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Study of Indonesia's Solar Energy Implementation Using Identification of Potency, Policies, and Cost-Benefit Analysis

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Abstract

The solar PV systems are semiconductor devices that precisely convert sunlight into electricity, through the transfer of electrons. They provide several advantages, such as high modularity, zero noise, and adequate availability of solar resources in Indonesia. Therefore, this study aims to determine the potency, policy perspective, and Cost-Benefit Analysis (CBA) of the solar energy implementation for electricity generation. A statistical analysis was used for measuring potency, as well as reviewing opportunistic policies and barriers. A review of some CBA-based journals was also carried out, to determine that the development of solar power electricity had more benefit than fossil fuels and LCOE (Levelized Cost Of Electricity). The results of the 10-days average value calculation in 2019 were 388-563 W/m^2, with the maximum values at 1137-1604 W/m^2. Meanwhile the analysis of the maximum hourly averages for Western, Central, and Eastern Indonesia were 570-719, 634-758, and 559-627 W/m^2 at 11.00-12.00 WIB, 11.00-13.00 WITA, and 12.00-13.00 WIT, respectively. The potency of solar radiation intensity in Indonesia was averagely 150-750 W/m^2, as the highest values were found in East Nusa Tenggara, Maluku, and Merauke.

INTRODUCTION

The urgency of solar energy implementation is an essential construct in tackling climate change, to reduce fossil fuel utilization that has negligible negative impacts on the environment. Some of these successful achievements include the existence of sunlight policies, to significantly increase solar power generation, as shown in Table 1 (Solangi et al., 2011). Furthermore, a feed-in tariff (FIT) is a strategy used to help the improvement of environmentally friendly power sources, through the provision of an ensured and above-market manufacturer costs. In addition, a Renewable Portfolio Standards (RPS) is an administrative command used to construct energy from inexhaustible sources, such as breeze, sunlight, biomass, and different options in contrast to fossil and atomic electric age.

The solar energy implementation is also in line with the 2015 Paris Agreement on Climate Change, which showed that all parties agreed to reduce greenhouse gas emissions and the increase in global average air temperature to approximately 1.5-2°C, as possible pre-industrial periods. Based on Indonesia's First Biennial Update Report (BUR) submitted to UNFCCC in January 2016, the national greenhouse gas (GHG) emissions were 1.453 GtCO2e in 2012, representing an increase of 0.452 GtCO2e from 2000. The main contributing sectors were Land-use Change and Forestry (LUCF), including peat fires (47.8%) and

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energy (34.9%) (KESDM, 2016). To realize the goals of the Paris Agreement, the economic growth promotion, job opportunities creation, and people's welfare improvement based on using renewable energy sources, emerged from solar power. Moreover, the deployment of renewable energy affects the trade of energy-related equipment and services. The equipment of the trade-in renewable energy as well as other investment goods and services are found to increase due to the scaled-up deployment in power and end-use sectors. At the same time, this decreases other trade of energy sources, especially fossil fuels (Ferroukhi et al., 2016).

Table 1. Comparison of Solar Energy Policy (Solangi et al., 2011)

Region	Feed-in-tariffs (FIT)	Renewable Portfolio Standard (RPS)	Incentives / Subsidies
North America	Encourages rooftop PV deployment due to its sliding-scale pricing structure	Allow utilities to exchange renewable energy certificates or credits (RECs)	Allows the residential solar and wind investment tax credits to expire, as well as create and subsidize domestic economic activity in other countries through imports
Europe	The mechanisms are found with contract time and constant remunerations for the produced energy. Therefore, different FIT values are established for distinguished types and rated powers of the generation system	-	Credit terms and tax incentives depend on whether the PV installations are privately or commercially performed.
Australia	Queensland and South Australia only have existing schemes	-	A large-scale solar thermal remains an expensive proposition, limiting commercial diffusion to subsidized programs, such as the Solar Flagships service
Malaysia	-	-	There is still massive support for conventional energy sources in subsidies and export credits, with Renewable Energy not being an exception

Indonesia has several power resources such as renewable energy and fossil fuel, which includes coal, natural gas, and oil (Sugiyono, 2001). Due to being located in the tropical region, the country is found to be rich in solar energy. As a maritime continent, Indonesia is also prosperous in hydro and wind energy, with the territory totally obtaining relatively high solar radiation at an average of 12.38 $MJ.m^{-2}.day^{-1}$. This is because the position of the sun is perpendicular to the equator (Septiadi et al., 2009). Solar energy is also one of the most potential sources in Indonesia, where daylight is abundant and available throughout the year. However, approximately 16 MWp (0.03% of the potential) was recently utilized, with the total production at 21.09 GWh (Hayati, 2021).

Based on the use of solar energy, a study was conducted on fishing vessels or ships, namely a Hybrid power generation system (Solar Cells and Diesel Generator) on a tanker (Putri & Koenhardono, 2016). The results showed that the Lifetime of the ship achieved 20 years, while the Break-Even Point (BEP) occurred less than 4 yrs. Meanwhile, Syahbana (2012), conducted experiments using solar energy as an alternative power to the navigation light electrical system on fishing vessels, through panels measuring 30 Wp. In Indonesia, an electric bicycle also used these panels as charging tools, to obtain the required amount of solar absorption. Moreover, sunlight is generally obtained, absorbed, and converted into electrical energy that lasts for 5 h, with the total power requirement being 455 W. The solar panels used in this study were 40 Wp, using batteries of 12 V 12 Ah (Prayogi et al., 2020).

This study aims to report the potency, policy perspective, and cost-benefit analysis (CBA) of the solar energy implementation in Indonesia. It also hypothesizes that the potency of solar energy is more massive

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at intervals. In addition, the coverage of policies becomes better and more manageable, with the cost-benefit analysis of sunlight being cheaper and efficient than other energy sources.

MATERIALS AND METHOD

The potency of solar energy implementation was analyzed using the average and maximum values of sunlight intensity data per ten days in 2019. These data were collected from several Automatic Weather Stations (AWS), such as AWS Maritim Paotere, Digi Stamet Ngurah Rai, Digi Stamet Pattimura, SMPK Semelagi, Stasiun Geofisika Pasuruan, Digi Stamet Banda Aceh, Digi Stamet Kupang, and Digi Stamet Merauke, respectively. The data further covered five big and three small Indonesian islands, such as Sumatera (Banda Aceh), Java (Pasuruan), Kalimantan (Sambas), Sulawesi (Makassar), Papua (Merauke), Bali (Denpasar), Nusa Tenggara (Kupang), and Maluku (Ambon). Furthermore, statistical analysis was used in analyzing the potency of the solar energy implementation. Several Indonesian time zones were also used in this study, such as WIB (Western Indonesian Time, 7 hours ahead of UTC), WITA (Central Indonesia Time, 8 hours ahead of UTC), and WIT (Eastern Indonesia Time, 9 hours ahead of UTC). The policies of solar energy implementation were further analyzed by reviewing Ministerial Regulations of Industry No. 04 and 05 in 2017, as well as Energy and Mineral Resources No. 50 and 49 in 2017 and 2018, respectively. As for the Cost-Benefit Analysis, the review of previous literatures was carried out. Further description of this study is shown in Figure 1.

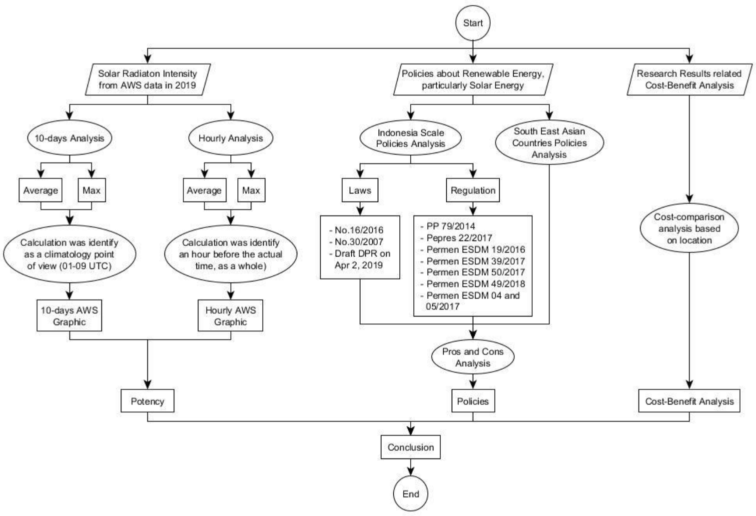

Figure 1. Research Framework

RESULT AND DISCUSSION

Potency

Based on Figure 2, the average value of solar radiation intensity in Banda Aceh is 269-690 W/m^2 per ten days. This showed that the average minimum and maximum values were observed in December and July 2019, respectively. Meanwhile, the total value for one year was 487 W/m^2. The maximum value of solar radiation intensity was observed during the second ten days in May, at 1179 W/m^2. According to the hourly chart interpretation in Figure 3, the average maximum value is observed at 617 W/m^2 at 12.00 WIB. In addition, the maximum values of solar radiation intensity were 1179 and 1178 W/m^2 at 12.00 and 14.00 WIB, respectively.

Figure 4 shows that the average value of solar radiation intensity per ten days in Pasuruan is 394-698 W/m^2, as the missing data for August and early September within the AWS caused the blank spaces on the graph. The average minimum and maximum values were also observed in February and October 2019, respectively. However, the total average value for one year was 535 W/m^2. The maximum value of solar radiation intensity was further observed within the first ten days in February, at 1278 W/m^2. According to the hourly chart interpretation in Figure 5, the average maximum value is 719 W/m^2 at 12 WIB. In addition, the maximum values of solar radiation intensity were observed at 12.00 and 13.00 WIB, respectively.

Based on Figure 6, the average value of solar radiation intensity per ten days in Sambas is 282-529 W/m^2. This showed that the average minimum and maximum values were observed in September and June 2019, respectively. Meanwhile, the total average value for one year was 395 W/m^2. The maximum value of solar radiation intensity was further observed within the second ten days in October, at 1272 W/m^2. According to the hourly chart interpretation in Figure 7, the average maximum value is 570 W/m^2 at 11.00 WIB. In addition, the maximum values of solar radiation intensity were 1271 and 1267 W/m^2 at 12.00 and 13.00 WIB, respectively.

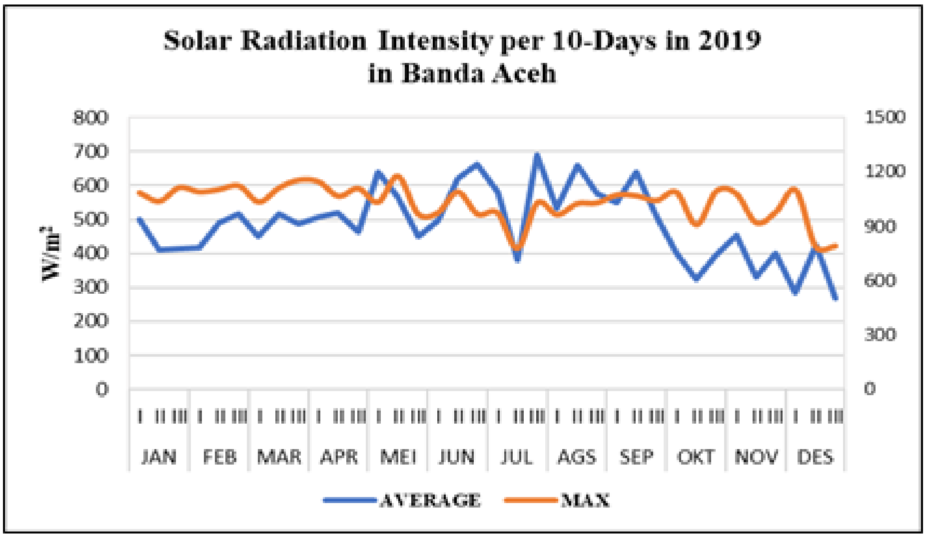

Figure 2. Banda Aceh solar radiation intensity in 2019 per ten days

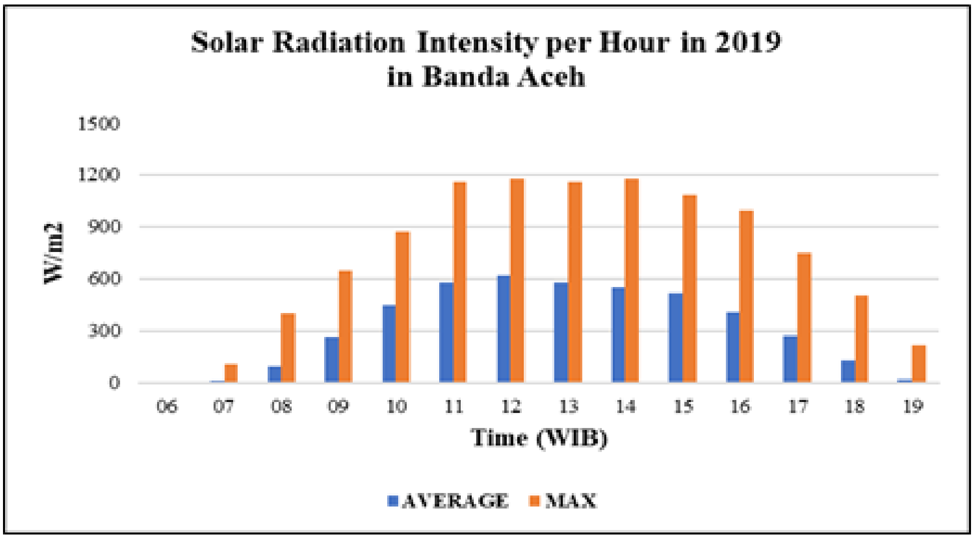

Figure 3. Banda Aceh solar radiation intensity in 2019 per hour

Figure 8 shows that the average value of solar radiation intensity per ten days in Denpasar is 353-634 W/m^2. It also indicated that the average minimum and maximum values were observed in August and February 2019, respectively. However, the total average value for one year was 487 W/m^2. The maximum value of solar radiation intensity was further observed within the second ten days in March, at 1327 W/m^2. According to the hourly chart interpretation in Figure 9, the average maximum value is 758 W/m^2 at 12.00 WITA. In addition, the maximum values of solar radiation intensity were 1326 and 1265 W/m^2 at 14.00 and 12.00 WITA, respectively.

Based on Figure 10, the average value of solar radiation intensity per ten days in Makassar is 326-680 W/m^2. This showed that the average minimum and maximum values were observed in January and September 2019, respectively. Meanwhile, the total average value for one year was 563 W/m^2. The maximum value of solar radiation intensity was further observed within the first ten days in February, at 1314 W/m^2. According to the hourly chart interpretation in Figure 11, the average maximum value is 690 W/m^2 at 13.00 WITA. In addition, the maximum values of solar radiation intensity were 1314 and 1252 W/m^2 at 13.00 and 14.00 WITA, respectively.

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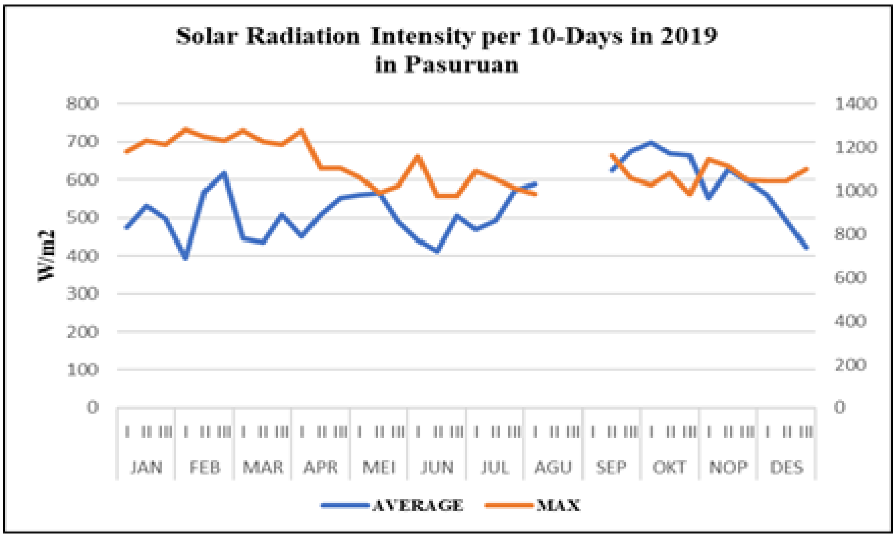

Figure 4. Pasuruan solar radiation intensity in 2019 per ten days

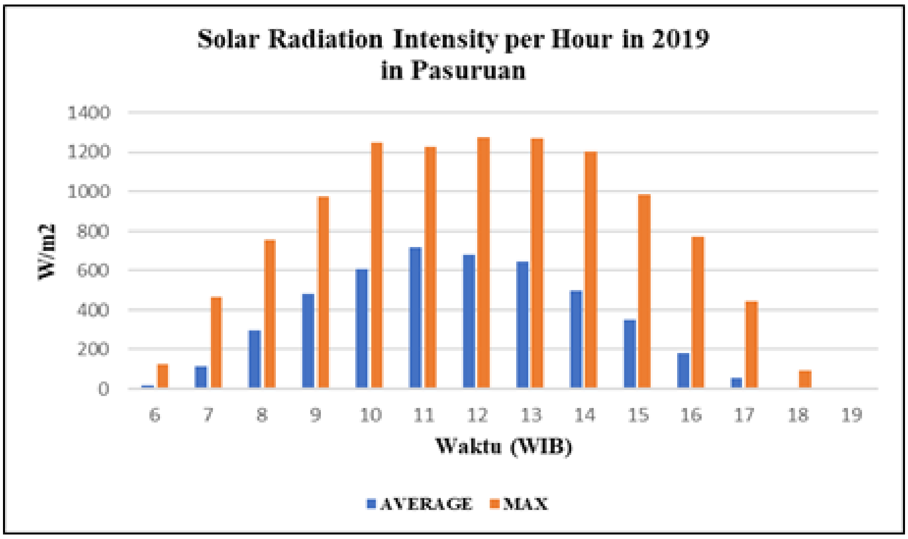

Figure 5. Pasuruan solar radiation intensity in 2019 per hour

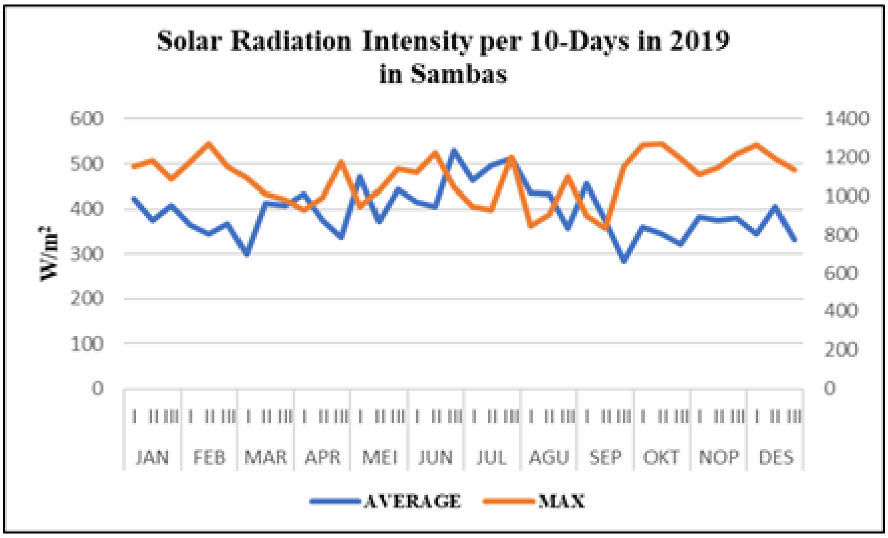

Figure 6. Sambas solar radiation intensity in 2019 per ten days

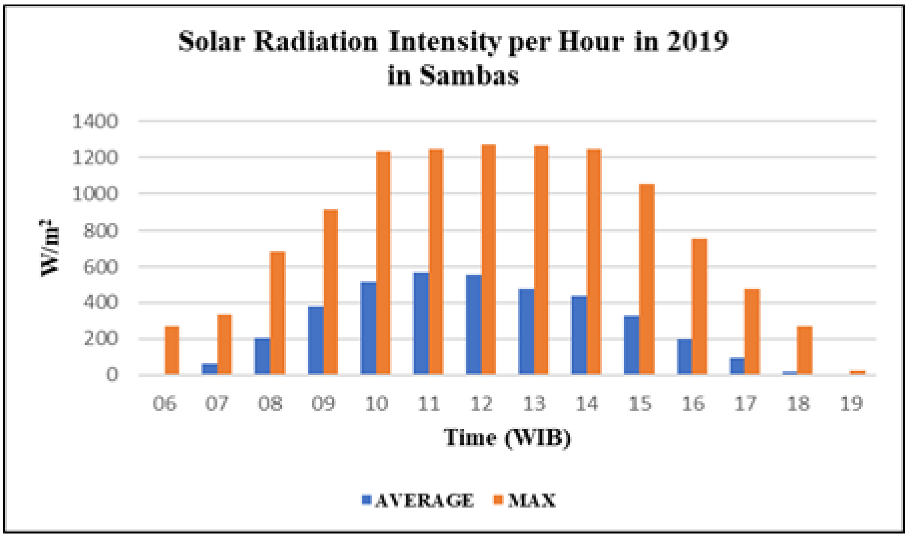

Figure 7. Sambas solar radiation intensity in 2019 per hour

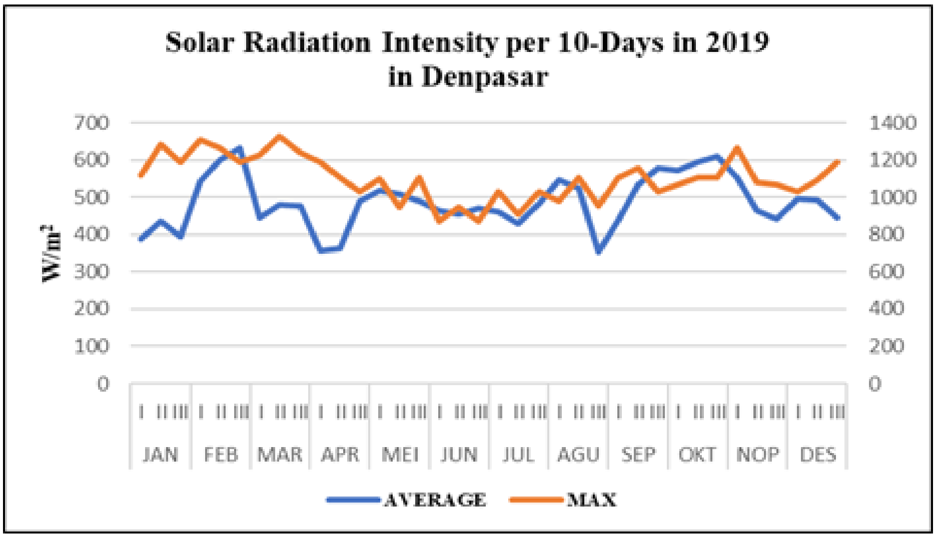

Figure 8. Denpasar solar radiation intensity in 2019 per 10 days

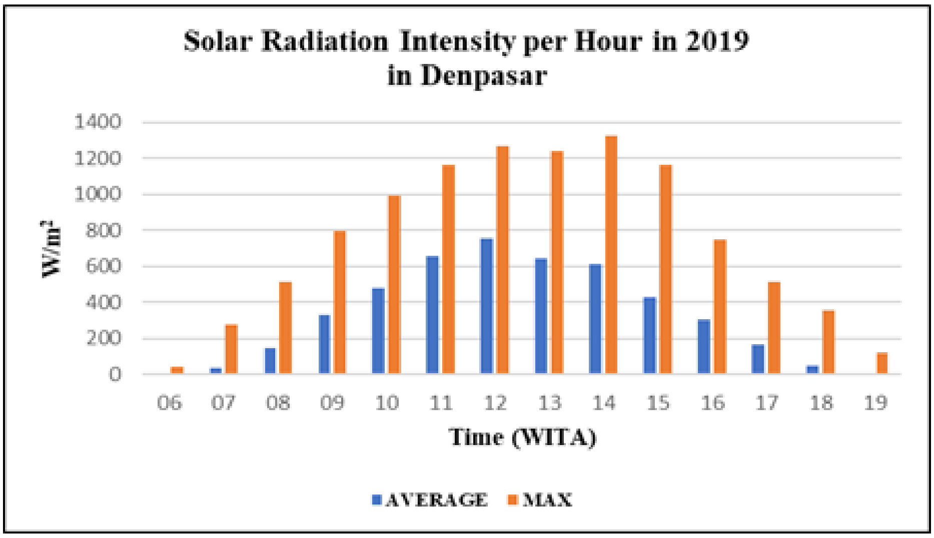

Figure 9. Denpasar solar radiation intensity in 2019 per hour

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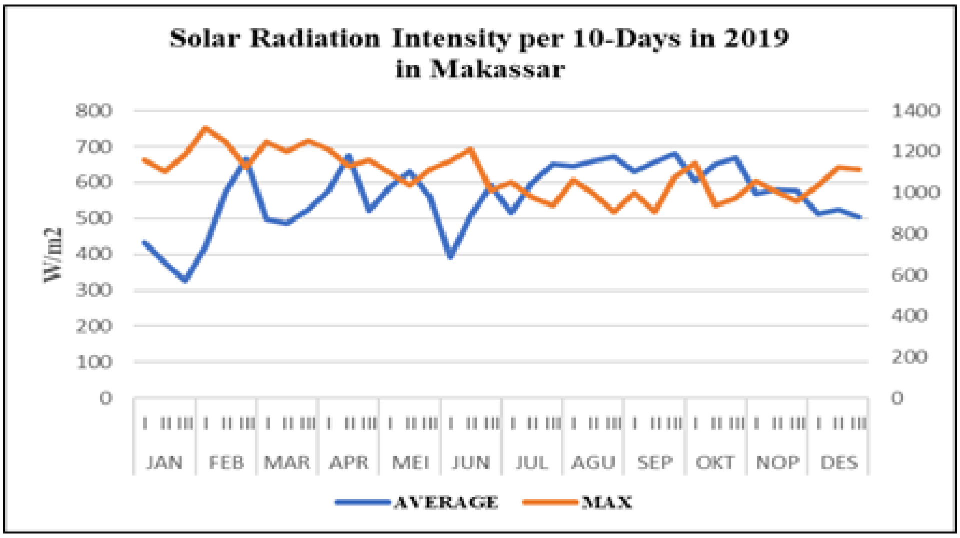

Figure 10. Paotere solar radiation intensity in 2019 per 10 days

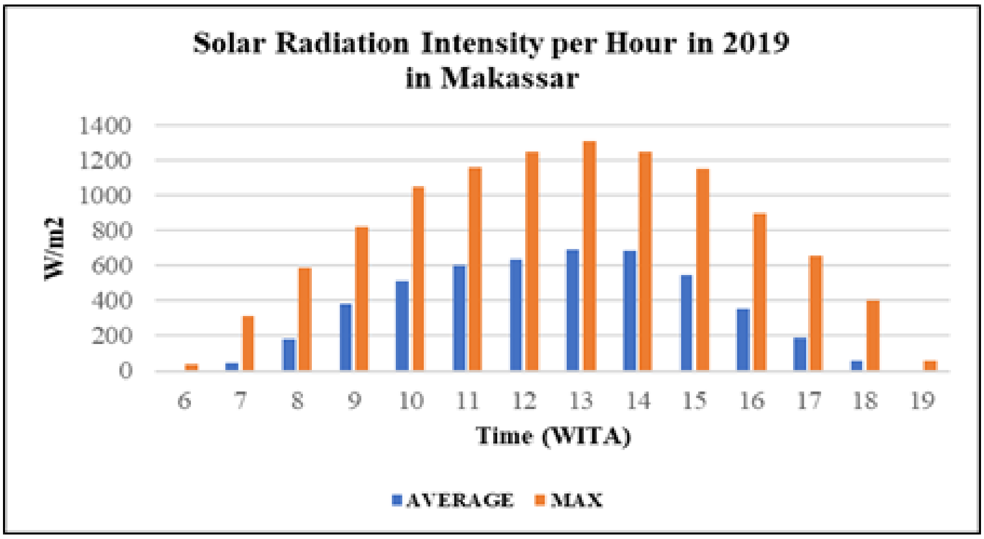

Figure 11. Paotere solar radiation intensity in 2019 per hour

Figure 12 shows that the average value of solar radiation intensity per ten days in Kupang is 227-487 W/m^2. It also indicated that the average minimum and maximum values were observed in January and November 2019, respectively. However, the total average value for one year was 403 W/m^2. The maximum value of solar radiation intensity was further observed within the third ten days in January, at 1137 W/m^2. According to the hourly chart interpretation in Figure 13, the average maximum value is 634 W/m^2 at 11.00 WITA. In addition, the maximum values of solar radiation intensity were 1314 and 1087 W/m^2 at 13.00 and 12.00 WITA, respectively.

Figure 14 shows that the average value of solar radiation intensity per ten days in Ambon is 159-580 W/m^2. It also indicated that the average minimum and maximum values were observed in July and February 2019, respectively. Meanwhile, the total average value for one year was 388 W/m^2. The maximum value of solar radiation intensity was further observed within the second ten days in February, at 1604 W/m^2. Based on the hourly chart interpretation in Figure 15, the average maximum value is 559 W/m^2 at 12.00 WIT. In addition, the maximum values of solar radiation intensity were 2000 and 1393 W/m^2 at 11.00 and 12.00 WIT, respectively.

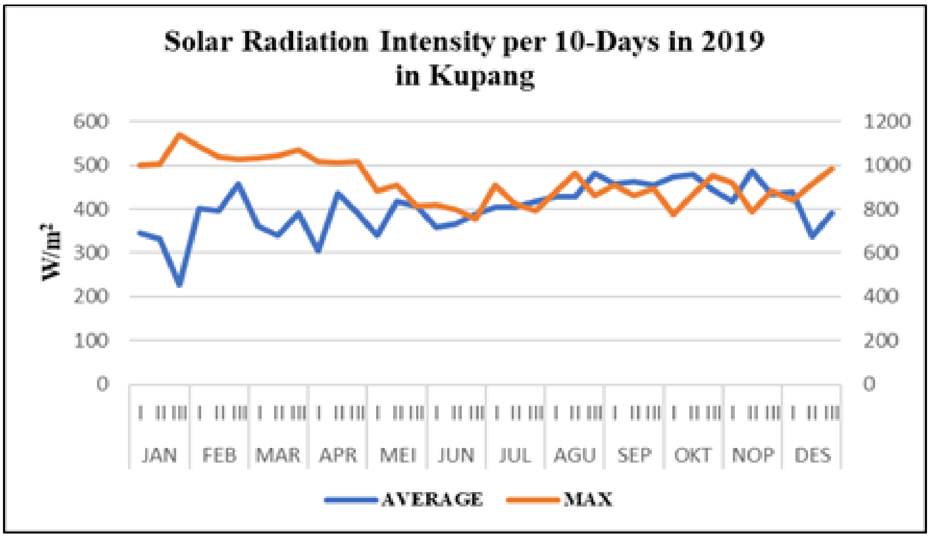

Figure 12. Kupang solar radiation intensity in 2019 per 10 days

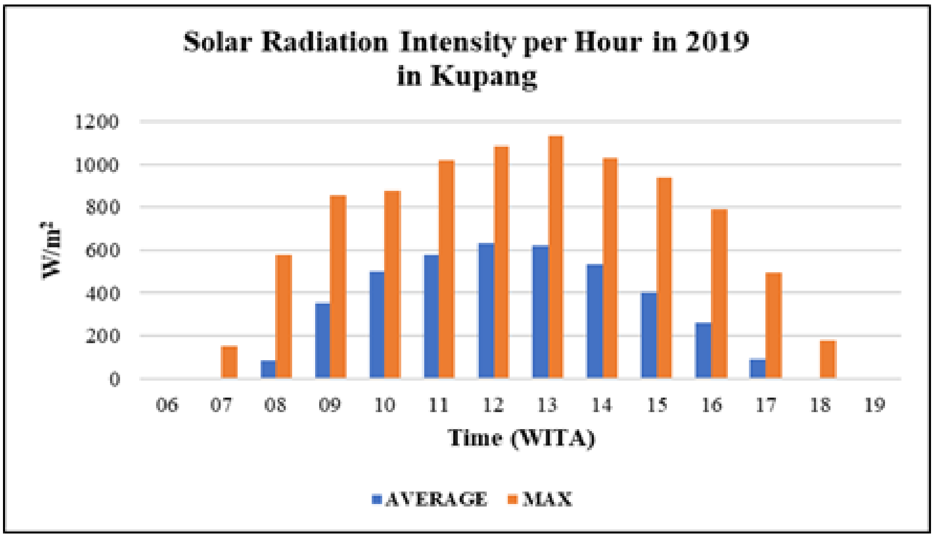

Figure 13. Kupang solar radiation intensity in 2019 per hour

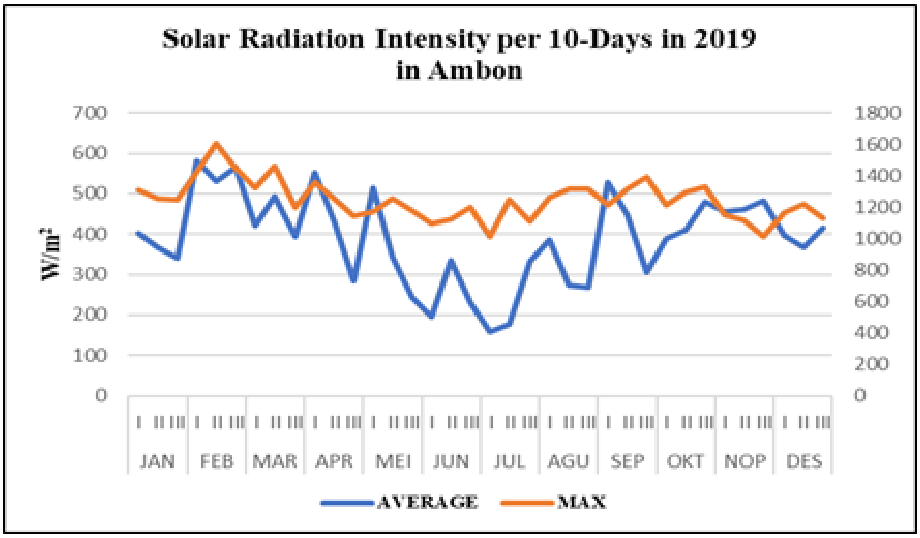

Figure 14. Ambon solar radiation intensity in 2019 per 10 days

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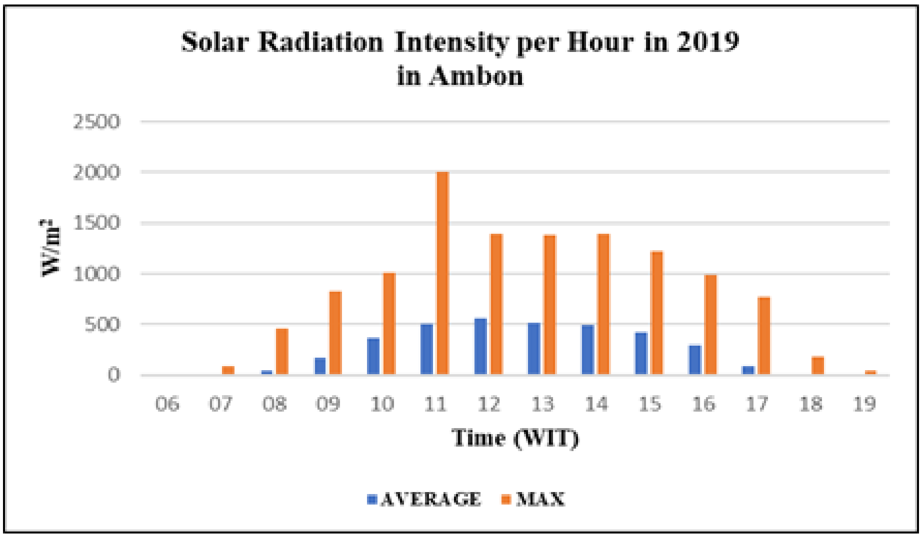

Figure 15. Ambon solar radiation intensity in 2019 per hour

Based on Figure 16, the average value of solar radiation intensity per ten days in Merauke is 299-749 W/m^2. This showed that the average minimum and maximum values were observed in June and November 2019, respectively. However, the total average value for one year was 521 W/m^2. The maximum value of solar radiation intensity was further observed within the first ten days in October, at 1394 W/m^2. According to the hourly chart interpretation in Figure 17, the average maximum value is 627 W/m^2 at 13.00 WIT. In addition, the maximum values of solar radiation intensity were 1394 and 1363 W/m^2 at 11.00 and 13.00 WIT, respectively.

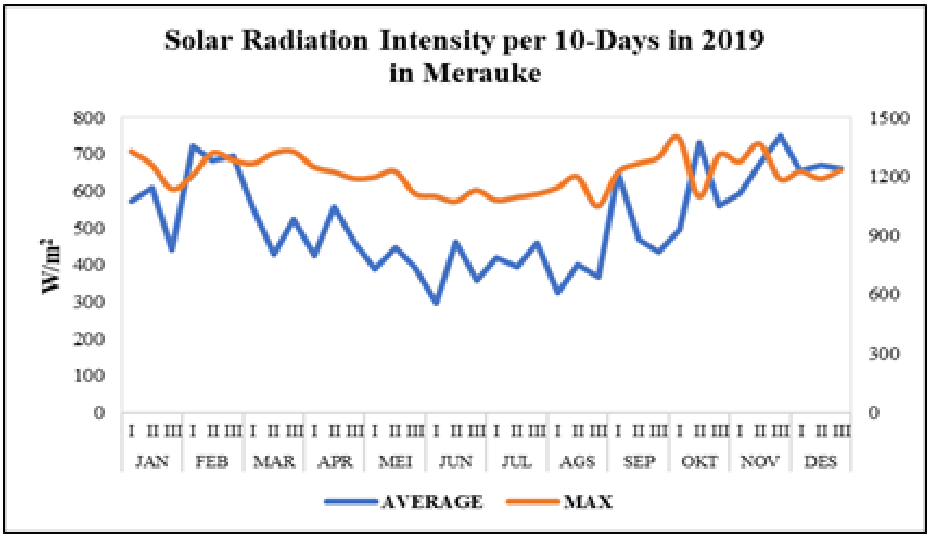

Figure 16. Merauke solar radiation intensity in 2019 per 10 days

The potential intensity of solar radiation (SR) averagely ranged between 150-750 W/m^2 in Indonesia, where sunlight was quite much in the Kupang, Ambon, and Merauke areas. When comparing the solar panel capacity development plan, the values of utilized sunlight intensity through PLTS ranged between 0.030-0.077, 0.025-0.064, 0.023-0.045, 0.010-0.024, 0.010-0.024, 0.023-0.042, 0.007-0.016, and 0.117-0.325%, in Banda Aceh, Pasuruan, Sambas, Denpasar, Makassar, Kupang, Ambon, and Merauke, respectively. In this study, the 2019 potential for solar radiation intensity generally increased than the 2014 data, based on the Presidential Regulation Draft of the Republic of Indonesia concerning the national energy policy (BAPPENAS, 2012). Furthermore, Table 2 shows that the potencies in Denpasar, Kupang, Maluku, and Merauke have significantly increased. According to the climatological conditions of these areas, Kupang, Merauke, and Maluku obtained quite a lot of sunlight, which had an equatorial or local type of season when compared to other regions. The potentials for PLTS development in these areas were also quite effective when realized.

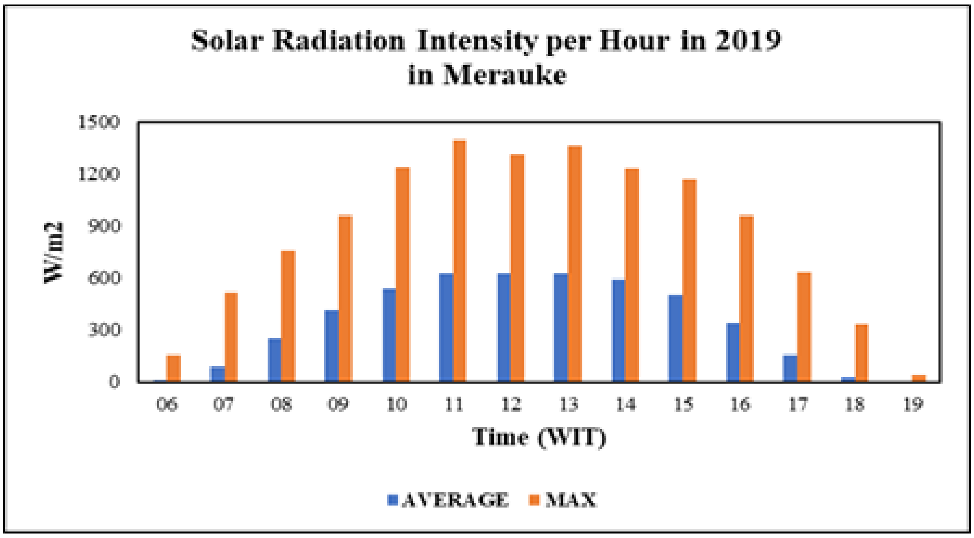

Figure 17. Merauke solar radiation intensity in 2019 per hour

Table 2. SR intensity potency in 2019 compared with PLTS capacity that the government planned in 2019

Region	Area (km²)	SR Intensity Potency in 2014 (MW)	SR Intensity Potency in 2019 (W/m²)		PLTS capacity that the government planned in 2019	Percentage (%)	
			Min	Max		Min	Max
Banda Aceh	61,36	7,881	269	690	12,7	0,030	0,077
Pasuruan	76,79	10,335	394	698	13,2	0,025	0,064
Sambas	198,76	20,113	282	529	24,3	0,023	0,045
Denpasar	127,78	1,254	353	634	8,2	0,010	0,024
Makassar	175,77	7,588	326	680	11,5	0,010	0,024
Kupang	180,27	7,272	227	487	20,3	0,023	0,042
Ambon	359,45	3,035	159	580	15,3	0,007	0,016
Merauke	45,07	2,035	299	749	39,4	0,117	0,325

Policy

According to the National Medium-term Development Plan (2020-2024), the Government of Indonesia had a policy and strategy to meet the access, energy consumption, as well as electricity equality, reliability, efficiency, and sustainability, through the diversification of power. This was based on utilizing solar rooftop and floating power plant, as well as the industrial development of cosmic cells. Furthermore, the Peraturan Presiden No. 18/2020 showed that the target was 134.6, 328.8, 339.1, 643.2, and 643.7 MW in 2020, 2021, 2022, 2023, and 2024, respectively, with the budget allocation estimated at Rp. 17,931.6 billion. The executor was also noted to involve the Ministry of Energy and Mineral Resources, Stated-owned Enterprises of Indonesia (BUMN), and the private sector. The commitment of Indonesia was further strengthened through the first Nationally Determined Contribution (NDC) document in November 2016, with the stipulations of unconditional and conditional targets of 29 and 41%, compared to the Business As Usual (BAU) scenario in 2030 (KESDM, 2016).

Based on the sub-sector of renewable energy to reduce greenhouse gas emissions, Indonesia ratified the Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC) in Law No. 16/2016, which stated that the target of mitigation was 170.42-million-ton CO_2e. Law No. 30/2007 was also regulated based on new and renewable energy resources, which were arranged by the state and utilized for the prosperity of the society. These were mandatory for the central and local governments, due

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to their authority on energy provision until the accomplishment of economic values. On April 2nd, 2019, The House of Representatives in The Republic of Indonesia (DPR-RI) on specifically had the draft of the Law layout on new and renewable energy resources. This showed that prices of renewable energy resources had been set by the central government based on fair economic value, through the reasonable consideration of Business Entity rates as follows,

- input rates based on the type, characteristics, technology, location, and the installed capacity of power plants from renewable energy resources,
- the market index price for biofuels,
- the reverse auction mechanism for obtaining the most efficient price for solar power electricity generation, with a capacity of more than 10 MW.

According to the Regulations of Government 79/2014 and President 22/2017 on National Energy Policy and General Plan, respectively, the direction of policies involved the maximization of renewable/clean energy, minimization of crude oil, as well as the optimization of natural gas and new power. It also involved the use of coal as a mainstay of national energy supply, and the utilization of the nuclear power as the last option. In 2018, renewable energy reached 8.55%, with the target expected to reach 23 % in 2025. Furthermore, the Annex of Ministerial Regulation of Energy and Mineral Resources (ESDM) No. 39/2017, stated that solar power electricity generation (PLTS) had the selling price at Rp. 750/kWh. This was useful based on the expectation of increased user demand in the society. The government also replaced the PLTS scheme with a First in First Out (FIFO) mechanism. The weakness of this mechanism was the higher payment of tax to the government, and the less accuracy of the profit generated. These were already stated in the Ministerial Regulation of ESDM No. 19/2016.

The Ministerial Regulation of ESDM Resources No. 50/2017, contained the Basic Cost of Provision (BPP) for the power generation from renewable energy. This regulation stipulated the purchase of PLTS Photovoltaic (PV) electricity at a maximum BPP value of 85% in the local electricity system. The Build Own Operate Transfer (BOOT) scheme whose power plant assets were constructed by private developers, also became the property of the State Electricity Company (PLN) after the end of their contract. This was because private developers were not interested in building power plants from EBT. Using the BOOT scheme, the barriers of this regulation are generally direct, based on the capacity quota, price of power, and cooperation pattern. Moreover, the Ministerial Regulation of ESDM No. 49/2018 showed the electricity formula calculation for rooftop PLTS to PLN. In this regulation, the calculation of the electricity for rooftop PLTS customers focused on the export-import kWh value, multiplied by 65% of the power tariff. However, the export value was initially calculated as 100%. With this formula, electricity sales to PLN was discounted by 35%. This indicated that industrial consumers need to pay the capacity and emergency charges, as Operation Eligibility Certificate (SLO) is not included. In addition, the Ministerial Regulation of ESDM No. 04 and 05 in 2017, contained the utilization of TKDN (Component Level of Home Affairs) for the electricity generation from renewable energy. The TKDN for PLTS was set at 60%, although the national product of Indonesia did not meet the requirements. When TKDN did not reach 60%, the government did not also grant permission to the contractors.

Based on belonging to the Association of Southeast Asian Nations (ASEAN), Indonesia should learn from neighboring successful countries, in terms of implementing renewable energy (especially solar power). Singapore is found to be the first in implementing sustainable energy policies (71.2), accompanied by Malaysia (68.5), Brunei (67.7), Thailand (64.6), and Indonesia (64.1). Indonesia is quite brave to set an expected medium-term target of 23% for renewable energy share in 2025. Based on the long-term target plan, Thailand was optimistic to set the share of renewable energy at 49% in 2037 (Eco-Business, 2020). The comparison of pros and cons for the solar energy policy implementation is shown in Table 3.

Table 3. Pros and Cons of Solar Energy Policy Implementation in Southeast Asia

Region	Pros	Cons	Remarks
Malaysia	In 2011, the Government of Malaysia presented a Feed-in Tax (FiT) law plot for its resident, to produce additional monthly pay by the sun-powered PV boards. The FiT framework of Malaysia obliged Dispersion Licensees (DLs) to purchase and set sustainable asset	The satisfaction level dropped because of the existing limit of the framework and also the decreased energy charge. Also, cash was discovered to be the most critical concerning factor for the low-pay family bunch.	(Malik & Ayop, 2020)

	electricity rate from Feed-in Approval Holders (FiAHs).		
Brunei Darussalam	A feed-in tariff scheme produced more social benefits than net billing schemes.	A feed-in tariff plan required a more significant sponsorship level. It contrasted higher monetary weight shoppers, and the self-utilization plots in executing the proposed 5-year roof sun, based on the PV arrangement program.	(Pacudan, 2018)
Singapore	In 2014, Singapore's energy regulator proposed a comprehensive framework that provided and distributed Photovoltaic (PV) system through the option of net metering, based on the nameplate capacity of the structure and the contestability status of the consumer. The contestable consumers were accorded with some benefits, such as the option not to register as a market participant in the wholesale market, however, receive or make payments through a central intermediary.	A Feed-in-tariff scheme has not existed yet, leading to the observation of some financial challenges. Firstly, the profit margins of solar developers fluctuated. Secondly, the payback periods were more extended than usual when the discount were on the regulated tariff, since most solar electricity users were industrial and commercial consumers.	(Midford & Moe, 2021)
Thailand	The Consumer Price Index (CPI) was positively significant at 5% for the supply of solar energy. An increase in CPI also improved the quantity of solar production.	Under the Feed-in-tariff policy, the electricity purchase price sets solar supply technology as the most expensive source of renewable energy.	(Tharisung, 2020)
Indonesia	The Rooftop Photovoltaic Solar Systems (RPVSS) policy was valued at 65% of the total retail tariff. This policy allowed customers of the State Electricity Company (PLN) to generate their power supply from solar photovoltaic (PV) systems, and also export surplus energy to the national grid.	Uncompetitive electricity export rate and the absence of government financing, as the economic factor is the most important in the willingness of investors to purchase PV system.	(Setyawati, 2020)

Cost-Benefit Analysis (CBA)

The position of Indonesia in the equator line highly impacted the potentials of solar radiation. Several studies on renewable energy are also presently a trend, especially the use of solar panels. The policies regarding solar energy were set by the Government of Indonesia (GoI), within the draft of the Regulation of President layout on National Energy Policy (BAPPENAS, 2012). To implement this industrial goal, the installation of equipment components for Electricity Generation of Solar Power (PLTS) are encouraged. This device functions during the day (sunrise to sunset), through the use of a photovoltaic system (PV System). Without pollution from the powered generation system, the PLTS also uses solar radiation as the primary energy source. Therefore, the rate of greenhouse gas emissions completely decreases. The utilization of this device is limited during severe weather, due to the less effect of solar intensity. Besides these conditions, the development of PLTS is very expensive.

The utilization of electricity (kWh) is not counted within every sample location in this study. Furthermore, previous Cost-Benefit Analysis (CBA) results in other regions were used to compare the outcome of this present study, in order to determine the potency of solar radiation intensity in the sample locations. According to Pratama (2017), the utilization of PLTS was more beneficial than the other energy sources. This was because the low diffusion of renewable energy-based village networks were attributed to the lack of private sector investment. The responsibility for rural electrification mainly depends on the government, which often prefers centralized and conventional solutions. In Indonesia, the need for private investment support within the development program of a village network was based on renewable energy, where local

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photo voltaic-powered connection had negative abatement costs with significant potential in reducing carbon emissions (Blum et al., 2013).

Table 4. Cost-benefit analysis between solar PV and wind power generation (Abadi et al., 2016)

Calculation	Interest Rate			Calculation	Interest Rate		
	5%	9%	11%		5%	9%	11%
Cost of Generation (USD)	91399.1	91399.1	91399.1	Cost of Generation (USD)	12,381.47	12,381.47	12,381.47
Operational Age (year)	20	20	20	Operational Age (year)	20	20	20
Capacity (Kw)	600	600	600	Capacity (Kw)	600	600	600
Capital Costs (USD/KWH)	0.15284	0.18200	0.20290	Capital Costs (USD/KWH)	0.20671	0.24735	0.27561
Operational & Maintenance Cost (USD/KWH)	0.03285	0.03285	0.03285	Operational & Maintenance Cost (USD/KWH)	0.03285	0.03285	0.03285
Total Costs (USD/KWH)	0.18568	0.21485	0.23575	Total Costs (USD/KWH)	0.23956	0.28020	0.30846
Profit 10%	0.20425	0.23633	0.25933	Profit 10%	0.26352	0.30821	0.33931
Investment (USD)	5,483,950.64	5,483,950.64	5,483,950.64	Investment (USD)	7,428,881.29	7,428,881.29	7,428,881.29

Based on Table 4, the same operational age and capacity were indicated at 20 years and 600 kW, respectively. The benefit was calculated from a profit of 10 % and the nominal USD investment. The also analysis showed that Romang Island had renewable, solar, and wind energy potentials, respectively. This indicated that solar (solar cells) and wind (wind energy) power plants were likely to be developed. Using the Cost-Benefit Analysis (CBA) method, the results showed that the construction of solar power plants (PLTS) provided more excellent benefits compared to PLTB (wind power plants). In housing, the use of PLTS to meet electricity needs was economically less profitable. This was due to the high investment costs of the system (Patricia, 2012).

Based on rural areas, the use of PLTS to electrify households was cheaper (around 19 %) than the utilization of power plants with diesel generators (Veldhuis & Reinders, 2015). The configuration of PLTS in the NTT and Papua regions was quite good, due to the slight maximal comparisons to other provinces where costs were cheaper by 0.05 USD/kWh. The results showed also that the NTT and Papua regions had the potential for more solar radiation, although constrained by slight higher installation costs. This was because of the limited access to transportation and availability of resources. Furthermore, there was need for good plans ranging from the early funding of Solar Power Plants (SPP) investment, to the system maintenance, and other operational activities (Setiartiti & Hisjam, 2019). Stakeholders or investors also optimize the developmental activities of PLTS in Indonesia. This is because the application of the system contributes to the reduction of CO2 and pressure on power plants during electricity generation. In addition, the maximum intensity increased the peak hour output of the solar station, to reduce Levelized Cost of Electricity (LCOE).

Based on the demand value analysis for selected areas, Pasuruan had the highest demand, accompanied by Makassar, Ambon, Sambas, Denpasar, Kupang, Banda Aceh, and Merauke. The LCOE for a lifetime of 25 years were estimated at USD 0.005, 0.01, 0.095, 0.025, 0.06, 0.08, -0.005, and 0.005 in Pasuruan, Makassar, Ambon, Sambas, Denpasar, Kupang, Banda Aceh, and Merauke, respectively. The LCOE is the average net present cost of electricity generation (including investment, operational, maintenance, and insurance) for a supplying plant. The most expensive and cheapest costs were observed in Ambon and Banda Aceh, respectively.

There was a potential of economic benefit in Kuwait, which reduced LCOE from 0.2 to 0.09 USD/kWh in the utilization of renewable solar energy for domestic consumption (Ramadhan & Naseeb, 2011). The application of photovoltaic solar system was also recommended in Kuwait, to diversify the energy sources that depends on fossil fuels to generate electricity. This showed system efficiencies of 20 and 12% for lifetimes of 10 and 30 years at similar LCOE of 4.7 $/kWh, respectively (Cai et al., 2017). However, the lifetime literature related to the long-term stability was still limited, as increasing efficiency was an urgent task from the perspective of cost. Also, it was a vigorous effort in the development of photovoltaic system.

CONCLUSIONS

Based on being located on the equator line, Indonesia benefited from the renewable energy of solar radiation. This was confirmed by the results of the 10-days calculation in 2019, which showed average and maximum values of 388-563 and 1137-1604 W/m^2, respectively. The results also showed that the hourly average maximum values for Western, Central, and Eastern Indonesia were 570-719, 634-758, and 559-627 W/m^2, at 11.00-12.00 WIB, 11.00-13.00 WITA, and 12.00-13.00 WIT, respectively. The potency of solar radiation intensity was averagely 150-750 W/m^2 in Indonesia, where the high values were observed in East Nusa Tenggara, Maluku, and Merauke.

The main opportunity was The Rooftop Photovoltaic Solar Systems (RPVSS) policy, which allowed the customers of the State Electricity Company (PLN) to have 60% of the total retail tariff. However, the main problems for the intention of investors were an uncompetitive electricity export rate and the absence of government finances. Due to the ineffective implementation of Feed-in-tariff (FITs) scheme in Indonesia, it is recommended that the country should learn from its neighbors within the ASEAN region, e.g., Singapore.

Based on the cost-benefit analysis (CBA) through the Levelized Cost of Electricity (LCOE), the most expensive and cheapest expenses were observed in Ambon and Banda Aceh, respectively. As the overall connection for this study, the potency for solar energy was relatively high, although the existing policies of Indonesia had not adequately guaranteed the effective conversion of fossil fuels into renewable power. The CBA perspective emphasized that most Indonesian eastern region had the most expensive cost, while the potency implementation of solar energy was also relatively high.

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