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Research article

Effects of wind speed and temperature on economics and environmental impact assessment of different solar PV systems in Malaysia

Efectos de la velocidad del viento y la temperatura en la economía y la evaluación del impacto ambiental de diferentes sistemas solares fotovoltaicos en Malasia

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Abstract. *This study aims to analyse the effect of temperature and wind speed on the performance of different types of photovoltaic (PV) systems at a different state in Malaysia and how it affects the economics and environmental impact assessment in the present year of 2018 as well as future years in 2030 and 2040. Three types of grid-connected solar PV modules namely Mono-Crystalline, Poly-crystalline, and Thin Film were selected to be implemented in different cities of Shah Alam, Chuping, Alor Setar, Ipoh and Kota Kinabalu. A mathematical model was adopted to estimate the performance characteristics of the solar PV modules. Based on the data in the present year, the highest power output produced by the Mc-Si module for Alor Setar city is given by 33.40 MWh/year while the lowest amount of power output provided by this PV panel is about 28.18 MWh/year in Shah Alam. Furthermore, an area of 144 m^2 for the Mono-Crystalline PV module can satisfy the total energy requirement by the resident as it was the most profitable to be implemented compared to Poly-crystalline and Thin Film. The findings of this study can serve as important information on the economic viability of installing PV systems in the selected cities in Malaysia.*

Keywords: Temperature; Wind speed; Solar radiation; PV performance.

Resumen.- *Este estudio tiene como objetivo analizar el efecto de la temperatura y la velocidad del viento en el rendimiento de diferentes tipos de sistemas fotovoltaicos (PV) en un estado diferente de Malasia y cómo afecta la evaluación del impacto económico y ambiental en el presente año de 2018, así como en el futuro. años en 2030 y 2040. Se seleccionaron tres tipos de módulos fotovoltaicos solares conectados a la red, a saber, monocristalinos, policristalinos y de película delgada, para implementarlos en diferentes ciudades de Shah Alam, Chuping, Alor Setar, Ipoh y Kota Kinabalu. Se adoptó un modelo matemático para estimar las características de rendimiento de los módulos fotovoltaicos solares. Según los datos del año en curso, la producción de energía más alta producida por el módulo Mc-Si para la ciudad de Alor Setar es de 33,40 MWh/año, mientras que la producción de energía más baja proporcionada por este panel fotovoltaico es de aproximadamente 28,18 MWh/año en Shah Alam. Además, un área de 144 m^2 para el módulo fotovoltaico monocristalino puede satisfacer el requerimiento total de energía del residente, ya que fue el más rentable de implementar en comparación con el policristalino y la película delgada. Los hallazgos de este estudio pueden servir como información importante sobre la viabilidad económica de instalar sistemas fotovoltaicos en las ciudades seleccionadas de Malasia.*

Palabras clave: Temperatura; Velocidad del viento; Radiación solar; Rendimiento fotovoltaico.

1. Introduction

Over the last decades, there has been a significant increase in the demand for fossil fuels for energy production to meet the energy requirement for industrial and domestic applications. The continuous exploration and ever-growing demand for these fossil fuels have led to the emission of toxic materials such as carbon dioxide into the atmosphere. Consequently, this has led to global warming [1], [2].

A growing body of literature recognises the threat posed by the depletion of fossil fuel such as natural gas, coal, and oil. These fuels also contribute significantly to global carbon dioxide and climate change [3], [4]. An obvious solution to curb the escalation of the ongoing depletion of global fossil fuel and environmental pollution is to promote the adoption of sustainable and renewable energy technologies; this concern has attracted extensive attention. Renewable energy can be produced from natural resources such as solar, wind, biomass and geothermal [5]. Among these renewable energy technologies, solar energy is the fastest-growing technology in Malaysia [3].

The potential application areas of solar energy are photovoltaic (PV) technology for electrical power production and solar thermal energy for thermal energy production [6], [7]. Solar PV consists of a semiconducting material such as silicon which directly converts solar irradiance into electrical energy [8]. Solar PV offers a promising technology with several benefits such as pollution-free and easy installation it is therefore expected to contribute significantly to global future sustainable energy development [9]. It is now well established from a variety of studies that, climate change has a considerable effect on renewable energy resources, for example in the case of solar energy, wind speed, and ambient temperature are the most important parameters of the climate that need considerable attention [10, 11].

In the new global economy, PV installation has become a central issue to meet the global energy demand and reduce emissions caused by traditional energy resources such as coal and natural gas [10], [11]. Therefore, the issue of PV installation and application, especially for domestic and industrial applications, has received considerable critical attention in Malaysia [12], [13]. For example, the Government of Malaysia has projected that by the year 2050, 11.5GW of renewable energy capacity be installed [14].

Recently, researchers have shown an increased interest in increasing the capacity of PV installation, for example, the International Energy Agency (IEA) estimated to produce 11% of global electricity demand through photovoltaic (PV) by the year 2050 and this is expected to reduce 2.3 Gt of global CO_2 emission of per year [15]. Ambient temperature has been instrumental in our understanding of photovoltaic module performance, and its efficiency reduces when the ambient temperature increases [16]. Existing research recognises the critical role played by ambient temperature in influencing the performance of photovoltaic modules. According to [16], Thin Film photovoltaic modules are better option in hot climates [17]. Recently investigators have examined the effects of ambient temperature on photovoltaic modules under Karabuk (Turkey) climatic conditions, they conclude that ambient temperature plays an essential role in the performance of photovoltaic

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modules [18]. Generally, the solar photovoltaic modules are manufactured at standard test conditions (STC) (i.e. 1000 W/m², Air Mass 1.5 and module operating temperature 25°C), however ambient temperature and wind speed at a specific location affect the performance of the module, especially if its application is for domestic purpose, hence the photovoltaic module's performance changes concerning the actual location and prevailing ambient conditions to which they are subjected [19]–[21]. Other literature also concluded that increase in wind speed results in cooling the PV through convection heat loss to the ambient and this would increase the PV module efficiency [22].

Since the government of Malaysia has planned to increase the capacity of PV energy production up to about 11% of the country's total energy demand, it is important to understand the performance of PV modules at different ambient temperatures and wind speeds of the country. However, even though previous research related to the performance of PV module efficiency and economic analysis for specific locations have been carried out, a lot more cities have not yet been covered, especially for domestic applications. Therefore, this study aims to fill this gap by investigating the effect of ambient temperature and wind speed on the economic and electrical efficiency performance of different PV modules in specific cities in Malaysia.

2. Methodology

2.1 Subsection title Proposed residential house, load consumption and load profile

Fig. 1 shows the proposed design of the residential house with a grid connection PV system and its respective predicted load. The system comprises PV panels, DC/AC inverter, Fuse boards, loads, and the PV meter. As the solar radiation falls on the PV panels, DC current is produced. The DC current can, however, be converted into AC current by means of an inverter which is used to match AC requirements in residential appliances. Any excess electrical power that is produced can be sent to Tenaga Nasional Berhad (TNB) grid.

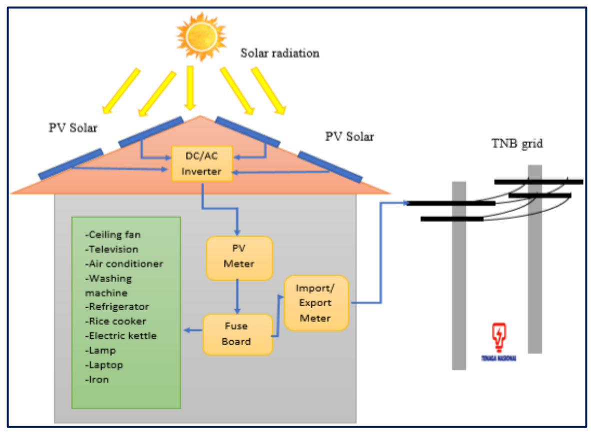

Figure 1. Proposed design of residential house with a grid-connected PV system.

All the estimated load and power consumption by the residential house were obtained based on the selected cities of this study, namely, Shah Alam, Chuping, Alor Setar, Ipoh and Kota Kinabalu. The detailed geographical location of the chosen cities is shown in Table 1.

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Table 1. Parameters for the selected cities

Selected Cities	Latitude (°N)	Longitude (°E)	Altitude (m a.s.l)	Time Zone (UTC)
Shah Alam	3.0733	101.5185	45	8
Chuping	6.4985	100.2580	105	8
Alor Setar	6.1248	100.3678	60	8
Ipoh	4.5975	101.0901	195	8
Kota Kinabalu	5.9804	116.0735	0	8

From the data collected, the total energy consumed by the resident per day is 27.432 kWh (refer to Table 2) while 822.96 kWh energy consumed monthly by the resident. Fig. 2 shows the hourly energy load profile of a residential house. It can be observed that the maximum hourly power consumption is 3.725 kW, which requires the PV system to produce at least 89.4kWh/day (3.725 kW × 24 hours) of energy in order to support the power consumed by the load. Thus, the PV system should yield at least 32.631 MWh/year (89.4 kWh×365 days). Therefore, base on the preliminary study, 23 kWp of PV capacity system has been chosen based on the size of the PV panel available in the market that is expected to produce annual energy of 36.364 MWh/year.

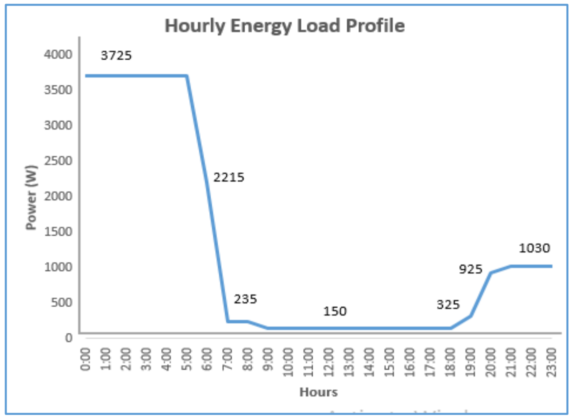

Figure 2. The hourly energy load profile

Table 2. Predicted load and power consumption

No.	Equipment	Quantity	Power rating (W)	Time usage (hour)	Energy (Wh)
1.	Ceiling Fan	5	75	13	975
2.	Television	1	150	8	1200
3.	Air Conditioner	1	3500	5	17500
4.	Washing Machine	1	500	1	500
5.	Refrigerators	1	150	24	3600
6.	Rice Cooker	1	627	1	627
7.	Electric kettle	1	480	1	480
8.	Fluorescent Lamp	10	100	14	1400
9.	Laptop	3	75	2	150
10.	Electric Iron	1	1000	1	1000
Average total daily power consumption					**27432**

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3. Model equations and simulation

Most previous studies have shown that solar cells' performance varies with temperature changes [23]. Therefore, to determine the performance of all the three (3) types of PV module in this study (Monocrystalline/Polycrystalline /Thin film), the cell temperature was estimated using the NOCT-Standard formula as shown below [24], [25].

$$T_c = T_a + \frac{T_{NOCT} - 20}{800} \times I(t) \tag{1}$$

Where T_c is the PV cell temperature, T_a is the ambient temperature, T_{NOCT} is Nominal Operating Cell Temperature. The solar radiation, I(t) is measured at 1000W/m^2 while the irradiance is fixed at 800W/m^2. Once the PV cell temperature is obtained, it can be used to determine the efficiency of the solar PV modules [27, 28].

$$\eta_c = \eta_{ref}\left[1 - \beta_{ref}\left(T_c - T_{ref}\right)\right] \tag{2}$$

All the parameters of η_{ref}, β_{ref} and T_{ref} are provided by the PV manufacturer [24]. Equation (3) can be used to determine the wind speed, where v_w= 1 m/s is the local wind speed close to the module while v_f is the wind speed measured 10 meters above the ground [24].

$$v_w = 0.68 v_f - 0.5 \tag{3}$$

The nominal power of the PV panel has been set at 23 kWp as available in the market. Other parameters that were used for the simulation are shown in Table 3.

Table 3. Constant parameter required

No.	Parameters	Value
1	Nominal power	23kWp
2	Module type	Standard
3	PV panel Technology	Monocrystalline/Polycrystalline/Thin film
4	Mounting Disposition	Facade or tilt roof
5	Ventilation property	Ventilated
6	Tilt Angle	30˚
7	Azimuth Angle	0˚

3.1 Economics and Environmental Impact Assessment

3.1.1 Economics models

Based on this case study, the economic profitability of the PV systems can be calculated by using three key indicators namely, Payback Period (PP), Net Present Value (NPV) and Life Cycle Cost (LCC).

i. Payback period

The payback period is the number of years it takes for the energy-cost saving to recover the initial investment costs of a system [26].

$$Payback \quad Period = \frac{Capital \quad investment}{Cash \quad in \quad flow \quad per \quad period} \tag{4}$$

ii. Net Present Value (NPV)

Net present value is the difference between the present value of cash flows into and from a project [29, 30]. Thus, the higher the amount of NPV obtained, the greater is the financial advantages.

$$NPV = -S + \frac{Q_1}{(1+i)} + \frac{Q_2}{(1+I)^2} + ... + \frac{Q_N}{(1+i)^N}$$

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$$= -S + \sum_{j=1}^{N} \frac{Q_J}{(1+i)^j} \quad (5)$$

From the equation, Q is the net cash flow, S is the cost of the PV system and N is the life cycle of the PV panel that is estimated to be 21 years [27].

iii. Life Cycle Cost (LCC) Analysis

Where C_{PV} represents cost of PV modules, C_{inv} is the inverter cost, C_{ins} is the installation cost, and the $C_{O\&M}$ is the operating and maintaining cost. Annualised LCC analysis of the PV systems can be calculated by the equation (7) below.

$$ALCC = LCC\left[\frac{1-\left(\frac{1+i}{1+d}\right)}{1-\left(\frac{1+i^N}{1+d}\right)}\right] \quad (7)$$

Where i represents inflation rate, N is PV lifetime that is 21 years, and d indicates the discount rate. Lastly, equation (8) can be used to determine the actual cost invested by the owner to produce 1kWh of energy.

Life Cycle Cost (LCC) is an analysis used to determine the cost involved in the project that includes the cost of maintaining, operating, owning and the project disposing of cost.

$$LCC = C_{PV} + C_{inv} + C_{ins} + C_{O\&M} \quad (6)$$

$$Unit\ electrical\ cost = \frac{ALCC}{365 \times E_{LOAD}} \quad (8)$$

3.1.2 Environmental Model

Estimating environmental impacts assessment of energy technologies in the early design stage is critical [26] to address global warming issues. United Nations report that CO_2 intensity of electricity generation needs to drop by 80%, by 2050 [32-34]. The result from the environmental impact assessment of PV systems can be used to establish a comparison on how much deployment of PV modules can save the amount of GHG emission and predict the potential for all cities in the future. Table 4 shows the GHG emission factors used in this stud

Table 4. The GHG emission factors

GHG gases product from coal power plants	Emission Factors (kg/kWh)
CO_2	0.97
SO_2	0.00124
NOx	0.00259
Ash	0.068

4. Results and Discussion

4.1 Solar radiation data for temperature

Fig. 3 shows the effect of solar radiation on ambient temperature for the five selected cities. The simulation was conducted to forecast the solar radiation for all the cities in the present year (2018) and the future year of 2030 and 2040 [35, 36]. Based on Fig. 3, it can be said that high global radiation leads to high ambient temperature.

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The amount of global radiation received by the PV panel in 2018, 2030 and 2040 is relatively the same with only a slight difference. As the year keep increasing, the ambient temperature also increases with increases in global radiation. The city that gained the highest global radiation is Chuping as shown in Fig. 3(b). In the present year and year 2030, Chuping acquired about 180W/m^2 of global radiation monthly with ambient temperatures of 29.5°C and 29.7°C, respectively). In 2040, an ambient temperature of 29.8°C that corresponds to global radiation of 181W/m^2 is expected. It can also be observed from Fig. 3(a) that Shah Alam obtained the lowest amount of monthly global radiation of 117W/m^2 in the present year and future year of 2030 and 2040, this corresponds to a progressive increase in ambient temperature from 26.8°C (2018) to 27°C (2030) and to 28.2°C (2040) respectively.

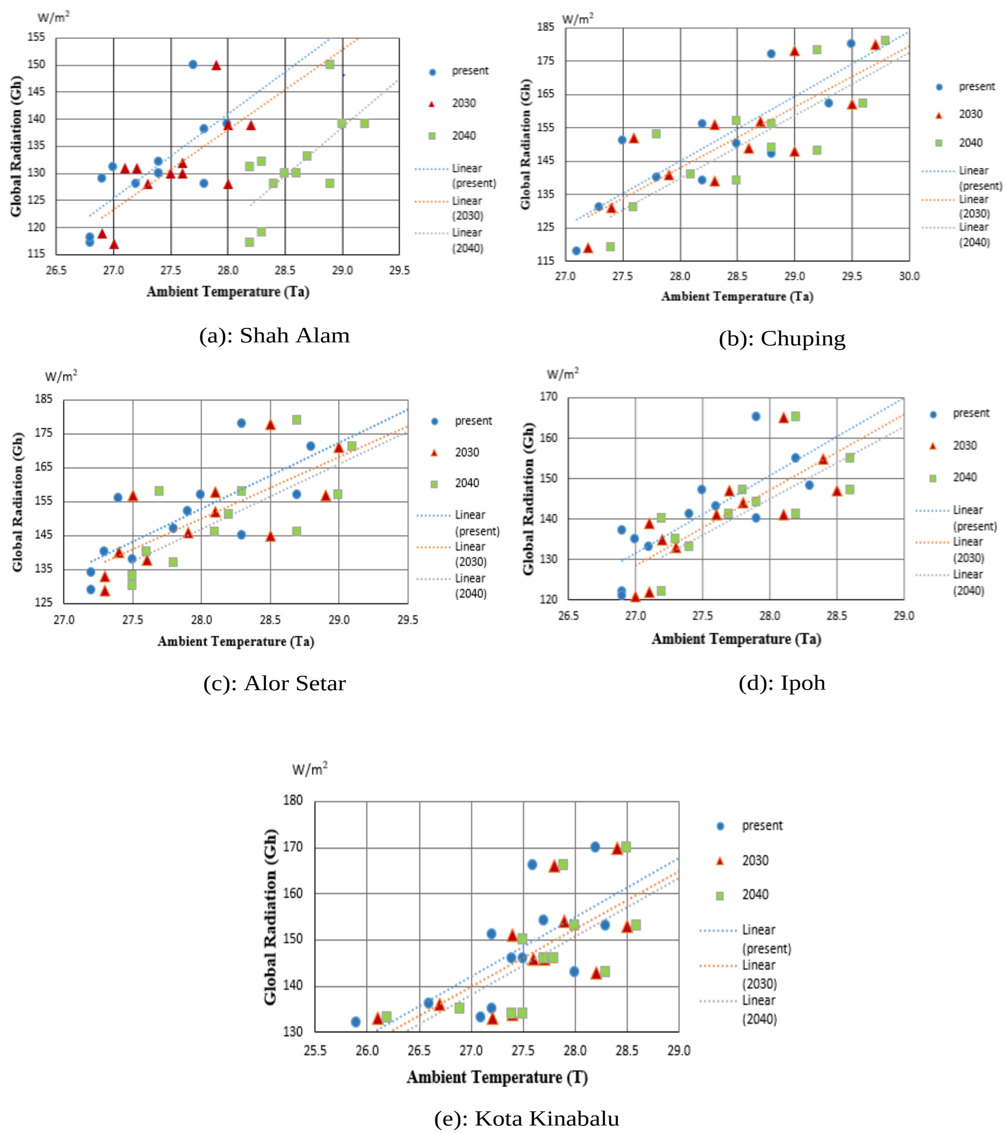

Figure 3. Global radiation versus ambient temperature.

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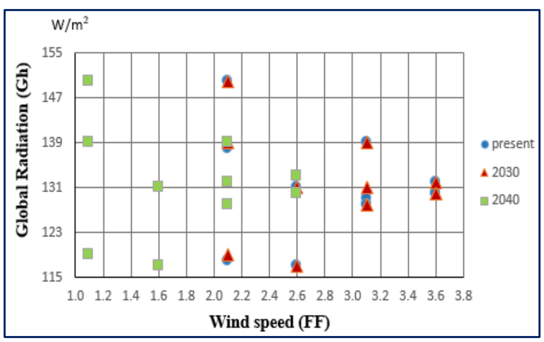
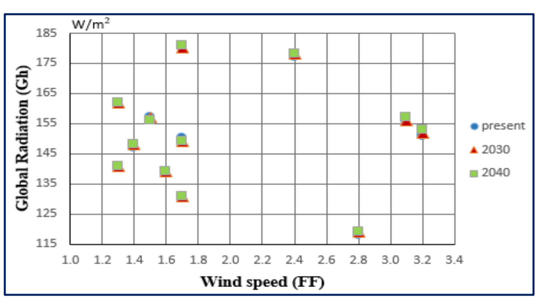
4.2 Solar radiation data for wind speed

Figure 4 shows the forecasted data for global radiation that is expected to be received by the PV panel at various wind speeds. The forecasted data of global radiation for the present year, the year 2030 and the year

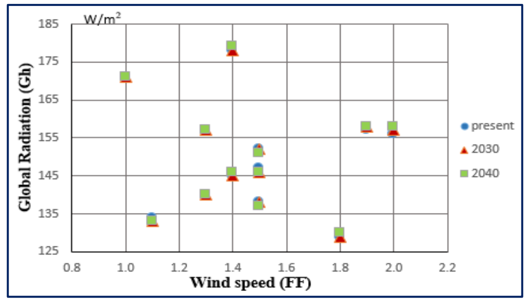
2040 for all five (5) cities were obtained through simulation. It can be observed from Figure 4 that there is a fluctuation in the amount of global radiation acquired as the wind speed increases for all the cities. Among all the selected cities, however, Chuping is the city that received the highest amount of global radiation of 180W/m^2 in the present year and year 2030, while in the year 2040, the amount of global radiation increased slightly to 181W/m^2 at the same wind speed of 1.7 m/s. Besides, Shah Alam also recorded the lowest monthly global radiation of only 117W/m^2 at 2.6 m/s wind speed for all the present year and future years of 2030 and 2040 as shown in Fig. 4(a). Therefore, it can be concluded that the higher wind speed received corresponds to the least amount of global radiation.



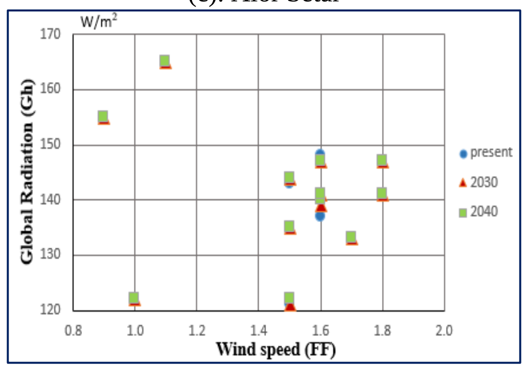
(a): Shah Alam



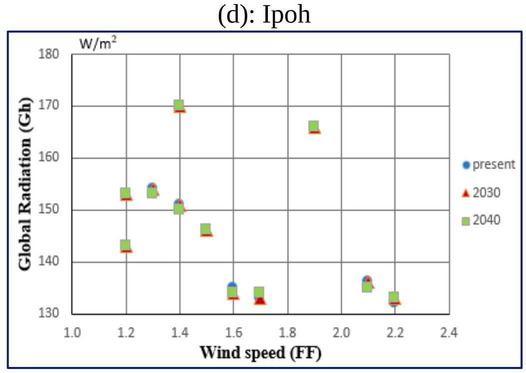
(b): Chuping



(c): Alor Setar



(d): Ipoh



(e): Kota Kinabalu

Figure 4. Global radiation versus wind speed

4.3 Effect of temperature on the PV performance

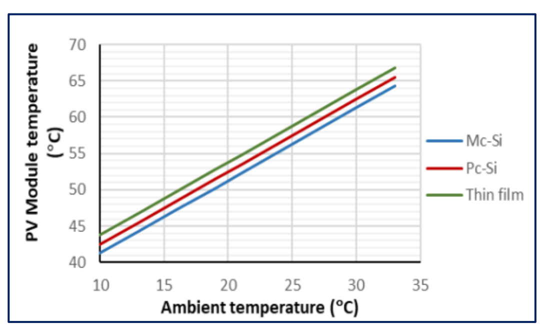


Figure 5. PV module temperature versus ambient temperature

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Figure 5 shows that, there is direct correlation between the ambient temperature and the PV module temperature, as the ambient temperature increases, the PV module temperature also increases. The thin film module obtained the highest module temperature compared to polycrystalline and mono-crystalline modules. The efficiency of the PV module has been estimated using equation (2). It is shown that, as the module temperature increases, it results in a decrease in PV module efficiency (Refer to Fig. 6). The monocrystalline PV panel produced the highest efficiency compared to the other two (2) types. For example, at PV module temperature of 48 °C, the efficiency of monocrystalline, polycrystalline and thin film modules are 18.60%, 13.19% and 8.29% respectively.

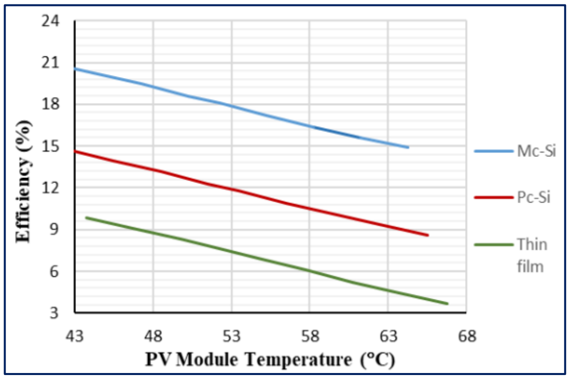

Figure 6. PV efficiency versus module temperature.

4.4 System simulation result

The performance of each PV module, namely, Monocrystalline Silicon (Mc-Si), Polycrystalline Silicone (PC-Si) and Thin Film technologies, was determined to identify which one is suitable to be installed at the rooftop by residents based on the cities selected. Each of the PV modules produces different efficiency and power output with respect to the global radiation received at the location of the cities. As shown in Fig.7, it can be clearly seen that the mono-crystalline silicon PV panel produces the highest power output for each of the five selected cities throughout the year 2018. Based on the data in the present year, the highest power output produced by the Mc-Si module for Alor Setar city is given by 33.40 MWh/year while the lowest amount of power output provided by this PV panel is about 28.18 MWh/year in Shah Alam. For Pc-Si module, the highest power output for Alor Setar city is 31.52 MWh/year and the lowest power output of 26.68 MWh/year was recorded for Shah Alam, whereas the highest power output for thin-film module is 17.71 MWh/year which corresponds to Chuping city, however, Shah Alam still produced the least power output with only 1.25 MWh/year.

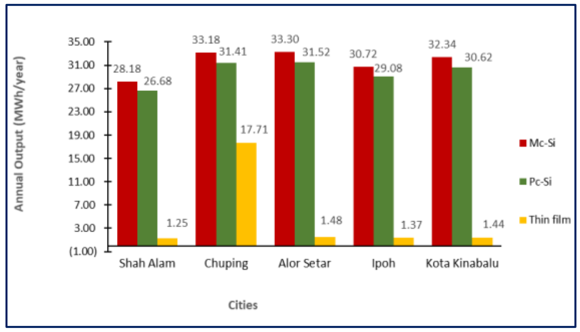

Figure 7. Annual PV Panels output of each sites for present year.

The forecasted data for the year 2030 and 2040 can be seen in Fig. 8 and Fig. 9 respectively. Both years indicate that Chuping has the potential to produce the highest PV power output for the Mc-Si, Pc-Si and Thin Film PV module while Shah Alam provided the least amount of power output throughout the year. From the present year until 2040, all of the output power for the three types of PV systems continued to increase in all of the cities except for Ipoh and Kota Kinabalu. The annual power output for Mc-Si panel in Ipoh decreased slightly by about 0.04 MWh/year, which is from 30.72 MWh/year in 2018 to 30.68 MWh/year in 2030 before it rises back to 30.79 MWh/year with an increase in power output of 0.11 MWh/year in 2040.

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Lastly, for Kota Kinabalu, the Pc-Si module shows an increase of 0.07 MWh/year from 2018 to 2030 before it decreases to 0.11 MWh/year in 2040 whereas the thin film panel shows a rapid increase from 1.44 MWh/year in the present year to 17.31 MWh/year in 2030 before it slightly decrease to 17.25 MWh/year in 2040. To recapitulate, the mono-crystalline silicon system is the most efficient PV panel as it produced the highest PV power output compared to the other PV system. Thus, Chuping proved to be the best location to install the PV panel as it received the highest amount of solar radiation throughout the present year and in the future also. It can be concluded that an increase in solar radiation will increase the PV power output and thus results in a better performance.

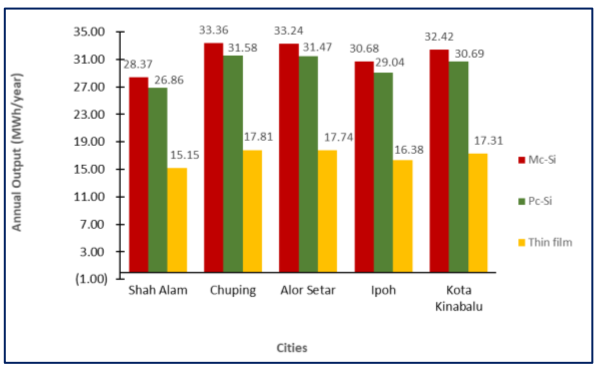

Figure 8. Annual PV Panels output of each sites for the year 2030.

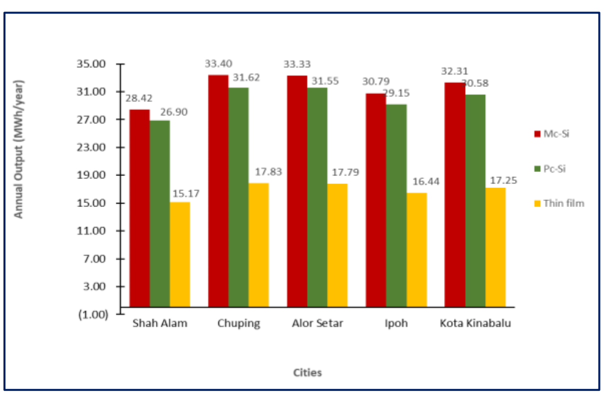

Figure 9. Annual PV Panels output of each site for the year 2040.

4.5 Economics impact Assessment result

4.5.1 Payback Period (PP)

Figure 10. Payback period of the selected cities

The payback period is the number of years the energy-cost saving takes to recover the initial investment costs of a system [26]. This payback period has been determined using equation (4). The initial investment cost for the monocrystalline is Malaysian Ringit (RM), RM 193,750.00, and RM 190,952.80 for polycrystalline while the cost for thin-film is RM 180,430.00. The shortest time taken to regain the initial cost is about 5 years for monocrystalline panels in the city of Chuping and Alor Setar as shown in Fig. 10 above. Both cities provide the highest amount of PV power output and thus the time required to pay back the investment cost will be shorter.

Plus, the thin-film panel results in the longest time taken to obtain the initial investment cost for all five cities. Based on the graph, it takes 11 years to get back the installation cost for Shah Alam city as it proves that the PV power output of thin-film module provides the least amount compared to monocrystalline and polycrystalline silicon modules. The payback calculation for the present year and for 2030 and 2040 results in almost the

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same amount with relatively small changes which does not significantly affect the payback time and thus only the present year data is shown in Fig.10 above. Through this payback calculation, the residents can predict the time taken to regain their investment cost and choose the suitable PV module to be implemented at their location whether it is beneficial or not for them to invest.

Table 3. Net Present Value (NPV) for all of the selected cities.

Site	Year	Monocrystalline	Polycrystalline	Thin Film
Shah Alam	present	RM 141,177.83	RM1 26,113.30	RM 31,432.52
	2030	RM 143,419.58	RM 128,228.14	RM 440.81
	2040	RM 143,990.01	RM 128,767.17	RM 79.96
Chuping	present	RM 200,551.42	RM 182,312.98	RM 30,060.34
	2030	RM 202,744.77	RM 184,400.24	RM 31,235.48
	2040	RM 203,172.60	RM 184,793.89	RM 31,457.89
Alor Setar	present	RM 201,953.31	RM 183,645.82	RM 4,393.87
	2030	RM 201,261.69	RM 182,994.10	RM 30,442.54
	2040	RM 202,288.40	RM 183,961.05	RM 30,987.30
Ipoh	present	RM 171,352.31	RM 154,676.31	RM 18,012.99
	2030	RM 170,828.97	RM 154,181.52	RM 14,195.13
	2040	RM 172,155.22	RM 155,442.19	RM 14,905.31
Kota Kinabalu	present	RM 190,615.92	RM 172,913.13	RM 9,442.25
	2030	RM 191,549.99	RM 173,803.05	RM 25,258.75
	2040	RM 190,195.21	RM 172,519.57	RM 24,535.65

On the other hand, the thin film module was not preferred and therefore not suitable to be invested into by the resident since the NPV results shown are very small which indicated that this PV module produced a very low value of the cash flow for 21 years. Thus, from this analysis, it can be said that the forecasted data for the three (3) PV systems is expected to increase in the year 2030 and 2040 except that for Ipoh and Kota Kinabalu where there is a slightly increase and decrease trend.

4.5.2 Net Present Value (NPV)

The Net Present Value (NPV) results for the cash flow were estimated using Excel and the calculation was done using equation (5). Cash flow takes into account the total amount of incomings and outgoings cash of the operating activities of an organisation. Table 3 below shows the NPV for the three (3) types of PV systems used in this study, the NPV is used to determine the profitability of the three (3) PV systems at each of the selected cities. Based on the tabulated data shown, the monocrystalline PV panel gives the highest amount of NPV for all five (5) selected cities. Thus, monocrystalline is the best PV module to be installed especially at Chuping, this is because the higher the amount of NPV obtained the higher the profit margin which eventually

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translates into a greater financial benefit for the residents.

4.5.3 *Life Cycle Cost Analysis (LCCA)*

Life Cycle Cost (LCC) is an analysis that is used in order to determine the cost involved in the project which includes cost of maintaining, operating, owning and the project disposing cost. By using equation (6) and the related parameter needed, the life cycle cost (LCC) for all three (3) types of PV systems were obtained as tabulated in Table 4. The highest life cycle cost (LCC) is the Monocrystalline PV Panel with RM 193,750.00, followed by the Polycrystalline PV panel which is RM 190,952.80 whereas the LCC for Thin Film PV Panel is RM 180,430.00. Next, to find the annualised LCC (ALCC) value, equation (7) was used. The ALCC for Monocrystalline PV Panel is RM 15,335.08 while for Polycrystalline PV Panel is RM 15,113.68 and for Thin Film PV Panel is RM 14,280.81. Lastly, equation (8) is the formula that was used to calculate the unit cost of electricity for 1kWh. From this calculation, the actual cost invested by the owner to produce 1 kWh of energy can be estimated. Based on the result of the analysis, the actual cost for producing 1 kWh of electricity for Monocrystalline is RM 1.00 and Polycrystalline is RM 0.99 while for Thin-film is RM0.93. Even though the Thin Film PV Panel provides a higher profit margin, however, it is still not recommended for the residents to implement the thin-film module because of its higher NPV value.

Table 4. The cost involved in the Life Cycle Cost Analysis (LCCA).

No	Parameters	Mc-Si		Pc-Si		Thin Film	
		Cost	Cost for 23 kWp (RM)	Cost	Cost for 23 kWp (RM)	Cost	Cost for 23 kWp (RM)
1	PV Panel	RM 13.90 /Wp	166,800	RM 13.90 /Wp	164,280	RM13.90 /Wp	154,800
2	Installation	10% PV cost	16,680	10% PV cost	16,428	10% PV cost	15,480
3	Inverter	RM 3.91 /W	8602	RM 3.91 /W	8602	RM 3.91 /W	8602
4	Operation & maintenance cost	1% PV Cost	1668	1% PV Cost	1642.80	1% PV Cost	1548
TOTAL		RM 193 750		RM 190 952.80		RM 180 430	

4.6 *Environmental Impact Assessment Result*

The environmental impact assessment is very important for the owner to consider in the investment of PV systems to make a comparison on the amount of GHG emission that can be saved with the deployment of solar PV and to predict the potential for all the cities in the future. The analysis shown in Fig. 12 shows that Alor Setar city has the potential to save a considerable amount of GHG emission per year followed by Chuping, Kota Kinabalu, and Ipoh while Shah Alam saves the least amount. It can be seen that the Monocrystalline is the best PV panel to be chosen by the residents as it can save the highest amount of GHG emission compared to the other PV types.

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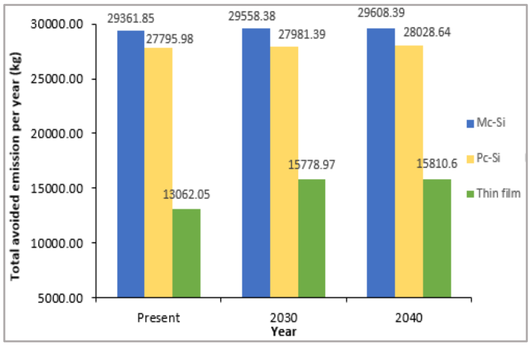
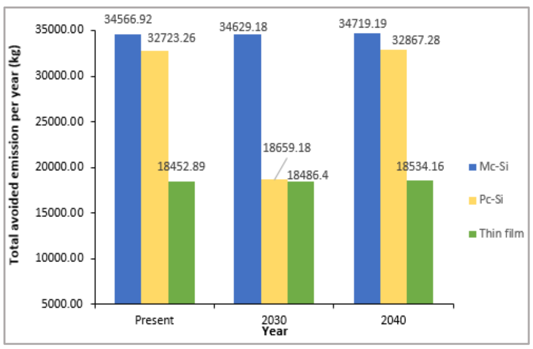
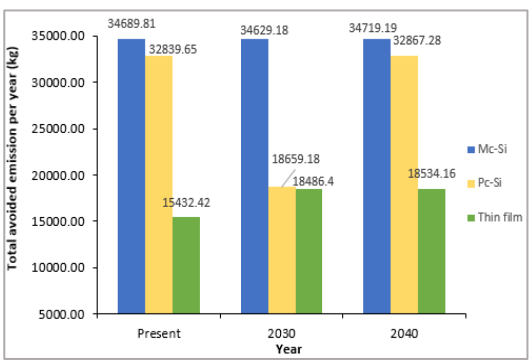


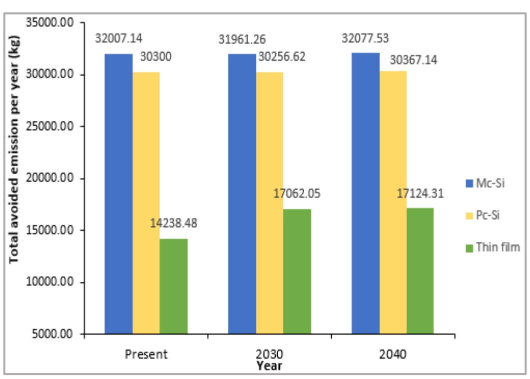
(a): Shah Alam



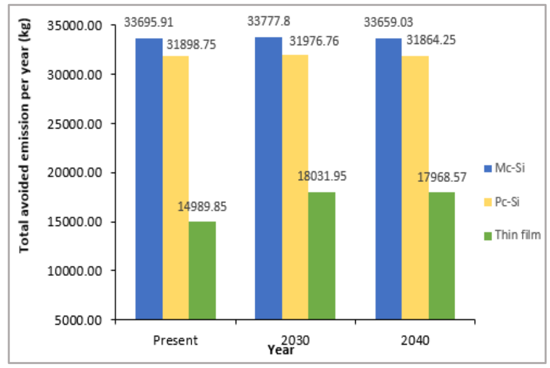
(b): Chuping



(c): Alor Setar



(d): Ipoh



(e): Kota Kinabalu

Figure 11. Total avoided amount of GHG emission for all selected cities

Fig. 11(c) confirms that, in relation to the present year and by using Monocrystalline PV panel, Alor Setar City can save up to about 34.69 tonne (34689.81 kg) of GHG followed by Polycrystalline PV panel which can also save up to 32.84tonne (32839.65 kg) of GHG while the Thin Film can save 15.43 tonne (15432.42 kg) of GHG. The forecasted data for the future year 2030, showed that there is a slight decrease in the amount of GHG emission that can be saved by the Mc-Si module which is about 0.061 tonne (60.63 kg) from 34.69 tonne to 34.63 tonne. However, the Pc-Si module showed a rapid decrease of about 14.18 tonne (14180.47 kg) from 32.84 tonne (32839.65 kg) to 18.66 tonne (18659.18 kg) GHG emission while the thin-film module resulted in an increasing amount of GHG emission that can save about 3.054tonne (3053.98 kg) from 18486.4 kg in 2018 to 15432.42 kg in 2030. In the year 2040, both Alor Setar and Chuping cities are predicted to save the highest amount of GHG emissions for all three types of PV panels. The Mc-Si, Pc-Si and thin-film panels each can save up to about 34.72 tonne (34719.19 kg) 32.87 tonne (32867.28 kg) and18.53tonne (18534.16 kg) GHG emission respectively. The city with the

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least amount of avoidable GHG emissions per year is Shah Alam as shown in Figure 9 (a). In the present year of 2018, all three (3) types of PV panels for Shah Alam save the least amount of GHG emission compared to the other cities. However, the amount of GHG emission that can be avoided by each of the PV Panels keeps increasing from the present year to 2030 until 2040. This showed that, as the year increases, the amount of GHG emission saved by all the PV panels in Shah Alam will also increase. At last, it can be said that the site of Chuping and Alor Setar is the best location compared to the other cities as they can avoid the highest level of GHG emission in the present year and also in the future year.

5. Conclusion and Recommendation

Throughout this study, the effect of temperature and wind speed on the performance of the three (3) types of PV panels has been analysed. It shows that an increase in temperature decreases the efficiency of the PV module. The increase in PV panel temperature was due to high solar radiation that leads to high ambient temperature with low wind speed. This paper also has simulated the economics and environmental impact assessment for all three (3) types of PV systems at the five (5) selected cities in Malaysia. Based on the research, it was found that Monocrystalline silicon PV panel is suitable to be invested in by the residents especially as it provides the best result for all the selected cities compared to the other PV panels. Although the initial investment cost for a Monocrystalline module is a bit higher, however, it proves to produce the highest annual PV power output and the time taken to regain the initial cost also is the shortest compared to the other two (2) systems. Furthermore, the Monocrystalline PV module only required an area of 144 m^2 to satisfy the total energy requirement by the resident compared to 153 m^2 area needed by the Polycrystalline panel while Thin Film PV panel required about 166 m^2 area.

Of all of the five (5) selected cities, Chuping has been the city with the highest potential to install the PV system whether in the present year or even in the future year since the city received the highest amount of global radiation, and it gives the best result in terms of environmental and economic impact assessments. As a recommendation, many environmental factors affect the performance of solar PV panels apart from temperature and wind speed. Thus, the study related to other factors such as humidity and dust deposition effects should be considered in more detail so that the solar PV panel can provide the highest efficiency. Also, many approaches such as mathematical, statistical modelling and experimental can be used for the analysis.

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Tijani Alhassan Salami: Original Idea; conceptualization; Methodology; Review first draft; Review and editing; Project administration; Review final draft. *Ariffin Salbiah*: Investigation; simulation; Analysis of data; Writing first draft; Review final draft.

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