Potential of Photovoltaic Technology in Indonesia based on Latitude Coordinate

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Keywords: DASI, Latitude, LCOE, Meteonorm, Photovoltaic, SAM.

Abstract: Based on previous research, solar radiation at every latitude is different. Indonesia is one of the few countries that is located on the equator furthermore in the tropical region, which is between 23.5° north latitude and 23.5° south latitude, where the sun will continue to move as if it were perpendicular, so tropical areas will receive more sunlight than other regions in the earth. With a lot of potential solar energy in Indonesia, the use of solar energy for electricity at 34 capital of the province in Indonesia can be considered. Climate data in this research obtained from Meteonorm than executed in SAM (System Advisor Model) then generated Daily Average Solar Irradiance (DASI), Annual System Output (ASO) in Alternating Current (AC), and Levelized cost of Electricity (LCOE). The highest DASI value is 5.26 kWh/m2/day in Kupang and the lowest at Bandung with value 4.12 kWh/m2/day. The highest LCOE value 35.43 $cents/kWh in the city of Pontianak at 0.08° south latitude coordinates, and the lowest in the city of Kupang at 28.16 $cents/kWh at 10.183° south latitude coordinates.

1 INTRODUCTION

Indonesia is an archipelago country with centralized system of electricity on one transmission and distribution network with a large capacity where ever the majority of power plants using energy from fossil fuel. This condition become an obstacle in meeting evenly electricity need. Solar energy is expected to become a solution to produce electricity that more environmentally friendly with energy production can be carried out directly by the energy users.

Figure 1 Indonesian Map (World Atlas, 2020)

Based on calculations from PLN (Perusahaan Listrik Negara) statistical data for 2019, total of PLN customers from the household sector are 91.96% (Statistik PLN, 2019). This means that the use of electricity in Indonesia is dominated for consumption, not production. In addition, the load of household sector is not the biggest contributor in PLN's revenue because it is still lower than industrial sector revenue.

From previous study, Stieven and Setiawan obtained formulation for optimum tilt angle especially in tropical area. Djamal and Setiawan obtained PV-performance thin film generates greater energy than crystalline PV in the tropical area. Danar and Setiawan have obtained the formulation for optimum tilt angle only in Indonesia that produce maximum potential economic benefit to be gained from the installation of solar panels. Isdawimah and Ismujianto obtained monitoring system to control environmental protection in PV system. Pratama and Kumara obtained that PLTS installed on the north side of the building's roof is capable of producing the largest amount of electricity using SAM.

From the facts above, the use of solar energy to meet the electricity needs of household consumers is expected to be a solution to improve the reliability of the electrical power system in Indonesia and simultaneously reduce dependence on fossil energy which is decreasing in number and has a negative impact on environmental sustainability.

Muchlishah, .
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DOI: 10.5220/0010507800003153
In *Proceedings of the 9th Annual Southeast Asian International Seminar (ASAIS 2020)*, pages 9-12
ISBN: 978-989-758-518-0

To encourage the use of solar energy in Indonesia, it is necessary to do research on the potential of solar energy in 34 capitals of the province in Indonesia, so it can be seen the effect of geographic location (latitude coordinates) on the amount of electrical energy produced. Furthermore, from this research, the LCOE (Levelized Cost of Electricity) value is obtained so that it is possible to do electricity purchase from the public or solar generation owners to PLN to meet the unmet load of electrical energy from existing PLN generators, and at the end it can help to improve the reliability of electrical energy system in the territory of Indonesia and also to encourage the further development of the renewable energy industry, especially from solar energy.

2 METHODOLOGY

Table 1 Latitude Coordinate of 34 capital of the province in Indonesia

Province	Capital of The Province	Latitude
Aceh	Banda Aceh	5.55
Sumatera Utara	Medan	3.58
Kalimantan Utara	Tanjung Selor	2.83
Sulawesi Utara	Manado	1.53
Kep. Riau	Batam	1.03
Maluku Utara	Ternate	0.783
Gorontalo	Gorontalo	0.55
Riau	Pekanbaru	0.482
Kalimantan Barat	Pontianak	-0.08
Kalimantan Timur	Samarinda	-0.5
Papua Barat	Sorong	-0.867
Sulawesi Tengah	Palu	-0.9
Sumatera Barat	Padang	-1
Jambi	Jambi	-1.63
Kep. Bangka Belitung	Pangkal Pinang	-2.08
Kalimantan Tengah	Palangkaraya	-2.2
Papua	Jayapura	-2.53
Sulawesi Barat	Mamuju	-2.669
Sumatera Selatan	Palembang	-2.98
Kalimantan Selatan	Banjarmasin	-3.31
Maluku	Ambon	-3.64
Bengkulu	Bengkulu	-3.8
Sulawasi Tenggara	Kendari	-3.967
Sulawesi Selatan	Makassar	-5.15
Lampung	Bandar Lampung	-5.43
Banten	Serang	-6.11
DKI Jakarta	Jakarta	-6.13
Jawa Barat	Bandung	-6.95
Jawa Tengah	Semarang	-6.97
Jawa Timur	Surabaya	-7.23
DI Yogyakarta	Yogyakarta	-7.8
NTB	Mataram	-8.6
Bali	Denpasar	-8.65
NTT	Kupang	-10.183

In this research, household consumers are limited to consumers that located in 34 capital of the province in Indonesia with assumption that all of consumers have been connected to PLN network. It is assumed that all of consumers are economically capable to investing in photovoltaic technology. This research is limited by collecting and processing of several secondary data variables for solar power generation with installed power capacity from PLN 2200VA or above.

Meteonorm data input used in this research is latitude and longitude coordinates for 34 capital of the province in Indonesia. For latitude coordinate which located above the equator the input value is positive and for latitude coordinate which located below the equator the input value is negative. Afterwards, because of Indonesia is located in the eastern hemisphere, which is located between 95˚ east longitude to 141˚ east longitude, the value input is always positive. Table 1 shown 34 capital of the province in Indonesia that sorted based on latitude coordinate.

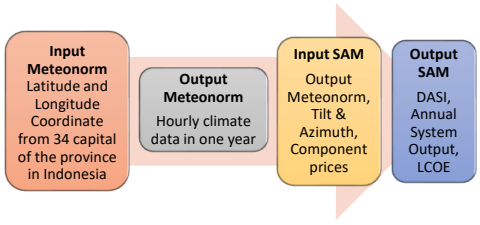

Figure 2 Methodology

Hereafter, climate data from Meteonorm will process using System Advisor Model (SAM). Besides climate data, tilt and azimuth optimum (Rumokoy, 2015) of the panel and component prices also added as input in SAM to generate Daily

Average Solar Irradiance (DASI), Annual System Output (ASO) and LCOE from the system. Figure 2 show the process of this research.

3 RESEARCH RESULT AND DISCUSSION

Daily average solar irradiance is the amount of solar radiation that measured in terms of electrical energy in units of kWh per square meter in a day. DASI in this research is seen from the average data in one year. From 34 capital of the province in Indonesia, Kupang is the city with the highest DASI, which is 5.26 kWh/m^2/day where Kupang is a city that is farthest from the equator at 10,183 latitude south side of the equator. The lowest DASI value of 34 capital of the province in Indonesia is Bandung, which is 4.12 kWh/m^2/day. If Bandung compared with other city nearby, the climate differences is quite extreme from the other city, so based on this condition Bandung data can temporarily ignore in order to see the true pattern of DASI.

By ignoring the city of Bandung, Pontianak is the city with the lowest DASI, which is 4.14 kWh/m^2/day. When viewed from the position of Pontianak at latitude coordinates, it is known that Pontianak is the capital of the province which closest to the equator at 0.08 to the south of the equator.

The annual AC system output is the average value in one year of the inverter power output that will distributed to PLN grid or to be used directly by the producer. The value of power is already in the form of Alternating Current (AC), not Direct Current (DC) that produced by solar panel.

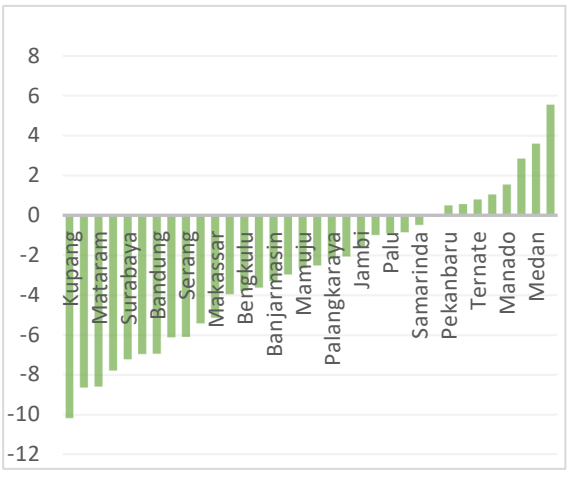

Figure 3 Latitude Coordinate from 34 Capital of The Province in Indonesia

The northernmost city is located in the Sumatra area, namely Banda Aceh at the coordinates of 5.55˚ north latitude and the southernmost city is Kupang, which is located in Nusa Tenggara Timur (NTT) area at 10,183˚ south latitude. There are eight cities that are located above the equator and 26 cities that are located below the equator. More details can see at figure 3.

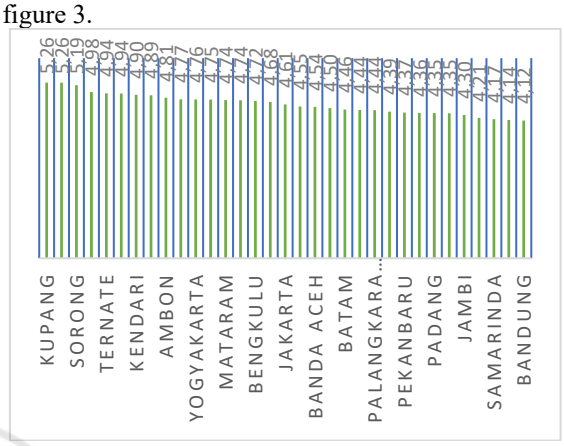

Figure 4 DASI from 34 capital of the province in kWh/m^2/day

From the discussion above it is known that if latitude coordinate closer to the equator, DASI will be smaller and if latitude coordinate farther from the equator, DASI will be greater. An exception occurs if at some point have significant differences in climate from surrounding area because it will affect the value of DASI.

From figure shown below, Annual AC System Output for 34 capital of the province in Indonesia with the highest value is Kupang as well as the value of DASI. For the city of Pontianak, annual AC system output remain at the lowest value because the position of Pontianak latitude coordinate is closest to the equator compared to the other city.

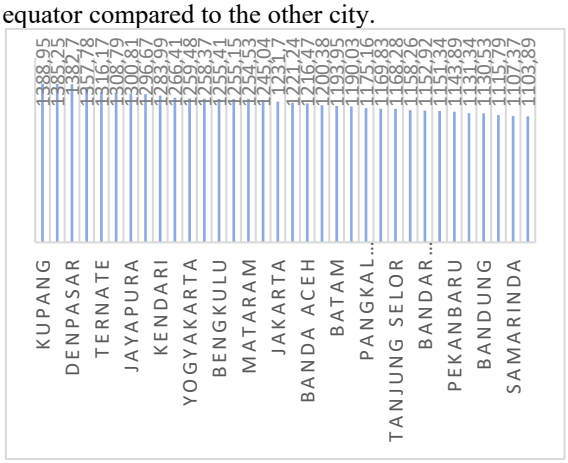

Figure 5 Annual AC System Output of 34 Capital of The Province in kWh

Kupang is the city with the lowest LCOE from 34 capital of the province in Indonesia at 28.16 $cents/kWh. Meanwhile, Pontianak is the city with the highest LCOE value at 35.43 $cents/kWh. This condition is inversely proportional to the value of DASI and annual AC system output where the LCOE value in the city with the farthest latitude coordinates from the equator will get the smallest value and the city with the closest latitude coordinate from the equator will get the largest value.

The value of LCOE in this research depends on price of the components that used. With different components, energy prices will also be different. Therefore, the LCOE value in this research is only used as a reference for obtaining the LCOE pattern from 34 capital of the province in Indonesia with the same components are used in the photovoltaic system.

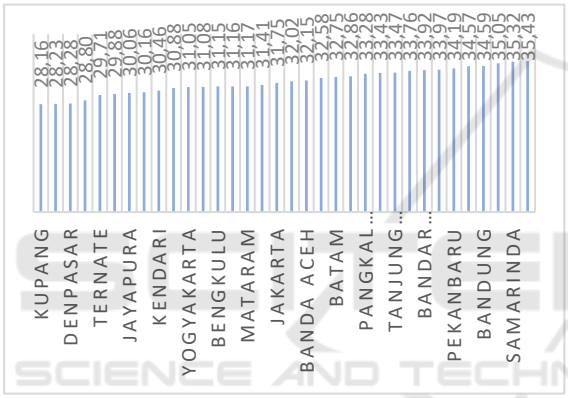

Figure 6 LCOE of 34 Capital of The Province in $*cents*/kWh

4 CONCLUSIONS

The shift in longitude has no effect on the resulting LCOE value. A coordinate that closer to the equator or zero degrees of latitude have the higher of LCOE value, and the farther from the equator have the smaller of LCOE value.

The LCOE value in a geographic coordinate point is inversely proportional to the daily average solar irradiance and annual AC system output values.

The lowest LCOE value of 34 provinces in Indonesia is in the city of Kupang with a value of 28.16 $cents/kWh where the city of Kupang is a city located at coordinates 10,183˚ south latitude that farthest province in Indonesia from the equator. The highest LCOE value of 34 provinces in Indonesia is in the city of Pontianak, at 35.43 $cents/kWh that also the closest capital of the province in Indonesia from the equator at 0.08˚ south latitude.

ACKNOWLEDGEMENTS

This research was supported by Tropical Renewable Energy Center, Faculty of Engineering, Universitas Indonesia.

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