IOP Conference Series: Earth and Environmental Science

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To cite this article: N F Othman *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **146** 012002

IOP Conf. Series: Earth and Environmental Science **146** (2018) 012002 doi:10.1088/1755-1315/146/1/012002

Promising Potentials of Agrivoltaic Systems for the Development of Malaysia Green Economy

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Abstract. Combination of solar photovoltaic (PV) systems with crops cultivation creates the need for renewable synergy known as Agrivoltaic (AV). The AV system is in line with the Kyoto Protocol which promotes the reduction of carbon emission and usage of fossil-fuel. The integration of these two resources would optimize the yield, improving AV system efficiency and solving the issue of land scarcity. Currently PV landscapes are transformed to a new transdisciplinary design of land used and extended to ecological performances and beneficial impacts to the surroundings. Malaysia has been actively promoting the adaptation of PV technology as an alternative energy mix for the country since 2010. This study provides some insights of techno-economic aspects with respect to the increasing number and size of PV installations. Detail calculation based on Monte Carlo Simulation for growth rate are also discussed. The large scale solar PV farms are a good indicator of inculcating the AV concept for pathway in developing Malaysia green economy.

1. Introduction

Over the last decade, Malaysia as an emerging developing country continues to pursue and actively promote Renewable Energy by launching several policies, programs, incentives and funding for the sustainability of future generation. Other efforts such as in the 7th Malaysia Plan, the Malaysian government has allocated large amounts for rural electricity programs to help provide solar energy installation in urban and remote communities such as powering individual homes, longhouses (culture house), rural schools and clinics [1].

Mekhilef et al., 2012 [2], in his recent study on solar energy in Malaysia also highlighted the strategies and actions taken by the Malaysian government and Non-Government Organization (NGOs) to implement solar PV systems and applications in the future as announced in the 9th Malaysia Plan. The Malaysian government has introduced the Feed-In Tariff programmed, Malaysia Building Integrated Photovoltaic (MBIPV) project, Rural Electrification Programme (REP) and financial support for the development of solar photovoltaic in Malaysia [3]. This effort, mostly are based on the fact that solar energy has great potential to be used efficiently in energy services like power generation, heating and transport. It is naturally available, no noise or pollution in its operation and provide clean electricity in a longer service lifetime. In a tropical country like Malaysia, average solar radiation is about 1643kWh/ m^2/ year, with rates above 10 sun hours per day [4].

A PV system or solar power system is a power system that consists of several components i.e solar panel, solar inverter, mounting, cabling and other electrical components commonly known as Balance of Systems (BOS). This PV system converts light energy from the sun into electricity. The PV module are structured from a single cell structure to an array formation from different materials such as crystalline, multi-crystalline, polycrystalline, microcrystalline and amorphous type as shown in Figure 1.

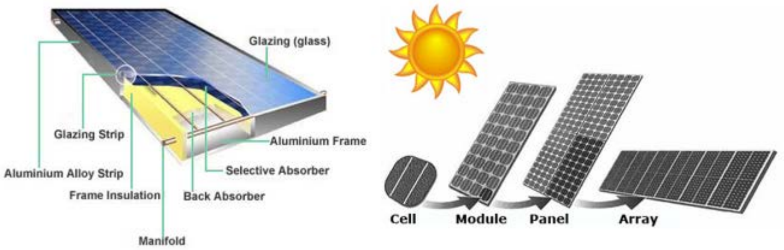

Figure 1: Illustration of PV module construction from a single cell. Source: http://sunmetrix.com

2. Agrivoltaic Technology Adaptation for Malaysia Green Economy

Photovoltaic landscape has been transformed not only to cater for clean energy generation but also a new transdisciplinary design of land used and extended to ecological performances and beneficial impacts [5]. The increasing of number and size of installation especially large scale solar PV farm may impacts in terms of the land scarcity and ecosystem services. One kiloWatt peak (1kWp) solar PV arrays covers about 6 to 9 square meter of land would simply create the suitable environment by making use of this vacant space under the solar panels. Most of the solar PV installation today are ground-mounted arrays and implies the fix structure PV panel. The adaptation of solar PV in large scale area need to be more future oriented by improving their design and the cost effective installation [5]. The idea of the AV or solar farming can be defined as an alternative conversion of agriculture (farming) into photovoltaics (solar panel) in a single land use system to optimize the yield [6]. The AV system considers appropriate plant characteristics based on crop height, sustainability, water requirements and shading tolerance. This new way of growing crops beneath solar panel is an experiment in integrating renewable energy with agriculture and is a part of bringing a new dimension to community agriculture [7]. Some of the published results relating to AV projects are listed in Table 1. Figure 2 shows the concept of AV system applied in some countries using the concept of utilizing unused land area with different kind of crop.

Table 1: Successful integration of PV Farms with agriculture cultivation.

Author/ Year	Country	Highlights/ Findings
Scognamiglio, [5]	Italy	The AV system allowing better ecological performance.
Dupraz et al., [6]	France	The AV system is able to provide more efficient use of light and space for the dual production of energy and food.
Dinesh & Pearce, [7]	USA	AV system can improve the technical potential for both PV production and agricultural production by propose a coupled simulation model.
Malu, Sharma, & Pearce, [8]	India	The AV system may increase the crop production as compared to conventional farming.

Figure 2: Typical Agrivoltaic projects in France and Japan (left to right).

Green economy is an alternative economy that can improve well-being and social equity, reduce environmental damage, climate change, help ecological scarcity issues and even incorporate natural resources into economic policy [9]. The green economy aims to enhance a sustainable and efficient economy for a better quality of life. Figure 3 shows the green growth effect by implementing the green economy. In Tanzania, the concept of green economy has been redesigned and reinterpreted green implementation to suit their basic aspects and governance in agri-business [10].

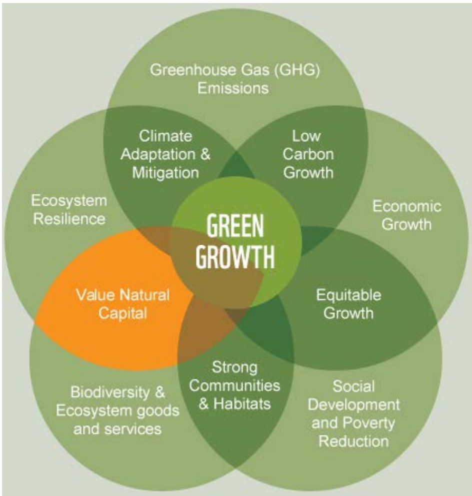

Figure 3: The concept of green economy towards sustainable development and efficient economy

The agricultural sector has good potential in the future, but there are some problems that arise such as problems of workers, capital and land. Most large companies rely on foreign workers while independent smallholders have limited capital resources. In line with the support of the Malaysian government's efforts in agriculture and renewable energy, the Agrivoltaic (AV) system is recommended for the Malaysian agribusiness industry as one of the methods for pre-industrial agricultural production systems such as viticulture, arboriculture, gardening market and plant crops[11].

Locally in Malaysia, one of the Agrivoltaic pilot project was set up in Universiti Putra Malaysia integrating Java Tea as the selected high-value herbal crops. Figure 4 shows the launching ceremony by the Ministry of Science Technology and Innovation (MOSTI) as to creating catalyst in promoting Green Energy to the society.

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Figure 4: Launching ceremony by the Minister on December 2015

The coverage area under PV array is 1 acre with 7 strings of 1 kWp PV array with consideration of 20% space buffers from the structure of PV and cabling works. This concept of integration shows some good growth progress to the crops which can sustain under PV shaded condition with increasing value of profit return. [12].

3. Monte Carlo Simulation for Agrivoltaic Growth Rate

Monte Carlo (MC) simulation is a statistical tool to accurately estimate the probabilities of uncertain events as illustrated in Figure 5, where the simulation model situations that present uncertainty and then play them out on a computer thousands of times within the range of 0 to 1 [13]. This estimation uses random numbers to represent uncertainty of Agro-PV annual income. Based on cost observation, the solar PV production is the highest operational cost component where to maintain good growth, the cost outlays must be lower than the benefits obtained. In the final accounting stage, the impact of applying herbal plant under the solar PV array shows positive cash returns. This finding supports the hypothesis of utilizing the unused space under the solar PV array for Agro-PV integration.

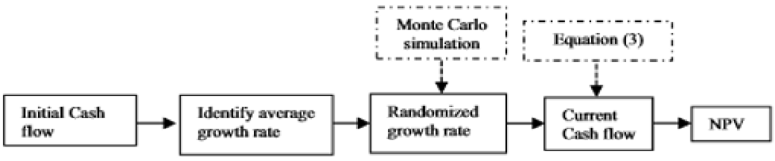

Figure 5: NPV Monte Carlo simulation using randomized growth rate.

The MC-Simulation process for Agro-PV data are projected in Table 2 and Figure 6 where the growth rate varies between -10% (economic downtime) up to 10 % (economic boost). Negative NPV of RM (1,794) shows the level of positive NPV projection can only withstand economic downtime not more than -10% of growth rate fluctuation. The value of IRR maintains at the range of 13 to 15 % with a good payback period of 6 years (at 3.36% discount rate constant).

Table 2: NPV-sensitivity analysis on varying growth rate for 10 years duration of Agrivoltaic operation

	Agro-PV (Monte Carlo Simulation)				
Growth rate	-10%	-5%	0%	5%	10%

NPV (RM million)	RM(1,794)	RM 2,678	RM 7,456	RM 15,162	RM 24,123
IRR (%)	13% - 15%				
Payback period	5-6 years				

The NPV mean value for Agrivoltaic (after 1000 random simulation) are calculated at RM14.3 million with minimum value of RM12.6 million and maximum value of RM16.2 million. The simulation projects a good payback period of 6 years with IRR values at ranging 13% to 15% as compared to 13.5% as previously calculated. The effect of cash flow after initial operation cost does not significantly affected by the fluctuating growth rate (varying range of 3.54% - 5.3% based on a good economic condition) which is justified by the linear cumulative cash flow projection.

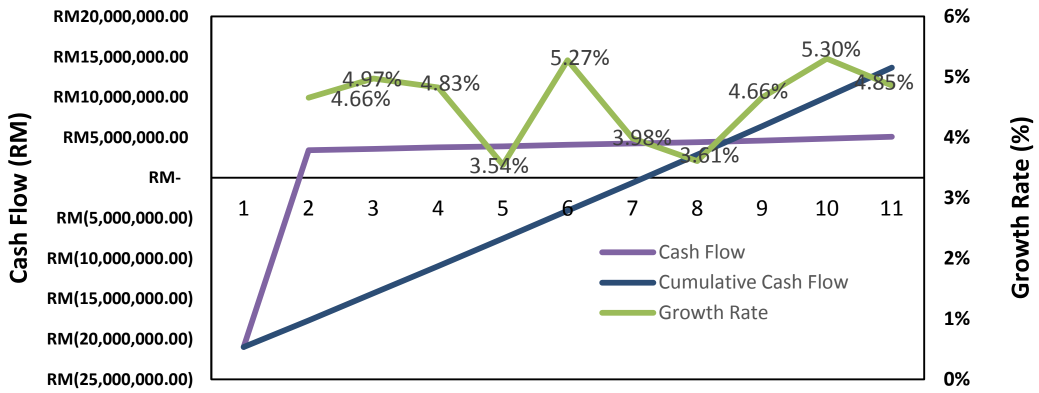

Figure 6: Monte Carlo Simulation based on random growth rate.

Based on these two simulated conditions, the MC simulation shows that when the growth rate decrease to -10% and below, the investment is showing negative net present value (-ve NPV). The output highlights that, higher probability of success from this project happen in 10 years of the project lifetime. Thus, this work highly suggest that Solar PV farms with integrated agriculture elements is the most suitable arrangements for a clean development projects.

4. Conclusion

The green economy approach for Malaysia development are presented with a typical Monte Carlo simulation for Agrivoltaic projects. The transdisciplinary design of land used and extended to ecological performances provides additional monetary benefits to the existing Solar Farm operators thus, will strengthen the platform for a mutual collaboration towards Malaysia Green Economy.

Acknowledgement

The authors delegate our thanks to the Research Management Centre (RMC), Universiti Putra Malaysia for the approval of research funding under the IPB Putra Grants Scheme (Vote no: 9515303)

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