solar power plant will directly cut 0.65 Watt of PLN electricity bill for the next month. Based on that, the customer will only pay for 35% of electricity plus PLN electricity utilization if there is any. Therefore, electricity bill will decrease significantly [9].

Rooftop solar power plant utilization has experience increases as much as 170% on the last six month of 2019. Until July 2019, there are 1059 PLN customers have already utilize rooftop solar power plant with total capacity of 2,564 kWp, meanwhile in January 2019, the number of customers installing rooftop solar power plant only reach 609 customers. Rooftop solar power plant is a smaller PV Photovoltaic system than PV installation on open land. Rooftop solar power plant is installed on buildings in residential, commercial building or industrial areas. Photovoltaic panel module structure used as sunlight collector is installed on top of a building or on other parts of the building. The panel installations are commonly known as Rooftop Solar Power Plant. Besides environmentally friendly and supporting clean and renewable energy programs, the panel can also help the customers to save on their electricity bill costs. The power produced from rooftop power plant will automatically deduct a maximum of 65% from the customers’ total electricity cost [10]. Electricity produced by the system can be inserted into the electricity network regulated with Feed in Tariff or consumed by net metering measurement [11]. Rooftop solar power plant system includes: solar module, inverter, customer electricity line, safety system, and Export-Import kWh meter, with installation location on: rooftops, walls or other available parts of PLN customer buildings.
This market study result has shown that there are a number of potential interested households to install rooftop solar power plant without a strict financial calculation, or households categorized as early adopters [12,13]. The percentage of early adopters and early followers reach 13% in Jabodetabek area and 19% in Surabaya. The technical potential in Surabaya is quite high it reaches 35 Megawatt-peak (MWp), only from government buildings and supermarkets. Meanwhile in Jakarta, the potential reaches 22 MWp. Two major universities in Surabaya, ITS and Airlangga University are two areas with highest rooftop solar power plant potential. With a large numbers of malls and supermarkets, Jakarta also possesses high potential. Meanwhile central government buildings, province and cities government buildings have low potential because they are usually consists of high-rise buildings with limited rooftop areas. Universities complexes in Jakarta which also possess high potentials are Universitas Negeri Jakarta and Universitas Indonesia in Salemba area. Rooftop solar power plant electricity has become relevant with electricity needs in government offices and universities because their activities are often take place during the day.

Solar energy possesses a high potential but its utilization level is still very low. There are several strengths and weaknesses identified from solar energy utilization [14], which are:

- Solar energy does not produce pollution and environmentally friendly: there is no pollution on solar cells operational system because the cells do not produce side effects such as smokes produced on electricity produced by machine or fossil fuel utilization. The captured sunlight causes electron movement in solar cells without any polluting effect.
- Solar energy is renewable: because solar energy’s main energy source is sunlight, energy will always available as long as the sun is rising. The sun produces its light through a fusion of hydrogen atom into helium atom. This fusion process can last for trillions of years. Because of that, the sun will provide energy for a long time.
- Utilizing sunlight as energy source is seen as an environmentally friendly steps.
- Economical: 5,000 MW of energy produced by solar power plant, if converted, will be similar as planting 18,124 trees, saving 1.5 million litres of fossil fuel used to power diesel power plant, and prevent 3.6 million tons of CO₂ emissions produced from diesel power plant utilization.
- Preventing emission: for every 1,000 kWh of energy produce by solar panels, we can decrease almost 8 pounds of sulphur dioxide, 5 pounds of nitrogen oxide, and 1,400 carbon dioxide emissions [15].

4. Conclusion
For urban areas, rooftop solar power plant electricity has become relevant to fulfil electricity needs in government offices and universities since their main activities are practiced during daylight. Jakarta and Surabaya are two major cities that have already utilize rooftop solar power plant. Households in urban areas have the potential to become early adopters and early followers of rooftop solar power plant utilization movement.

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