

Tapping the Potential of Large Scale Solar PV System in Sabah: The Feasibility Analysis

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Abstract

As a developing country with the rapid growth of economic and population like Malaysia, energy and electricity play a critical role towards sustaining and supporting the development of the nation. However, like many countries across the world, Malaysia is facing challenges in reducing the carbon footprint while attending the expanding growth. In the Eleventh Malaysia Plan, Malaysia has pledged to renew and increase its commitment to the environment and long-term sustainability by adopting green growth initiatives. According to the plan, one of the approaches towards pursuing green growth is by undertaking the sustainable consumption and production concept that promotes economic growth without compromising the environment. One of the strategies is to focus on promoting renewable energy sources as well as boosting up the development of the systems. The last decade has seen a growing trend towards renewable energy in Malaysia, particular in solar photovoltaic applications in recent years. This paper will investigate the potentials of installing 5 MW solar PV plants in the state of Sabah according to feed in tariff incentives and its financial and environmental assessment in order to promote large scale solar PV in Malaysia. This paper calculates the economic viability through IRR and simple payback indicators and the environmental impact through CO₂ emission reduction indicator for the proposed 5 MW plant.

Keywords

Large Scale Solar PV, Feed in Tariff, Renewable Energy, CO₂ Emission Sabah Malaysia

1. Introduction

Malaysia is a country made up of Peninsular Malaysia and the states of Sabah and Sarawak on the island of Borneo. The population in this country has reached 29.72 million today, with 80% of the total 23.5 million people live in Pe-

ninsular Malaysia, 3.5 billion in Sabah and 2.6 billion in Sarawak. Energy has been the most important catalyst towards the rapid growth of Malaysia's population as well as the economy. The fast pace developments, as well as the rising living standards and greater income per capita, have stimulated a tremendous energy demand. However, the high consumption of fossil fuel resources is known to give more damage than good to the environment. Therefore there has been a trend in developing countries towards shifting to renewable energy resources in order to mitigate the impact on the environment. Malaysia is no exception in this commitment in the energy balance towards a more sustainable development. Malaysia has promised to continue pursuing green growth, in terms of policy and regulatory framework, and green technology investment. According to the plan, Malaysia is committed to continuing the required capacities, capabilities and skills towards supporting the green growth development including the renewable energy initiatives [1] [2].

1.1. Malaysian Energy Supply

Malaysia is known for a diversified primary energy resources country. The primary energy supply includes oil, natural gas, coal and a variety of renewable energy resources mainly hydro and solar power and biomass. However from a total of 141,266 GWh (2013) fossil fuels call for 90% of Malaysia electricity generation mix. [3] The dependency on fossil fuels due to the cheaper option as well as rising electricity demand is unavoidable. It is notable that the fuel consumption in Malaysia has dropped in 1997 due to the economic and financial crisis which affected domestic consumption and investment. However in April 2010, along with the Fifth Fuel Policy, the Malaysian government approved the National Renewable Energy Policy and Action Plan to promote further development in the renewable energy (RE) sector [1] [2].

1.2. Sabah Generation Mix and Electricity Demand

Sabah is a state in Malaysia located on the island of Borneo next to Sarawak as shown in **Figure 1**. With population of more than 3.5 million. Sabah is known for its maturing economy of local tourism and natural produces such timber and palm oil. The growing economy of Sabah has driven an increasing energy as well as electricity demand. However, Sabah is now facing a dilemma where high occurrence of power shortage is experienced throughout the state. As of 2015 Sabah total generation mix is primarily fuelled by gas 76%, followed by diesel/MFO 15%, hydro 6% and biomass/biogas 3% (**Figure 2**). As shown in **Figure 3**, apart from the stagnant growth in 2010, a contraction caused by the global financial crisis in 2008 onward which slowed down the manufacturing sector, Sabah electricity demand is increasing at over 7% per year and forecasted to continue growing alongside the rise of GDP. However, much of Sabah's existing capacity is in the form of aging, expensive, and unstable diesel plants. The east coast of Sabah, almost wholly relies on these diesel plants (**Figure 4**) and the high occurrence of outages may affect the economy as well as the utility company financially. In



Figure 1. Map of Malaysia.

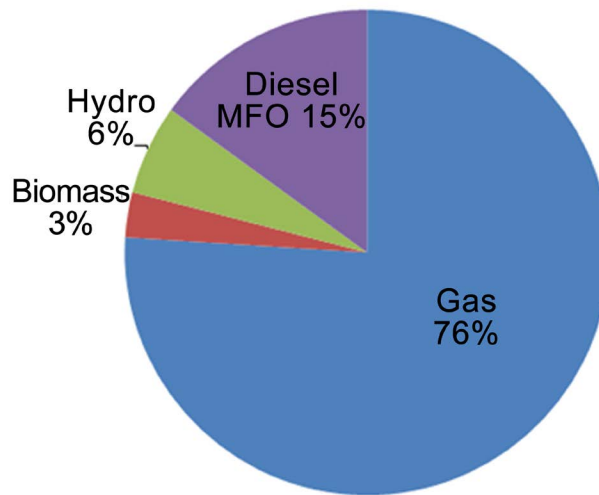


Figure 2. Sabah generation mix in 2015 [4].

order to meet the growing demand, Sabah’s electric utility—Sabah Electricity Sdn. Bhd (SESB) is planning to expand the generation capacity over the next 10 years, and phases out some MFO plants from the overall mix. Total generation from diesel by SESB in 2014 accounts for of 488 GWh and SESB is still dealing with the issue of lack of generation capacity to meet the growth in electricity demand. Sabah electricity demand is forecasted to grow at a rate of 5.8% through out the coming years as shown in Figure 5 [4].

1.3. Feed-in Tariff Policy in Malaysia

FiT mechanism was introduced by the Malaysian government under National Renewable Energy Policy and Action Plan (2010) and is currently carried out by

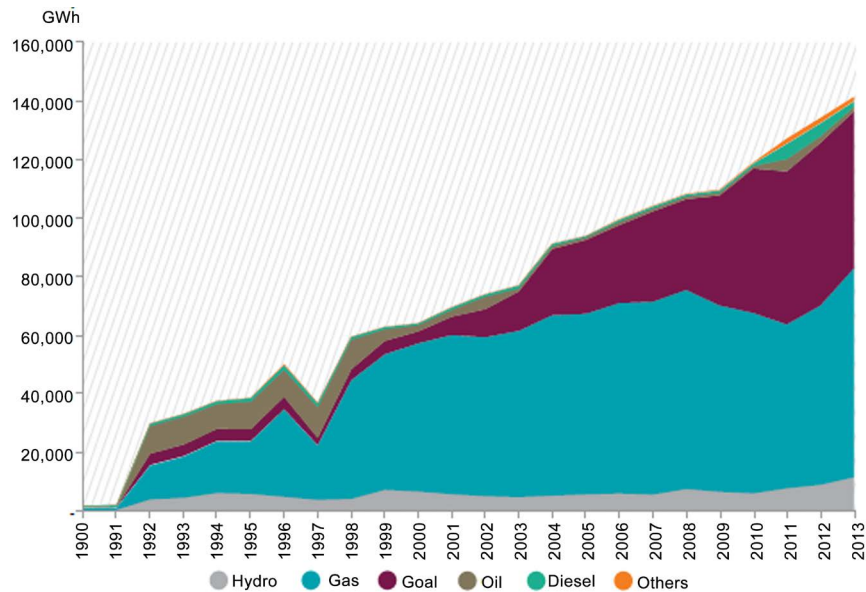


Figure 3. Malaysia electricity generation mix by fuel type (Suruhanjaya Tenaga).

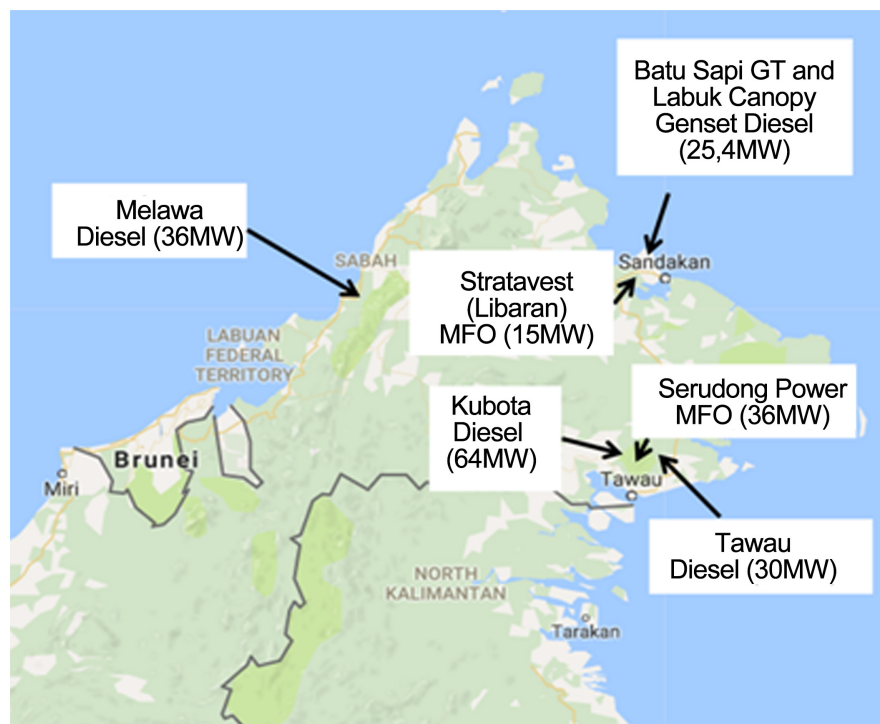


Figure 4. Existing diesel and MFO power plants in Sabah [4].

Sustainable Energy Development Authority, Malaysia (SEDA Malaysia) under the authority of by Ministry of Energy, Green Technology and Water (KeT-THA). FiT is a policy described as a mechanism that allows RE producers to generate electricity from any RE resources by offering long-term contracts for the generated power to be sold to power utilities at a fixed premium price. The objectives of FiT mechanism are

- To increase RE contribution in the national power generation mix;

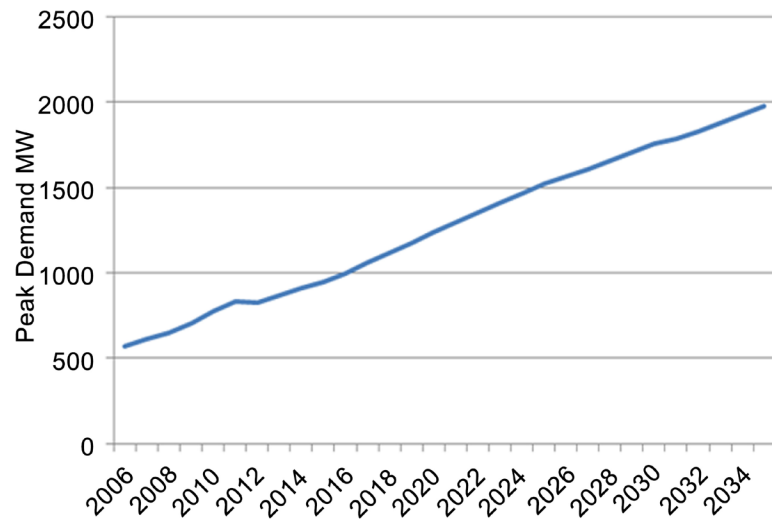


Figure 5. Sabah Electricity demand forecast [4].

Table 1. Feed in Tariff rate for Solar PV (Non-Individual) [6].

Installed Capacity	Fit Rates (RM per KWh)
Up to and including 4 kW	0.8249
above 4 kW and up to and including 24 kW	0.8048
above 24 kW and up to and including 72 kW	0.6139
above 72 kW and up to and including 1 MW	0.593
above 1MW and up to 10 MW	0.4651
above 10 MW and up to and including 30 MW	0.4162

- To facilitate the growth of the RE industry;
- To ensure reasonable RE generation mix;
- To conserve the environment for future
- To enhance awareness on the role and importance of RE [5] [6].

The FiT rate for solar photovoltaic for 21 years from commencement date is shown in **Table 1**.

2. Objective

According to Malaysia Eleventh Plan, one of the approaches towards pursuing green growth is by undertaking the sustainable consumption and production concept that promotes economic growth without compromising the environment. One of the strategies is to focus on promoting renewable energy sources as well as boosting up the development of the systems. Prime Minister YAB Dato' Sri MohdNajibTun Abdul Razak announced that Malaysia would voluntarily reduce its emissions intensity of GDP by up to 40% based on 2005 levels, by 2020. [1] [2] In line with the target, this study is to investigate the potentials of one of the low-carbon measures in term or integration of renewable energy in Malaysia's electricity generation specifically solar photovoltaic technology. Due to the advantage of its location in the tropical region, there is a strong pro-

spective to install large scale solar PV throughout the country [9]. This paper will investigate the potential available for large scale solar PV installation in Sabah, and the amount of CO₂ mitigated by replacing the diesel power plants with 5 MW solar PV plants. Installation of large scale solar PV plants are may contribute to the reduction of the total amount of CO₂ emission in Malaysia.

3. Methodology

This analysis consists of 3 main elements;

- Estimation of the energy production potential,
- Financial feasibility in terms of simple payback and IRR from the proposed 5MW plant,
- Assessment of the anticipated reductions in CO₂ emissions if the plant were constructed

To estimate the energy production and financial feasibility of the hypothetical PV plant, this study uses RETScreen software. RETScreen was created in 1996 by Natural Resources Canada's Canmet Energy Research Center to provide low-cost preliminary assessments of RE projects. Independent reviews of RETScreen software validate its results all reporting RETScreen calculations to be within 0% - 6% of actual energy production [7]. Solar irradiation in the area are taken from the NASA website of Surface meteorology and solar energy [8]. To estimate the amount of carbon dioxide emissions avoided, the RETScreen predictions of the energy production of the PV plant are used to estimate the amount by which energy production from all the diesel plants in Sabah could decrease over the period of 10 years. Annual emissions data obtained from the power plant are used to estimate the air pollutant emissions avoided when a portion of the diesel plants' energy production is replaced with PV energy based on 2 scenarios:

Scenario 1 (S1): proposed one 5MW solar PV plant for each diesel plant in Sabah.

Scenario 2 (S2): proposed 5MW solar PV plants to cover for 2025 electricity production from diesel.

The Proposed 5 MW Plant

The proposed solar PV power plant-which is a grid-connected system with 5 MW installed capacity-consists of 15,625 unit one axis tracking modules with a total area of 30,506 m². The slope and azimuth angle was taken as zero for all the studied sites. **Table 2** shows the module's specifications. The financial assumptions for this plant are presented in **Table 3**. The initial cost for the plant is assumed as MYR 40 million [10] with operation and maintenance cost MYR 100,000 while the inflation rate is taken as 3%.

4. Results and Discussion

4.1. Electricity Production

The annual amount of electricity generation, which is the amount of equivalent DC electrical energy actually delivered by the proposed grid-connected 5 MW

Table 2. PV Module Specifications.

Item	Specification
Manufacturer	JA Solar
PV module type	Poly-Si
Module number	JAP672-320/4BB
Module efficiency	16.51%
Dimensions	1956 mm × 001 mm × 45 mm
Maximum System Voltage	DC1000V
Operating Temperature	-40°C - 85°C
Maximum Series Fuse	15A

Table 3. Financial Assumptions.

Initial cost	MYR 40,000,000
O & M cost	MYR 100,000
Feed-in Tariff	MYR 465/MWh
Project life	21 years
Inflation rate	3%

solar PV power plant to the utility, was calculated for all the 8 locations, with all plants located within 1.5 km radius from main substation or grid to minimize transmission and distribution loss. The results are exhibited in **Figure 4**. The highest production was obtained from Tawau, Tenom, Beufort, and Papar power plants. Their production was close to each other, and equal to 8.876, 8.851, and 8.852 and 8.857 GWh/year respectively. The average electricity production for the proposed 5MW power plant is projected to be 8377 MWh annually available for export in Sabah. **Figure 6** shows Sabah generation forecast of diesel power plants in ten years whereby the diesel power plants will slowly be reduced and replaced with electricity generation from natural gas power plants. This forecast is plotted together with the two proposed scenarios for large scale solar PV power plants.

As illustrated in **Figure 7**, in Scenario 1, a single power plant in Sabah would be able to export at least 7.5 GWh of electricity annually. Sabah utility company forecasted by 2025 total of 194.94 GWh of diesel generation is still needed to accommodate the demand and will be retiring several diesel and MFO power plants by then [4]. Therefore in comparison with this forecast with average of 8377MWh of electricity production annually, approximately 24 of solar PV plants are needed to cover for electricity production from diesel in 2025 as for Scenario 2.

4.2. Financial Analysis

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 and the sim-

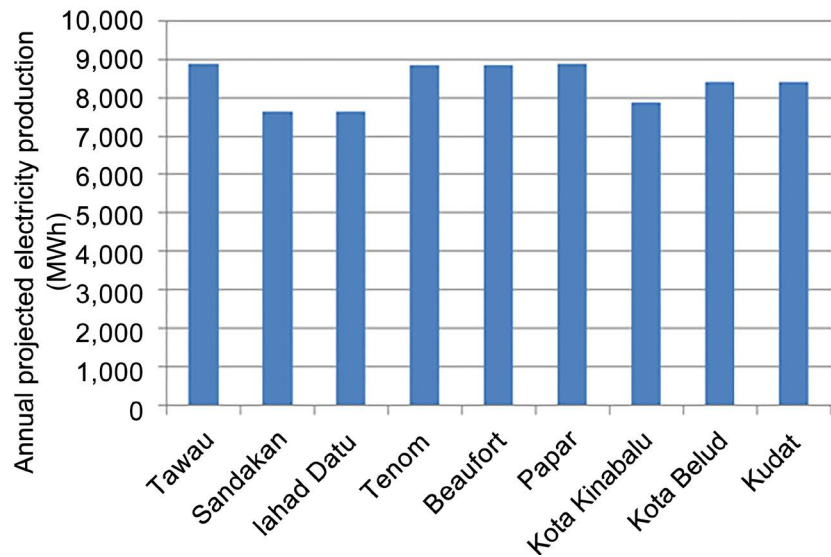


Figure 6. 5MW solar PV plant potentials in Sabah.

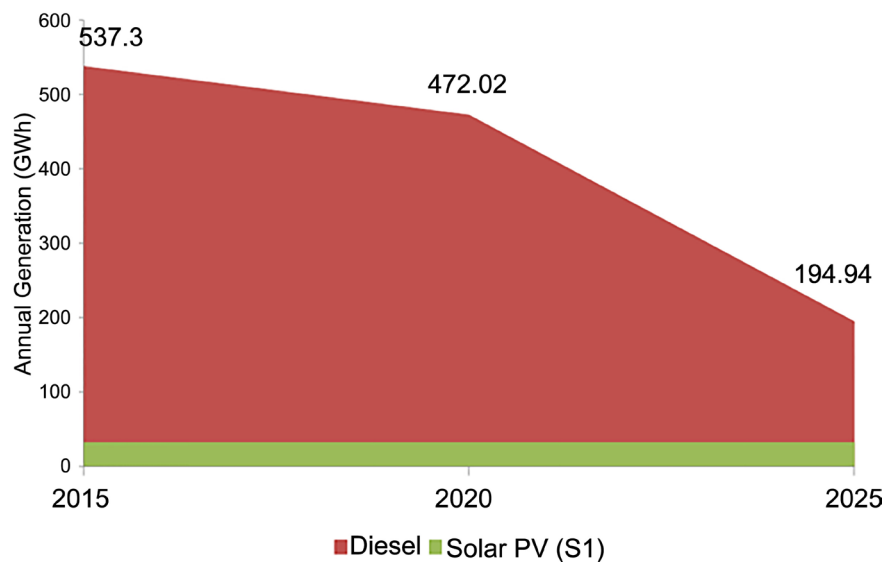


Figure 7. Sabah generation forecast for diesel power plants.

ple payback for each proposed solar PV plant. From the financial analysis, it can also be found the average of 9.8% IRR was observed. From the proposed large scale plants the shortest payback period noted was 10 years as shown in Figure 8 and Figure 9. A proposed 5MW solar PV plant was calculated will take 9 years for the cash flow to equal the total investment as stimulated in Figure 9.

4.3. CO₂ Emission Mitigation

Fossil fuel power generation has a high CO₂ emission especially those from oil combustions. The application of the renewable energy such as solar power plant can reduce the greenhouse gas emission such as CO₂, CH₄ and N₂O. Although here is a plan of reduction in diesel power plants in Sabah, the current existing plants may contribute an amount of CO₂ therefore by replacing these diesel

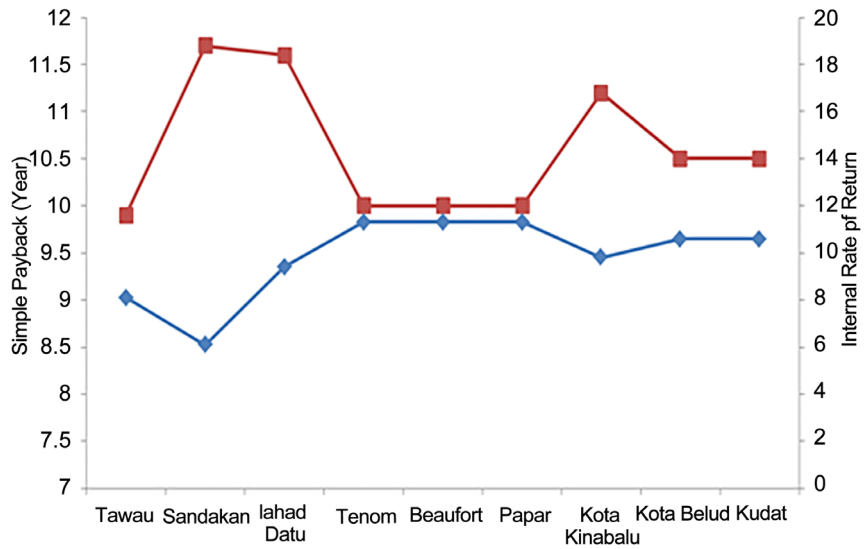


Figure 8. IRR and Simple payback analysis.

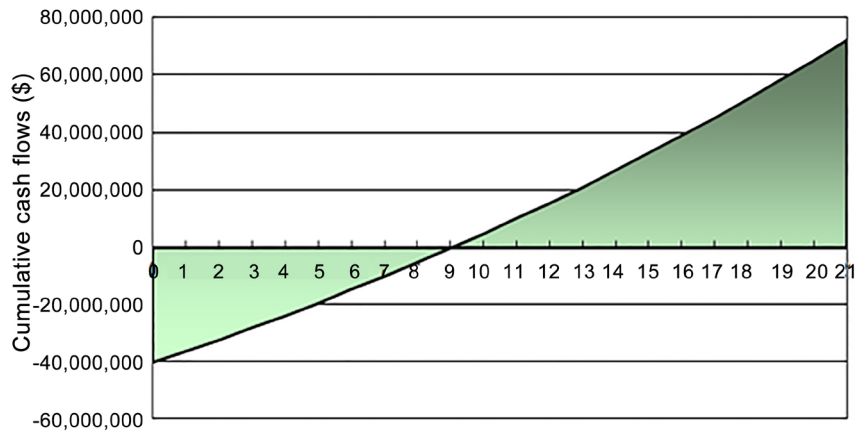


Figure 9. Cumulative cash flows in a 5 MW solar PV plant in Sabah (Malaysian Ringgit RM).

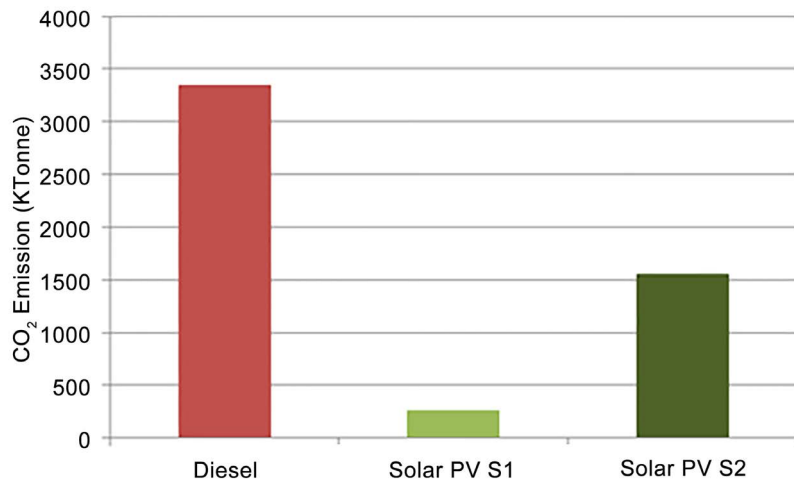


Figure 10. Projected CO₂ emissions from diesel and the amount of CO₂ mitigated by proposed solar PV plants in Sabah over 10 years.

plants with large scale solar PV emission mitigation can be achieved. As shown in **Figure 10**, in Scenario 1 where one solar PV plant with capacity of 5 MW electricity generation, annually this can reduce the CO₂ emission from the diesel plant for 260 kT CO₂. On the other hand in Scenario 2 where all the electricity generation from diesel power plants in another 10 years be replaced by Solar PV plants, the amount of CO₂ emission avoided is 1.55 GT CO₂.

5. Conclusion

This study examines the technical and economic potential of solar photovoltaic-grid connected system in Sabah, Malaysia. The current policy of the feed in tariff is included in the study. This study investigates potential locations for 5 MW solar power plant with grid connected to fill up the peak load demand with objective to replace diesel power plants all over Sabah. Two scenarios were introduced to observe capability of one single 5 MW plant and another scenario with number of plants to replace the diesel generation plants in the next 10 years. This study found that for the selected locations, the proposed system can generate electricity annually with average of 8.377 GWh/year. From the financial analysis, it can also be found the average of 9.8% IRR was observed. From the proposed large scale plants, the shortest payback period noted was 10 years. With 21 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 CO₂ emission at least 260 kT CO₂ in Scenario 1 and an amount of 1.55 GT CO₂ mitigated for Scenario 2. 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. In order to promote developments in RE installations, the government may introduce investment incentives due to high initial cost of the solar plant installation.

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