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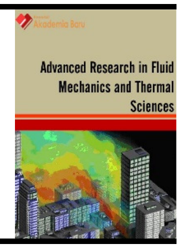

A Comparative Study of Levelized Cost of Electricity Between Photovoltaic and Concentrated Solar Powered Power Plants in Malaysia

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ABSTRACT

Renewable Energy (RE) is crucial in energy generation towards a more sustainable and low-carbon approach. One of the well-known sources of RE is the sun through solar energy harvesting. Equatorial region like Malaysia seems to be at the very best advantage for generating energy from solar since that it receives sufficient solar radiation for the purpose. Photovoltaic (PV) and Concentrated Solar Power (CSP) technology are the current technology in harvesting solar energy to generate power. However, referring to the Malaysian context today it seems that solar PV is the only technology practiced as one of the RE technologies that are eligible for tariff payment. The purpose of this study is to investigate the future prospect on current solar technologies which are PV and CSP by determining Levelized Cost of Electricity (LCOE) and land usage comparison to determining the cost comparative between solar technologies for future sustainable energy generation. The result is very positive as CSP has the advantage to be the future sustainable energy generation in Malaysia although there are some setbacks at the moment. Collaboration between all parties such as researchers, industry players as well as support from the government will aligned CSP on the right direction upcoming years to come.

Keywords:
Renewable Energy, Photovoltaic (PV) technology, Concentrated Solar Power (CSP) technology, Levelized Cost of Electricity (LCOE)

1. Introduction

Malaysia, covering an area of approximately 329,750 km^2 located strategically in South East Asia [20]. With the population about 30 million people in 2013, it is expected that the number could increases to 40 million people by the year 2040 referring to 1.1% average annual rate [11]. These numbers reflect high energy demand especially in term of electricity. The International Energy

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Agency [12] reported that Malaysia was the third-largest energy demand in South East Asia in 2013. The demand for electricity doubled since the year 2000 making it is among the highest in the region (per-capita electricity use).

As the world facing shortages in energy resource mainly from fossil fuels and coals, there is a plan to develop more sustainable energy system to promote better energy generation in the upcoming years.

One of the counter measures taken by the world leaders, researchers is promoting the usage of Renewable Energy (RE). RE is sustainable, economically and most importantly environmentally friendly that produces and gives less negative impact to the environment [22]. Malaysian Federal Government recognizes the potential of these clean energy and make efforts towards using a low carbon energy source. The introduction of 5th Fuel Policy 2000 (5FP2000) recognizing RE as the fifth fuel was the key point expressing the government's seriousness and commitment to develop a better and sustainable energy source leading to the establishment of several policies and acts related to RE development in the country later on.

Taking advantage of its location in the equatorial region, Malaysia has the capabilities to maximize the solar energy usage. With the abundance exposure to the sunlight, opportunity of developing or adopting solar technology system to generate electricity are beyond limits. Starting with the Malaysia Building Integrated Photovoltaic (MBIPV) project in 2005 initiated by the government which then lead to several programs related to PV system application for residentials as well as for the commercials in order to generate electricity with cleaner and environmental-friendly approach. Solar energy is a clean, sustainable and never ending source of energy therefore making it suitable and reliable for tariff payment in Malaysia [1].

However, CSP technologies were not given enough attention by the authorities and still in research stage by energy and university researcher. Challenges in developing sustainable power sector is the issue of sustainability and reliability of energy supply [9]. Lack of findings regarding the feasibility of CSP implementation in Malaysia [1], making it is critical to assess the specialized and monetary part of CSP before taken into bigger scale compared to current PV technologies. Furthermore, there is a chance for CSP to be the next solar technology in Malaysia since PV usage are not fully utilized yet. Nevertheless, the cost factor maybe will be quite a challenge since that current PV technologies is evolving and matured over time and cost competitive compared to new technologies such as CSP that need more research and innovation to be done [16]. Therefore, this research aims to investigate the future prospect on current solar technologies which are PV and CSP by determining Levelized Cost of Electricity (LCOE) and land usage comparison to determining the cost comparative between solar technologies for future sustainable energy generation

Section two will discuss about renewal energy generation in general then focusing on the solar technology in Malaysia. Also, will be highlighted Levelized Cost of Electricity (LCOE) as a method of determining the cost of electricity generate. Section three mainly focusing on the methodology adopted for the research which involves semi-structured interview sessions with related officials and reviewing related data sources regarding PV and CSP. Data collected from section three are then analyzed and discussed in section four. Further detailed discussion and recommendations will be presented in section five in order to determine the capability of CSP to be Malaysia's future solar technology. Lastly, a brief conclusion will be presented in section 6 regarding the application and prospect of CSP in Malaysia.

2. Literature Review

2.1 Renewable Energy Generation

Renewable energy could be defined as type of energy generated from natural process such as solar, wind, geothermal, hydropower, and ocean power. Renewable energy has significance potential to use globally for power generations, heating and cooling and transportation to achieve specific benefits which are to reduces environmental impacts, energy security, economic development and energy access [12]. Rapid depletion of fossil fuel reserves (petroleum, coal and natural gas) so as due to the climate change phenomenon facing nowadays forcing the world community towards RE as more reliable and sustainable sources of energy [24]. Realizing this alarming situation, the government has dispatched various number of arrangements of plans to energize and maximize the use of RE.

During the 8th Malaysian Plan (8MP) 2001-2005, Malaysian Government introduced the 5th Fuel Policy 2000 (5FP2000) recognizing RE as the fifth fuel reducing the dependence on oil and natural gas as main source of energy instead of focusing to new sources such as biomass, biogas, municipal waste, solar and mini-hydro for electricity generation [5]. The government's commitment for sustainable energy development further extended in the 9th Malaysian Plan (9MP) 2006-2010, through the launching of National Green Technology Policy (NGTP2009) in July 2009 by the Prime Minister of Malaysia, Datuk Seri Najib Tun Abdul Razak focusing on energy efficiencies, environmental conservation, economic enhancement through technology and improvement in quality of life [4].

The commitment then strengthen in the 10th Malaysian Plan (10MP) 2011-2015, by the establishment of several policies and acts regarding RE management and enhancement such as National Renewable Energy Policy and Action Plan (2009), Renewal Energy Act 2011 and Sustainable Energy Development Authority Act 2011 which all under the governance of Sustainable Energy Development Authority (SEDA) respectively ("Sustainable Energy Development Authority Malaysia (SEDA)," n.d.). Current electricity capacity through RE for Malaysia stands at 50MW and by 2020 the value is expected forty times higher, almost 2000MW [6]. However, the advancement of RE in Malaysia facing some significant downsides as the improvement is slower as planned affecting the country's target to use use 56% of electricity generation by 2050 [4,19].

2.2 Solar Energy Demand and Technology

Current world demand for energy is escalating exponentially and affecting the environment by carbon emission from energy generation. Thus, the development and usage of alternative clean energy which is renewable energy can minimize the impact on carbon emissions and to the environment. Among renewable energy, solar energy has the highest potential to accommodate current energy generation [2]. It is projected that 30% of the world's energy demand will be supplied by solar energy and will reach almost 64% by 2100 creating an industry surpassing the global automotive industry [27]. Referring to the global cumulative PV installed capacity, Europe is heading the way with over 65% (65 GW), followed by Japan by 15% (2.1 GW) and the US of 8% (1.2 GW) [18].

Solar energy technologies have become major contributor to the future energy supply in order to reduce climate change and fossil fuels depletion. There are numerous sorts of sunlight based energy innovations in the business sector, as of recently it is indistinct which sun energy harvesting innovation is the most suitable. Thus, study of solar energy is important to determine which type is suitable and reliable [26]. In current world market, there are number of choices of solar technologies available. Each technology has their own unique advantages and mechanisms. However, among these technologies only two major categories often used in solar energy market which are non-concentrated PV and CSP. Both of these technologies have been proven commercialized used in present day and expected to growth in the future [3]. PV can be alluding as immediate sun based forces that proselytes sun powered radiation specifically to power utilizing boards. Meanwhile, CSP can be refers as indirect solar powers that undergo process which converts concentrate solar energy to heat into a generator to produce electricity using concentrated mirrors [8].

2.3 Types of Solar Energy Technology
2.3.1 Photovoltaic (PV)

PV is a standout amongst the most utilized sunlight based advances strategy to create electrical force power by changing over sun oriented radiation by utilizing photovoltaic semiconductors into direct current electricity. In current market, solar PV panel is the most used technology to generate electricity. Photovoltaic are cutting edge technology sort of sun powered cell that is one of the quickest developing clean energy innovations. PV anticipated that would get to be one of the fundamental system later on world power generation. PV system is a system which consist of PV module and auxiliary component [3,8]. In the last few years, Photovoltaic system has widely used in the world has become one of the alternative energies. Development of high scale PV plant has been increasing to meet need of clean energy. PV plants can be ordered into two principle mode, which are stand-alone and grid-connected. Stand-alone is PV plant that are not connected to main local electrical grid suitable for low electrical load. Meanwhile grid-connected is PV plant that connected to electrical grid utility which suitable for high electrical load [8]. Solar PV generates electrical with no greenhouse gas (GHG) emissions and pollutants during operation with consumes little or no water in the process. These are the benefits of solar PV that gives the world clean energy current and future. In 2020, it is expected to generate cumulative capacity of 210 GW worldwide of clean energy from solar PV. PV installed capacity worldwide has grown massively at rate 49% per year [13].

2.3.2 Concentrated solar power (CSP)

CSP uses indirect solar radiation converting it to heat to generate electrical energy. Electrical generation from CSP is by concentrate sun’s radiation using mirrors or lenses to generate heat, then transfers it using steam, then transferred to turbine to generate electrical energy. While applying it onto utility-scale, CSP plant executed a framework system which sun radiation are centered around a warmth exchanger, then the heat is utilized for drive power generation turbine. Moreover, CSP can be equipped with thermal storage system which are great to generate electricity in low or no sunlight. Generally, CSP gives huge benefits to economic sector which give a significant contribution to environment by maximizing the renewable energy production and fuel cost effectiveness [29]. The emergence of other renewable energy and decreasing price of PV panels gives CSP challenges to remain competitiveness as it remains more expensive than others. The cost of CSP system can be reduced if CSP development trend towards larger plants and economics scale. Figure 1 shows World CSP capacity from 2009 to 2014.

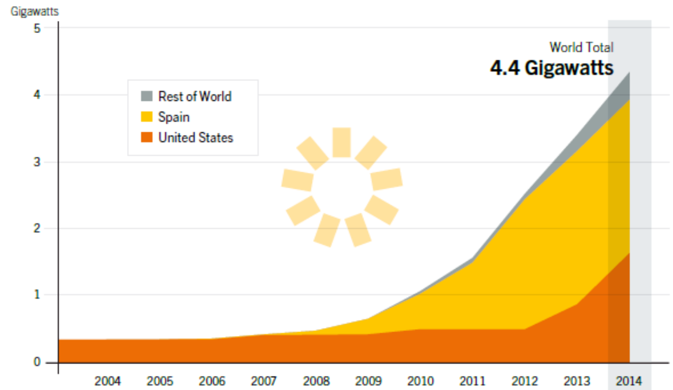


Fig. 1. Concentrating Solar Power Global Capacity [28]

2.4 Solar Energy in Malaysia

Geographically, Malaysia lies between 1ºN and 7ºN of the equator, and 99.5ºE and 120ºE (Ministry of Natural Resources and Environment Malaysia, 2011). With the exposure almost 6 hours of direct sunlight per day Malaysia has the advantages of maximizing the solar energy usage through the development of solar technology system. This lead to the launching of Malaysia Building Integrated Photovoltaic (MBIPV) project in 2005, SURIA 1000 programme in 2006 and SURIA for Developers Programme in 2007 [6]. International Energy Agency (IEA) together with GreenTech Malaysia (previously known as Malaysia Energy Centre - MEC) estimated that just buy using 40% of existing house roof-tops combined with 5% of commercial building could generate 6500MW of power which almost equivalent to large-land-space of multimegawatts PV power system [6]. The Government of Malaysia then introduces Feed-in Tariff (FiT) Scheme as a medium to accelerating the development of RE in the country. After a year of its implementation, significant change of RE usage are recorded most of it from solar PV. The trend shows that solar PV is the most popular technology in the country. FiT scheme ensure PV market remains strong and will contribute to 78% of RE mix by 2050 [21]. National Renewable Energy Policy and Action Plan was acquainted in 2009 with improving the use of indigenous RE sources to accomplish towards security of supplying energy and feasible financial improvement. One of the strategic thrusts on the plan was to enhance RE research and Development. With the destinations of increment to expand RE commitment in the national generation of energy power mix, to upgrade the development of the RE business, to guarantee sensible RE era costs and to improve mindfulness on the part and significance of RE [17]. Thus, need of research for new RE technology is important to fulfil government goals toward renewable energy generation mix in the future.

2.5 Levelized Cost of Electricity (LCOE) Calculation

LCOE is an important metrics for utility industry that determine the cost of electricity generate. It is ascertained by utilizing specific calculation formula and adding machine bookkeeping the greater part of a framework system's lifetime cost which are starting financing cost, development cost, maintenance fees, fuel cost and related applicable rates. All expense and advantage assessments are balanced for swelling and markdown rates to modify for the time-estimation of cash. As a money related apparatus, LCOE is exceptionally significant for the examination of different era choices. A generally low LCOE implies that power is being created requiring little to no effort, with higher returns for the investment [16]. The strategy for LCOE makes it conceivable to look at the expense of power created in energy generation plants of various generation and cost structures. The LCOE are calculated using the following formula [10].

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}} \quad (1)$$

where
I_o = Investment Expenditures
A_t = Total Costs (Fuel, O&M)
$Mt_{,el}$ = Electricity energy generated
i = Discount Rate (%)
n = Operational lifetime in years
t = year of lifetime

3. Methodology

This section presents the exploration approach of this study. It gives the clarification of exploration techniques which are utilized all through the study to get pertinent information for examination of results later on. Generally, two types of data information gathering were employed which are primary and secondary data. Primary data is the arrangement of information gathered from the key personnel who are impacted from this examination. It can give the latest and exact data with respect to sun oriented energy technology in Malaysia. Secondary data are the second wellspring of data that are accumulated through survey of past related diaries paper, industry report, arrangements, government arrangements, daily papers or expositions that the points talked about are identified related with this exploration of research. There are two common approaches available in research. Qualitative approach and quantitative approach. In this research a mix of qualitative and quantitative research approach is applied.

3.1 Interview

Two semi-structured interview sessions were made between the researcher and representative from Sustainable Energy Development Berhad (SEDA) and Tenaga Nasional Berhad (TNB). Both of the representatives are engineers in charge of renewable energy in Malaysia. In-depth interviews were made with both of energy player to understand more about renewable energy which are solar energy technology in Malaysia and to explore their individual perspectives on the idea of CSP technology compared with PV technology with referencing of current renewable energy policy. Interview data are in the form of qualitative and quantitative data are based on questions made as shown in Table 1.

Table 1
Interview Contents data with SEDA and TNB

Parts	Interview Contents	Representative
1	Current Situation of Solar Energy in Malaysia	SEDA & TNB
2	Issues in Solar PV in Malaysia	TNB
3	Implementation of Solar CSP in Malaysia	SEDA & TNB
4	LCOE of PV system in Malaysia	SEDA

3.2 Data and Review Sources

Data sources enable researcher to find and learn from the past experience to be adopted in this study. It involves research on official documents and energy report, published paper regarding solar technology and research reports. Since CSP technology in Malaysia still in its infancy, almost all the vital data and related information needed for the study are very scarce. Thus, the researcher decided to adopt some of the data from the neighbouring country Thailand as reference since CSP technology are widely applied and well established.

3.2.1 Concentrated solar power (CSP) technology in Thailand

According to Janjai *et al.,* [15], Thailand receives direct normal irradiation (DNI) with the range of 1350 – 1400 kWh/m2 which shows similar pattern with DNI in Malaysia. Solar CSP technology requires DNI of at least more than 1800 kWh/m2 in order to be economically feasible and recommended for the installation. This indicates that although an area that does not have enough DNI, solar CSP can be developed. Other than Thailand and Malaysia, German also is another country that shared similar pattern of DNI. In 2012, Thailand had successfully operated its first Solar CSP power plant project called Thai Solar Energy 1 (TSE1) located in Kanchanaburi Province with capacity of 5 MW. TSE1 is a collaboration project between Thailand utility company, Thai Solar Energy and German base company Solarlite. It is first solar CSP plant from 15 that were planned by Thai Solar that expected to have a total capacity of 135MW in the future [31]. Solar experts believe that conditions and development of CSP in Thailand are excellent as the technology should be also applied Malaysia signaling that solar CSP has a bright future in the country [7].

3.2.2 Land use comparison between solar PV and solar CSP technology

Report submitted by National Renewable Energy Laboratory (NREL, 2013) of USA presents a specific study to determine how much land is needed to a solar power plant of various technologies. NREL presents the information in the types of total and direct land-use necessity for different sunlight based energy technology as shown in Table 2.

Table 2
Land-use necessity for PV and CSP technologies projects

Solar Technology	Direct Area		Total Area	
	Generation-weighted average land use (acres/GWh/year)	Generation-weighted average land use (GWh/yr/km2)	Generation-weighted average land use (acres/GWh/year)	Generation-weighted average land use (GWh/yr/km2)
PV (1MW – 20MW)	3.1	81	4.1	61
CSP	2.7	92	3.5	71

4. Data Collection and Analysis

In this chapter, the data collected from section three stated will be analyzed. The result break down of data information which will be presented in tables and figures to give a reasonable view of clarification of the outcomes and will be remarked based upon the discoveries. Understanding of the result will be given to propose appropriate clarifications and to portray the noteworthiness of the discoveries.

4.1 Levelized Cost of Electricity (LCOE) of Solar PV and Solar CSP

In this research, researcher managed to collect all the parameters of LCOE calculation for PV system in Malaysia and solar CSP in Thailand. Based on data collected from interviews and obtained from literature, which has been summarized that LCOE of PV solar plant in Malaysia compared to LCOE of Solar CSP Thailand.

4.1.1 Comparison of present LCOE of solar PV and solar CSP

Both data from solar PV and solar CSP will be compared in graphical form as shown in Figure 2. Parts of the parameters which are fuel cost, electricity price are based on current data from the Energy Commission of Malaysia (EC) meanwhile the operating period of solar power plant in Malaysia is 21 years under SEDA requirement. The LCOE of CSP in Thailand used as benchmark for the system applied in Malaysia combined with fuel and electrical price, and operating period in Malaysia. These measures is to generate general ideas of how much of energy cost use if solar CSP implemented compared to Solar PV in Malaysian condition.

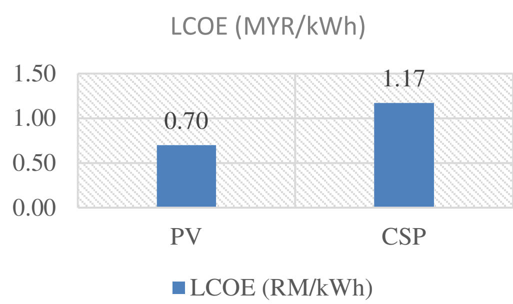


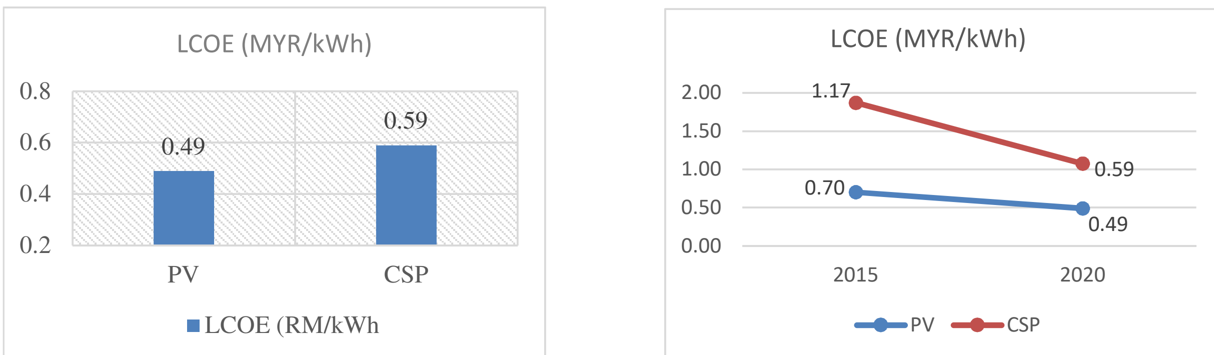
Fig. 2. Comparison of LCOE in 2015 between Solar PV and Solar CSP

We can see that if the CSP system be implement in Malaysia now, the energy cost is not economically feasible compared to solar PV which well-known and established system in Malaysian environment. When the two solar technologies are compared, LCOE of solar CSP are 40% higher than solar PV technologies. This is because market of CSP is low in current situation with high initial investment cost compared with Solar PV. Other than that, global factor also plays role in the energy cost of solar technologies in a country.

4.1.2 Comparison of present and future LCOE of solar PV and solar CSP

Future development of solar energy technology is bigger and more promising rather than other type of renewable energy. International Energy Agency projected that by the year 2020, solar technologies will become matured enough in the market making it more economically feasible and likeable renewable energy sources. It is expected that the cost of CSP panel and technology will fall maximum 50% of current scenarios in 2020. Meanwhile, industry expert’s projects that PV system costs will fall maximum 30% from current scenarios in 2020 [10,29]. Figure 3 show the comparison of expected LCOE between two solar technologies based on system price falling in 2020 with the current LCOE of both solar technologies.

Based on Figure 3 (a) and (b), it is shown that, difference between LCOE of CSP in 2020 in only 10% higher than Solar PV plant. The data shows reducing 30% from 2015 data. This is because the advancement of solar CSP innovation is prone to quicken start of 2020 with the commitments of delegates from sun energy based industry, power segment, innovative work (R&D) and the administration of the government. The thermal energy storage capabilities of CSP plant are contributing to increase demand in solar technology by referencing to the technology ability, current economic scale and improvements in manufacturing of the system. Furthermore, several massive scale of CSP power plants being planned and under construction around the world together with aggressive deployment of government policies on solar energy, this will lead to significant cost reduction from learning effects [14].



(a) (b)

Fig. 3. (a) Comparison of LCOE in 2020 between Solar PV and Solar CSP. (b) Comparison of LCOE of the year 2015 and 2020 of PV and CSP

4.2 Land Use Requirement Between Solar PV and Solar CSP

Land acquisition before developing solar plant in an area is important as the area of the land will determine how efficient and economically feasible of s system. Considering information acquired from writing with respect to land utilization of PV and CSP sun powered technology in past chapter, the total range relates to all area encased by the site boundary. The direct area includes arrive straightforwardly possessed by sun powered clusters, access streets, substations, administration structures, and other base infrastructures as shown in Figure 4. Figure 5 shows the differences on how much land is require between both solar energies. Figures shows comparison and differences between the direct area and total area of Solar PV and Solar CSP system.

Figure 5 (a) and (b) shows differences of land use and how much energy generated for certain land area between solar PV and Solar CSP power plant both in direct area and total area. It is shown that Solar PV acquired total land area (direct and total area) almost 13% higher than solar CSP to generate the same amount of power (GWh). Meanwhile, above data shows Solar CSP generate more energy in an area (km^2) with total difference almost 14% higher than Solar PV. This happened because PV and CSP system are affected by different amount of land use, plant configuration, and types of technology used in an area to produce specific amount of energy to become economically feasible.

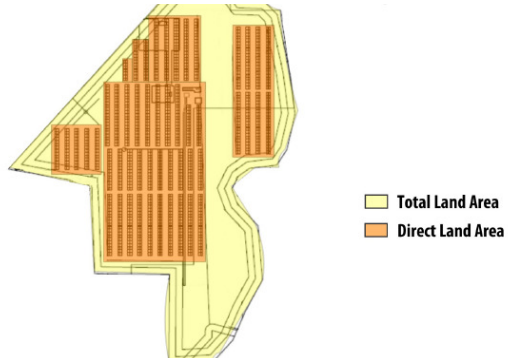
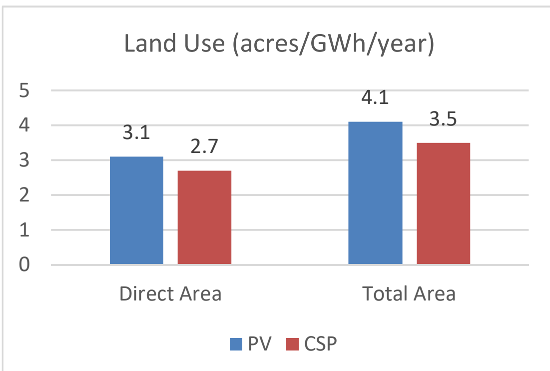
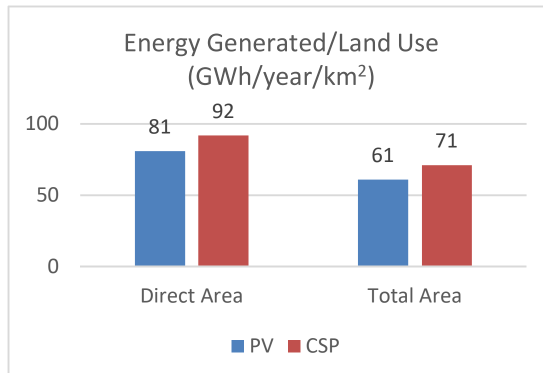


Fig. 4. Example of Direct Land and Total Land Area [25]



(a)



(b)

Fig. 5. (a) Comparison on Land Use of Solar PV and Solar CSP (acres/GWh/year). (b) Comparison on Energy Generated with Land Use Solar PV and Solar CSP

5. Discussions and Recommendations

Based on the results, it shows that the trend of solar energy generation is very likeable in Malaysia. With the price reduction of both solar PV and CSP for the next 5 years, investors and industry have broad selection of solar technologies to be implement with cooperation of FiT scheme from SEDA. For current circumstance, solar energy technology of PV innovation still the dependable decision of sunlight based innovation in Malaysia, however as the information appears in the following 5 years as CSP innovation and frameworks are coming to business development, it will guarantee of expanded proficiency, declining costs and higher worth through expanded dispatch capacity. Improvement would increment quickly after 2020 when CSP gets to be aggressive for crest and mid-merit power in a carbon-obliged world, running from 30 GW to 40 GW of new-assembled plants every year after 2030. Later on, inside the expansive innovation classifications of PV and CSP, land-use measurements are likewise affected by particular innovation decisions, for example, cell proficiency, following technique, and incorporation of warm vitality stockpiling, and are an element of the sun oriented asset accessible at every site. Other than that, disadvantage on PV that can't store heat energy from the sun is adding to CSP innovation to rise. In nations or locales area with solid daylight and clear skies, CSP plants with inherent heat stockpiling capacities might be preferable set over PV with capacity to catch an expansive offer of power interest when the sun is not shining. This shows the technology is suitable to be develop and implement in Malaysia as because Malaysia climate are hot and humid throughout the year with sometimes cloud cover is too high for certain area making solar PV cannot receives solar UV light to generate power. Other than that, Solar CSP is suitable for remote and rural areas as it can store high amount of energy generated from the radiation in the day making it suitable for night or emergency no electric usage. Thus, this study recommends on more study has to be made to investigate solar energy generation in terms of economic evaluation, physical development and potential of developing other than Solar PV technology in Malaysia to help Malaysia achieve more RE based energy generation in the future.

6. Conclusion

There are many study done on application of CSP in Malaysia. All of it recommends the usage of CSP in the future as one of the RE generation. This study was done with limited time and sources of data because Malaysia are still behind in solar energy generation. From all the data findings and analysis, it can be concluded that it meets the purpose of this study which to compare study on energy cost of Solar PV and Solar CSP and to find which system is suitable for future sustainable energy generation in Malaysia. Generally, there are barriers from developing CSP in Malaysia but in the future or the earliest next 5 years, we can take CSP as one of the reliable RE technology. Cooperation between researchers, industry player as well as government's support will help bring new technology in RE like CSP to a market-ready and development position in the upcoming years.

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