A Technical and Economic Potential of Solar Energy Application with Feed-in Tariff Policy in Indonesia

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Abstract

This paper presents a technical and economic potential of Solar Energy Application in Indonesia. Indonesia consists of thousands islands. Meanwhile, according to the latest data from the Department of Energy and Mineral Resources in 2012, Indonesia’s electrification ratio is only around 74%. Renewable energy especially solar energy is one of the most potential energy sources as Indonesia lies in the equator line where the daylight is abundant and available throughout the year. The solar energy technology is also eco-friendly and its application has the potential to reduce the greenhouse gas emission. A review of solar energy potential in Indonesia based on the solar resource data is presented. Estimation of solar resource in Indonesia was done using solar radiation data from NASA Surface Meteorology and Solar Energy (SSE). Retscreen software was used for all of the calculation in the study. It is found that the proposed system can generate electricity annually vary from 0.46 GWh/year in Denpasar to 217 GWh/year in Pontianak. This paper also calculates the economic viability through pre-tax IRR and simple payback indicator. It was observed that the highest IRR was observed in Makassar and the lowest IRR was observed in Banjarmasin. Meanwhile, it can be observed that Makassar got the shortest payback period for 11 years and Banjarmasin got the longest payback period of 17.6 years. From the side of environmental impact, the proposed system can reduce the GHG emission up to 243252 tons per year in particular selected location.

Keywords: Solar energy potential; grid-connected PV system; economic analysis; green house gas emission; feed-in tariff policy

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1. Introduction

Indonesia is still struggling in increasing its electrification ratio. In 2012, the electrification ratio is only 74% [1]. State Electricity Company (PLN) has set a target to increase the electrification ratio by 2-3% in year 2013. In order to achieve this target, Indonesia government sets some projects by constructing 10,000 MW power plant. Most of them will come from coal power plant. Despite its low electrification ratio, electricity consumption in Indonesia has also been rapidly increasing since 1990 (over 8.5% each year). The share of electricity in energy consumption has now increased to 9% in 2010 from 3% in 1990. Construction of power plant is definitely needed.

Indonesia itself lies in the equatorial line of earth. Its climate is tropics. Daylight is abundant in this area as it is available throughout the year. Therefore, solar energy can be one of the best solutions to provide electricity. The government itself has committed to increase the electrification ratio by maximizing the electricity generation through renewable energy especially solar energy. Indonesia government has targeted the capacity installed from solar energy up to 0.87 GW by 2025 [2]. To reach that target, the government has decided to have a feed-in tariff for solar energy as an incentive to grow the interest in developing solar energy in Indonesia [3]. This policy is expected to increase the installation of grid-connected photovoltaic (PV) system. Such policy has been implemented and also been studied in a number of countries such as United Kingdom [4], Ukraine [5], Australia [6], Spanish [7], Taiwan [8], Germany [9], even in Tanzania [10] and other countries.

A number of research have been conducted to show the solar energy potential in Indonesia [11-12] and other countries [13-18]. However, no paper has reported including feed-in tariff as an aspect in the research. This can be accepted as feed-in tariff policy is quite new in Indonesia. Greenhouse gas emission has been a big issue for quite a while as it is strongly related to climate change. Indonesia relies most of its electricity generation to fossil fuel power plant. This will obviously increase the greenhouse gas to the atmosphere. The use of renewable energy such as solar PV power plant to substitute fossil fuel power plant can reduce the greenhouse gas emission. Unfortunately, no paper reported about the potential of Solar PV application in reducing the Green House Gas emission in Indonesia. Furthermore, this paper aims to study the feasibility and potential of a grid-connected PV system in the techno-economic and environmental aspect.

2. Retscreen Software

Retscreen software [19] is a free software developed by the government of Canada. This software is mainly used for simulating and calculating a clean energy project such as renewable energy, energy efficiency and cogeneration (combined heat and power) projects. There are two types of retscreen software which are widely used, retscreen 4 and retscreen plus. Retscreen 4 is an excel-based software and retscreen plus is a windows-based software. The softwares can be used to determine the technical and financial viability of a such clean energy project. In this paper, all calculations were done by retscreen 4 and retscreen plus to get a more precise technical and financial viability calculation.

3. Solar Resource Potential in Indonesia : Site selection and its annual solar potential

3.1. Site selection and Proposed PV Grid-Connected System

In this paper, the proposed solar power plant is assumed to be built to cover the peak load in each provinces. Table 1 shows the electricity condition in Indonesia in each selected province. The locations for case studies were selected based on the electricity condition. Since the load factor was bigger than the peak load, the province was chosen as a case study in this paper. As in this paper, greenhouse gas emission reduction is calculated, only certain location is chosen. This is related to the data of emission factor calculation of grid interconnecting system which is provided by the department of energy and mineral resources. Emission factor data is only available for electricity interconnecting system in Java, Madura, Bali, Sumatra, Kalimantan and Sulawesi. Thus, provinces outside those islands were not chosen as case studies. Load demand for this case that will be supplied by the proposed solar power plant is determined by using (1).
\[ \text{Demand} = \text{Load factor} - \text{Peak load} \]  

(1)

After calculating the demand, solar power plant (SPP) capacity can be calculated by using (2).

\[ \text{SPP Capacity} = 1.3 \times \text{Demand} \]  

(2)

As can be seen in Table 1, the highest peak load and demand comes from Sulawesi Selatan province which is located in the south part of Sulawesi island resulting the highest solar power plant capacity of 435 MW. The lowest one is Bali with only 2.45 MW on peak load and 0.22 MW of demand, resulting the lowest solar power plant capacity of 0.29 MW. Electrification ratio is somewhat different. Riau has the lowest electrification ratio of 54.8% and Nanggroe Aceh Darussalam gets the highest one with 87.21%.

### Table 1 Selected locations, its current electricity status and its proposed solar plant capacity

| Province                  | Load factor (MW) | Peak load (MW) | Demand (MW) | Electrification Ratio | Solar Plant Capacity (MW) | Area needed (m²) |
|---------------------------|------------------|---------------|-------------|-----------------------|--------------------------|-----------------|
| Nanggroe Aceh Darussalam  | 89.2             | 92.12         | 2.92        | 87.21                 | 3.79                     | 25,608          |
| Sumatera Utara            | 7.91             | 20.07         | 12.16       | 80.11                 | 15.81                    | 106,824         |
| Sumatera Barat            | 19.42            | 23.67         | 4.25        | 76.21                 | 5.52                     | 37,297          |
| Riau                      | 49.33            | 139.73        | 90.4        | 54.8                  | 117.52                   | 794,054         |
| Sumatera Selatan          | 4.3              | 4.74          | 0.44        | 65.18                 | 0.57                     | 3,851           |
| Bengkulu                  | 13.84            | 17.91         | 4.07        | 64.48                 | 5.29                     | 35743           |
| Kalimantan Barat          | 174.45           | 282.68        | 108.23      | 64.86                 | 140.69                   | 950,608         |
| Kalimantan Selatan        | 224.96           | 285.1         | 60.14       | 73.95                 | 78.18                    | 528,243         |
| Kalimantan Tengah         | 53.67            | 58.4          | 4.73        | 52.97                 | 6.15                     | 41,554          |
| Kalimantan Timur          | 200.35           | 264.38        | 64.03       | 61.48                 | 83.24                    | 562,432         |
| Gorontalo                 | 19.5             | 116           | 96.5        | 67.38                 | 125.45                   | 847,635         |
| Sulawesi Selatan          | 266.54           | 601.2         | 334.66      | 71.97                 | 435.06                   | 2,939,595       |
| Bali                      | 2.23             | 2.45          | 0.22        | 68.63                 | 0.29                     | 1,959           |

3.2. Annual solar radiation average in selected locations

Due to the lack of weather station data in Indonesia especially on solar resource data, online data provided by NASA Surface Meteorology and Solar Energy (SSE) was used [20]. An average annual data from 1985-2005 was used in this paper. As mentioned in Part 3.2, 12 locations were selected. The selected locations can be seen in Table 1 and Table 2. Since the proposed system is a PV grid connected system, a certain location which is near the grid system in every province should be selected. The certain selected locations can be seen in Table 2. The data in Table 2 was taken from NASA SSE data. NASA SSE stated that all of their daily irradiation data was measured at 10 m above the ground surface. It can be seen that Makassar area has the highest solar radiation potential with 5.88 kWh/m²/day. Meanwhile, Medan has the lowest with 4.55 kWh/m²/day. This indicates that Indonesia, theoretically, has a great potential for developing solar power system as its average daily radiation is above 4 kWh/m²/day annually.

### Table 2 Certain selected locations and its average daily radiation

| Province                  | Certain location | Elevation (m) | Latitude ('N) | Longitude ('E) | Radiation (kWh/m²/day) |
|---------------------------|------------------|---------------|--------------|----------------|------------------------|
| Nanggroe Aceh Darussalam  | Banda Aceh       | 172           | 5.6          | 95.3           | 5.1                    |
| Sumatera Utara            | Medan            | 25            | 3.6          | 98.7           | 4.55                   |
| Sumatera Barat            | Padang / Tabing  | 3             | -0.9         | 100.4          | 4.91                   |
| Riau                      | Dumai            | 25            | 1.7          | 101.5          | 4.71                   |
| Sumatera Selatan          | Palembang        | 9             | -3.0         | 104.8          | 4.67                   |
| Bengkulu                  | Bengkulu         | 488           | -3.8         | 102.3          | 4.79                   |
| Kalimantan Barat          | Pontianak        | 40            | 0.0          | 109.3          | 5.12                   |
| Kalimantan Selatan        | Banjarmasin      | 22            | -3.3         | 114.6          | 5.07                   |
| Kalimantan Tengah         | Palangka Raya    | 53            | -2.2         | 113.9          | 4.87                   |
| Kalimantan Timur          | Bontang          | 63            | 0.1          | 117.5          | 4.78                   |
| Gorontalo                 | Gorontalo        | 287           | 0.6          | 123.1          | 5.14                   |
| Sulawesi Selatan          | Makassar         | 14            | -5.1         | 119.6          | 5.88                   |
| Bali                      | Denpasar         | 1             | -8.8         | 115.2          | 5.34                   |
4. Technical and Economic Viability of Grid-Connected System in Indonesia

4.1. Technical specification and financial assumption

As it will take some time for the project to do feasibility study, engineering and procurement phase, this project is assumed to be constructed in the next 2 years ahead. A simple linear regression was used to estimate the value of solar panel installed. International price trend of solar panel installed was used for this study. Solar panel from BP-Solar was chosen for this study as it can be easily purchased in Indonesia. The efficiency is about 14.8% and BP Solar guarantees that its products have a lifetime until 25 years. Table 2 shows the detail technical specification of the solar panel that will be used for the study.

| Table 3 Solar panel specification |
|-----------------------------------|
| **Item**          | **Specification**           |
| Manufacturer      | BP Solar                   |
| PV Module type    | Mono-si                    |
| Module number     | BP Solar                   |
| Efficiency        | 14.8%                      |
| Frame area        | 1.24 m                     |
| Lifetime          | 25 years                   |

In this study, the panels will be installed horizontally. There is no need to install them at a particular angel as the selected locations are quite close with the equatorial line. Project life is assumed to be 25 years. Calculation of the total cost has been simplified. Feasibility study phase would cost 3% of the total cost, development phase would cost 5% of the total cost, engineering phase would cost 10% of the total cost. Cost of the construction phase (solar panel purchased and installation and others) would be 80% of the total cost. Table 4 shows some detail assumption and data which were taken for the financial analysis. As the government started to include feed-in tariff policy to develop the application of renewable energy, this paper also includes its policy to the calculation. The electricity export to the grid will be paid for $250/MWh by the government [21]. As can be seen on Table 4, we can also see that the larger the system, the cheaper the cost of solar panel installed.

| Table 4 Assumption taken for the study |
|----------------------------------------|
| **Parameter** | **Unit** | **Value** |
| Solar panel installed | $/Wp (> 100 kW) | 4.6 |
|                        | $/Wp (< 100 kW) | 5.3 |
| Inverter cost         | $/W          | 1    |
| Annual O&M            | $            | 50000|
| Inflation rate        | %            | 7%   |
| Feed-in Tariff        | $/MWh        | 250  |
| Project life          | Years        | 25   |
| Debt ratio            | Percent      | 70   |
| Debt interest rate    | Percent      | 11   |
| Debt term             | Years        | 10   |
| Electricity export escalation rate | % | 7 |
4.2. Techno-economic analysis

4.2.1. Techno analysis

Technical, specification and financial assumptions were inputted to the Retscreen Software. The software then calculated the electricity generated by the solar power plant. Fig. 1 shows the amount of electricity generated by the proposed system in each selected location. It can be seen that Makassar’s plant generated the highest electricity 762 GWh/year resulted an electricity export income of around $190 million in a year. The main reason for this is that Makassar’s high solar radiation falls on its surface. As can be seen in Table 2, among all the locations selected, Menado got the highest solar radiation for around 5.88 kWh/m²/day. Besides, the capacity of solar power plant that will be built in Makassar is also the biggest with 435.06 MW.

4.2.2. Financial Analysis

As we use calculation method I, in the financial module, Retscreen software calculated the Pre-tax IRR (internal rate of return) and simple payback. The internal rate of return IRR is the discount rate that causes the Net Present Value (NPV) of the project to be zero. The pre-tax IRR was calculated using pre-tax cash flows, while the after-tax IRR was calculated using the after tax cash flows. In this paper, we only calculate the pre-tax IRR. The highest IRR was observed in Makassar and the lowest IRR was observed in Banjarmasin. This can be seen in Fig. 2 (a). Meanwhile, the simple payback SP is the number of years it takes for the cash flow (excluding debt payments) equal to the total investment (which is equal to the sum of the debt and equity). From Fig. 2 (b), it can be observed that Makassar gets the shortest payback period for 11 years and Banjarmasin gets the longest payback period of 17.6 years.

4.3. Emission analysis

Greenhouse gas emission is one of the problems of fossil fuel power plant. This also happens in Indonesia as most of its electricity powered by the fossil fuel power plant. The application of the renewable energy such as solar power plant can reduce the greenhouse gas emission such as CO₂, CH₄ and N₂O. Retscreen software can help in the calculation of the greenhouse gas emission reduction. The calculation is based on the emission factor of the base system. Since Indonesia uses mix of power plant, this paper will use the emission factor from the interconnecting system in every location. The emission factor data has been provided by the government as can be seen in the Table 5 [23]. The emission factor in the interconnecting system uses 2 methods of ex-ante and ex-post as referred to UNFCCC guideline. Ex-ante emission factor uses 3 years data, while ex-post emission factor uses 1 year data. In this study, we will only use Ex-Ante method.
Fig. 2. Financial analysis of the solar system

Table 5. Emission factor of the interconnecting system in Indonesia

| Interconnecting System      | Selected location | Emission factor (tonCO2e/MWh) | Ex-Ante | Ex-post |
|-----------------------------|-------------------|-------------------------------|---------|---------|
| Java-Madura-Bali            | Serpong           | 0.741                         | 0.730   |         |
| Sumatera                    | Banda Aceh        | 0.748                         | 0.749   |         |
| Katulistiwa                 | Pontianak         | 0.748                         | 0.733   |         |
| Mahakam                     | Bontang           | 0.820                         | 0.861   |         |
| Minahasa-Kotabomagu         | Menado            | 0.319                         | 0.332   |         |
As can be seen in Fig. 3, the highest GHG reduction mitigation of 243,254 tons/year was observed in Makassar. Meanwhile, the lowest GHG emission reduction was observed in Palembang which only got 272 tons/year.

5. Conclusion

This study examines the technical and economic potential of solar photovoltaic-grid connected system in Indonesia. A new policy of the feed-in tariff is included in the study. This study proposed a solar power plant with grid connected to fill up the peak load demand in any locations selected. This study found that for the selected locations, the proposed system can generate electricity annually vary from 0.46 GWh/year in Denpasar to 217 GWh/year in Pontianak. From the financial analysis, it can also be found the highest IRR was observed in Makassar and the lowest IRR was observed in Banjarmasin. Meanwhile, it can be observed that Makassar gets the shortest payback period for 11 years and Banjarmasin gets the longest payback period of 17.6 years. With 25 years project lifetime, this shows that the application of Solar photovoltaic for grid-connected system is quite feasible financially. From the environmental aspect, this proposed system also proves that it can reduce the GHG emission. From all of this calculation, based on the technical, economic and environmental indicator, it can be seen that the application of the proposed system is quite feasible to supplement the electricity grid and supply electricity when the load demand is in peak period. Meanwhile, due to the high initial investment, a policy for investment subsidy is proposed.

References

1. Indonesian Statistical Bureau BPS.2011, BPS Strategic data, Badan Pusat Statistik.
2. PT. PLN (Electricity State Owned Company). Yearly electricity report, 2011 (Available online at http://www.pln.co.id/ntt/)
3. Republika. Government agrees the electricity cost from solar energy. 2013 (Available online at http://www.republika.co.id/berita/ekonomi/makro/13/03/10/mjgadn-pemerintah-sepakati-harga-listrik-tenaga-matahari)
4. Sukki, FM. Ramirez-Iniguez, R. Bakar Munir, A. Mohd Hasin, SH. Abu Bakar, SH. McMeekin, S. Steward, B. Revised feed-in tariff for solar photovoltaic in the Unite Kingdom: A cloudy future ahead ?. Energy Policy. 2013; 52:832-839.
5. Trypolska G. Feed-in Tariff in Ukraine: the only driver of renewables’ industry growth ?. Energy Policy. 2012; 45:645-653.
6. Zahedi A. A review on feed-in Tariff in Australia, what is now and what it should be. Renewable and Sustainable Energy Reviews. 2010; 14:3252-3255
7. Rodriguez J, Haas R. Fixed feed-in tariff versus premium: A review of the current Spanish system. Renewable and Sustainable Energy Reviews. 2012; 16:293-305
8. Huang YH, Wu J. Assessment of the feed-in tariff mechanism for renewable energies in Taiwan. *Energy Policy*. 2011; 39:8106-8115
9. Drechsler M, Meyerhoff J, Cornelia O. The effect of feed-in tariffs on the production cost and the landscape externalities of wind power generation in West Saxony, Germany. *Energy Policy*. 2012; 48:730-736
10. Rumbayan M, Abudureyimu A, Nagasaka K. Mapping of Solar Energy potential in Indonesia using artificial neural network and geographical information system. *Renewable and Sustainable Energy Reviews*. 2012; 16:1437-1449
11. Hasan M, Mahlia T, Nur H. A review on energy scenario and sustainable energy in Indonesia. *Renewable and Sustainable Energy Reviews*. 2012; 16:2316-2328
12. Syafawati A, Daut I, Irwanto M, Farhana Z, Razliana F, Arizadayana Z, Shema S. Potential of Solar energy harvesting in Ulu Pauh, Perlis Malaysia using Solar radiation – Analysis studies. *Energy procedia*. 2014; 16:1503-1508
13. Sorapipatana C. An assessment of solar energy potential in Kampuchea. *Renewable and Sustainable Energy Reviews*. 2010; 14:2174-2178
14. Sozen A, Arcaklioglu E, Ozalp M, Kanit E. Solar energy potential in Turkey. *Applied Energy*. 2005; 80:367-381
15. Ouderni A, Maatallah T, Alimi S. Experimental assessment of the solar energy potential in the gulf of Tunis, Tunisia. *Renewable and Sustainable Energy Reviews*. 2013; 20:155-168
16. Yue C, Huang G. An evaluation of domestic solar energy potential in Taiwan incorporating land use analysis. *Energy Policy*. 2011; 39:7988-8002
17. Yue C, Huang G. An evaluation of domestic solar energy potential in Taiwan incorporating land use analysis. *Renewable Energy*. 2011; 36:1869-1874
18. Alam Hossaim Mondal, M, Sadrul Islam A. Potential and viability of grid-connected solar PV system in Bangladesh. *Renewable Energy*. 2011:1869-1874.
19. Retscreen software. 2013. (Available online at http://www.retscreen.net/th/home.php)
20. NASA SSE. Surface meteorology and Solar Energy. (Available online at http://eosweb.larc.nasa.gov/sse)
21. Antara. Peraturan harga tenaga surya ditetapkan pekan depan.2013.(Available online at http://www.antaranews.com/berita/364689/peraturan-harga-tenaga-surya-diterbitkan-pekan-depan)