CO_2 Emission Reduction from Solar Power Plant in Rural Area (Study of Solar Power Plant in Sukaraksa Village, Tanjung Sari Sub-District, Bogor Regency)

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Abstract. Development of renewable energy power plant represents a strategic way to increase electrification ratio and to reduce CO_2 emission. One of renewable energy potential resources in Indonesia is solar power since the country is located in the equator line. In 2014, there are 8,170 kWp community based solar power plant that has been built by the government in the rural area. However, advantages of community based solar power plant will depend on its sustainability. This study examines the sustainability of community based solar power plant based on an interview with local government. It also determines the potential of community based solar power plant reduces CO_2 emission at the research location. The interview was conducted with Authorized Environmental Agency. The results show that sustainability of solar power plant in the research area is considered to be good. It is also known that CO_2 emission reduction in research location during its lifetime is 316,302 kg. It is believed that this successful example can provide policy recommendation for government to develop a more solar power plant in another rural area.

1 Introduction

The problem of energy availability is still an obstacle for Indonesian including for electricity. Electricity demand in Indonesia increases by 10.1% per year, while the development of electric infrastructure only raises by 7% per year [1]. Thus, there is a gap between electricity supply and demand, especially for the area outside PLN's electricity system Jawa-Madura-Bali. During 2014, electricity demand per capita in Indonesia is considered as low, which is around 788 kWh/capita [2]. In 2014, electrification ratio was only 84.35% [1]. It means there were 15.65% of household in Indonesia that has not been electrified. Based on Government Regulation No. 79 the Year 2014 regarding National Energy Policy, the use of renewable energy must be 23% in 2025 from the total energy mix.

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The government of Indonesia has committed to reducing Green House Gasses (GHG) emission within 2030, which consist of 29% with their own capability and 41% if Indonesia has received assistance from international parties [3]. It was mentioned in Presidential Regulation No. 61 the Year 2011 regarding National Action Plan for GHG Emission Reduction that one of the national action plans is the development of a renewable energy power plant. This situation has encouraged the government to continuously develop renewable energy power plant to improve electricity. Additionally, electricity has an important rule in increasing quality of life, especially for the community in a rural area [4]. Type of renewable energy power plant that usually built in rural areas by the government is a solar power plant, because the solar energy resources are available throughout Indonesia, while other renewable energy resources such as water, wind, and geothermal are site specific and not necessarily available in all rural areas. The solar energy potential in a western part of Indonesia is 4.5 kWh/m^2/day, while in the eastern part of Indonesia is 5.1 kWh/m^2/day, with the average 4.8 kWh/m^2/day [5].

Up to now, Ministry of Energy and Mineral Resources (MEMR) through Directorate General of New, Renewable Energy and Energy Conservation (NREEC) has built 494 units of a solar power plant with a total capacity of 21,548 kW for 63,193 households throughout Indonesia [6]. However, since 2011, about 10% of the total solar power plant unit built by the government were broken [7]. It is also seen in MEMR Regulation No. 3 the Year 2014 regarding Technical Guidelines for the Use of Special Allocation Fund (Dana Alokasi Khusus - DAK) for Energy Sector in Rural Areas for the Fiscal Year 2014. It was stated in Article 4 that one of DAK purpose is to rehabilitate the broken solar plant in the rural area, while such activities are not stated in similar ministerial regulations for the fiscal year 2013 and also the previous year. The broken solar power plant in a rural area could occur due to technical and nontechnical aspects. The reliability, stability, and quality of electricity are central issues in the utilization of renewable energy sources due to its fluctuation, unpredictable, seasonal, and location-dependent [8]. In addition, planning of renewable energy systems not only shall comply with technological and economic requirements but also shall consider environmental dimensions [9]. Therefore, research on the sustainability which consists of technical, economic, environmental, and social sustainability of the solar power plant in rural areas is needed. This research asks two questions: (i) how much contribution of CO_2 emission reduction from a solar power plant in the rural area, and (ii) how does the sustainability of solar power plant in the rural area. Based on that, this research aims to: (i) examine CO_2 emission reduction from a solar power plant in the rural area, and (ii) determine the sustainability of solar power plant in the rural area.

Implementation of sustainable development through policy and a series of actions is a big challenge because it contains the relationship between present and future generations. Also, it is related to three dimensions, namely economic, social, and environment [10]. Additionally, energy is an associated component of those three dimensions.

Availability of energy, especially electrical energy is one of the basic human needs. Such availability has affected humans way of life in the process, such as in producing materials and agricultural product, providing educational, health, and telecommunication facilities, etc. In many rural areas, humans still struggle to collect firewood far away for cooking and heating up. Such activities can take up considerable time, such as school activities or business. The humans quality of life generally determined by the use of electricity or energy consumption. It shows that electricity plays an important role in improving the quality of life, especially for communities in rural areas [4]. Based on previous research conducted in the rural area, most people in rural areas have access to electricity through diesel power plant, which will produce GHG emission from its operation. In addition, the costs required to produce electricity from diesel power plant and

air pollution resulting from diesel fuel combustion have made the use of renewable energy became more popular [11].

Based on Law No. 30 the Year 2009 regarding Electricity, the development of electricity adheres to this following principles: (a) benefits, (b) fair efficiency, (c) sustainable, (d) economic optimization in the utilization of energy resources, (e) rely on their own ability, (f) business rules, (g) security and safety, (h) environmental conservation, and (i) regional autonomy. Development of electricity was conducted to ensure the availability of electricity which has good quality and reasonable price in order to improve the welfare and prosperity of the people, also to promote sustainable development. Additionally, previous research has shown that in areas with high population growth, renewable energy resources is one of the mechanisms in facing the increasing of electricity demand [12].

As located on the equator, the solar power plant is suitable to be developed in Indonesia, especially in rural areas that have not been electrified by the PLN. During the operational phase, solar power plant does not produce CO_2 emission from its power plant. The emission only generates through its supply chain, such as in transporting the solar module's materials [13]. This is in accordance with the formula stated by National Planning Agency (Bappenas), which mentioned that CO_2 emission reduction calculated did not include the emission from its supply chain.

Having easy access to various types of energy sources and with low cost and also support from the government will help communities in rural areas to maximize their potential [14]. The solar power plant has successfully improved the quality of life of local communities, which has increased access to social services, such as health and education [15]. Nevertheless, every stakeholder in the renewable energy sector has an independent view of the economic, social and environmental criteria of developing renewable energy systems [16]. The similarity of views from each stakeholder to these criteria will be able to promote sustainable development.

2 Material and method

This research is using the mixed method, which contains quantitative and qualitative. A quantitative method was used for calculating GHG emission reduction, particularly CO_2 emission, from solar power plant based on a series of the equation from Bappenas, while qualitative method was used to assess the sustainability of solar power plant in the rural area, through an interview with local government. The calculation of CO_2 emission was conducted as the CO_2 value of Global Warming Potential (GWP) is one, therefore, the CO_2 is selected as a reference, as shown in Table 1 [17]. Global Warming Potential defined as the time-integrated radiative forcing due to a pulse emission of a given component, relative to a pulse emission of an equal mass of CO_2, as shown in Table 2 [18].

Table 1. Radiative Heating Effect per Molecule and per Unit Mass of Various GHG Relative to CO_2

No	Trace Gas	Heating Relative to CO_2 per Molecule	Per Unit Mass
1	CO_2	1	1
2	CH_4	26	72
3	N_2O	206	206
4	HCFC-22	10,700	5,440
5	CF_3Br	16,000	4,730

Table 2. Global Warming Potential Value

No	Type	Chemical Formula	GWP 100-year
1	Carbon dioxide	CO_2	1
2	Methane	CH_4	28
3	Nitrogen oxide	N_2O	265
4	CFC-11	CCl_3F	4,660
5	CFC-12	CCl_2F_2	10,200
6	CFC-13	$CClF_3$	13,900
7	CFC-113	CCl_2FCClF_2	5,820
8	CFC-114	$CClF_2CClF_2$	8,590
9	CFC-115	$CClF_2CF_3$	7,670

A local government chosen in this research is Environmental Agency which relates to emission reduction, as sustainability of solar power plant may reduce a certain amount of GHG emission. Additionally, sustainability of solar power plant consists of technical, social, and economic aspect.

In order to calculate GHG emission reduction from a solar power plant, it is important to assume the total operational hour of solar power plant within a year. Table 3 below describes the total operational hour of several off-grid renewable energy resources, while Formula 1 and Formula 2 are used to calculate activity from renewable energy resources and emission reduction form its activity respectively [19].

Table 3. The assumption of Off-Grid Renewable Energy Resources

No	Action	% Operation in a Year	Total Hour in a Year	Total Operational Hour within a Year
1	Mini Hydro Power Plant	70%	24x365=7,860	6,132
2	Micro Hydro Power Plant	70%	24x365=7,860	6,132
3	Wind Power Plant	20%	24x365=7,860	1,572
4	Solar Power Plant	20%	24x365=7,860	1,572
5	Hybrid Power Plant	20%	24x365=7,860	1,572
6	Lightning facilities from Solar Power	20%	24x365=7,860	1,572
7	Biomass Power Plant	90%	24x365=7,860	7,884

Emission Factor (EF) used in this research is 0.706 as stated by Directorate General of Electricity for West Java transmission [20].

$$An\ activity = total\ capacity\ x\ total\ operational\ hour\ in\ a\ year \quad (1)$$

$$Emission\ Reduction = Activities\ x\ Emission\ Factor \quad (2)$$

3 Result and discussion

The capacity of a solar power plant in the research area is 15 kW. According to Formula 1 and 2, the indirect CO_2 emission reduction for the solar plant is 16,647 CO_2 per year. Since solar power plant was built in 2013, emission reduction during 2013 has not been calculated as the solar power plant is still in the construction phase. As long as the solar power plant is operated, the CO_2 emission reduction will be accumulated in the following year. Assuming that the lifetime of the solar power plant is 20 years, CO_2 emission reduction during its operation is 316,302 kg in the year 2032. Indirect CO_2 emission reduction in research location per year area can be seen in Table 4.

Table 4. CO_2 Emission Reduction per Year

Year	Capacity (kWp)	Total Hour in a Year (Hour)	% Operation in a Year (%)	Total Operational Hour within a Year (hour)	EF (kg CO_2/ kWh)	Activity (kWh)	CO_2 Emission Reduction (kg CO_2)
2013	15	7,860	20%	1,572	0.706	-	-
2014	15	7,860	20%	1,572	0.706	23,580	16,647
2015	15	7,860	20%	1,572	0.706	23,580	33,295
2016	15	7,860	20%	1,572	0.706	23,580	49,942
2017	15	7,860	20%	1,572	0.706	23,580	66,590
2018	15	7,860	20%	1,572	0.706	23,580	83,237
2019	15	7,860	20%	1,572	0.706	23,580	99,885
2020	15	7,860	20%	1,572	0.706	23,580	116,532
2021	15	7,860	20%	1,572	0.706	23,580	133,180
2022	15	7,860	20%	1,572	0.706	23,580	149,827
2023	15	7,860	20%	1,572	0.706	23,580	166,475
2024	15	7,860	20%	1,572	0.706	23,580	183,122
2025	15	7,860	20%	1,572	0.706	23,580	199,770
2026	15	7,860	20%	1,572	0.706	23,580	216,417
2027	15	7,860	20%	1,572	0.706	23,580	233,065
2028	15	7,860	20%	1,572	0.706	23,580	249,712
2029	15	7,860	20%	1,572	0.706	23,580	266,360
2030	15	7,860	20%	1,572	0.706	23,580	283,007
2031	15	7,860	20%	1,572	0.706	23,580	299,655
2032	15	7,860	20%	1,572	0.706	23,580	316,302

To assess the sustainability of solar power plant, an interview has been conducted with Environmental Agency of Bogor Regency. Based on the interview, environmental sustainability of solar power plant is considered as good. The assessment particularly related to the environmental impact of the solar power plant. Additionally, water usage for the operation of the solar power plant is less than another power plant. However, as a solar power plant in research location is using batteries to store electricity during daytime in order to be used in the night, there will be used batteries that shall be treated as hazardous waste. Generally, the lifetime of the batteries is around 5 years. Therefore, after 5 years of operation, the operator shall manage the used batteries.

Related to technical sustainability, it was stated that there was socialization from the government prior to the construction of a solar power plant in the research location. There was also a training to operate a solar power plant which also conducted by the government. However, it is not clear whether the training was conducted regularly or not. Further, local government has to plan the training on annual basis as part of their monitoring to the national asset, which manages by the community [21]. The problem of electricity availability is still a constraint for Indonesia, it is a necessary policy to support renewable energy project [22][23]. Community empowerment approach needs to be done because it can encourage self-reliance on a small scale such as in Sukaraksa[24]

There are several challenges of operating the solar power plant. A lifetime of solar power plant usually is 20 years, depending on the solar module. After 20 years of operation, the solar power plant shall be dismantled and there will be waste from solar modules, batteries, and another component of the solar power plant. Further research on the decommissioning plan shall be conducted to assess the environmental and social impact of solar power plant after its operation.

4 Conclusion

From the research conducted it can be concluded that:

1. The indirect CO_2 emission reduction resulting from the use of solar power plant in the research location is 316,302 kg after 20 years of operation.
2. Sustainability of solar power plant in the research area is considered to be good.
3. Further research on hazardous waste management after operation of solar power plant need to be conducted.

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