Energy Proceedings
Vol 27, 2022
ISSN 2004-2965

Exploiting Rooftop Solar Photovoltaic Production at Educational Building in Malaysia#

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ABSTRACT

The application of rooftop solar photovoltaic (PV) systems is currently experiencing a significant increase as an alternative energy provider for different buildings in Malaysia. However, not many educational institutions other than university buildings install solar PV systems. The present work studies the potential of installing solar PV on the rooftop of the public skill training institutions with various roof tilted angles. Results show that even for small rooftop areas, the solar PV potential generation is significantly high and can accommodate the institute's energy load demand.

Keywords: rooftop solar photovoltaic, PV generation, education institution, energy demand profile

1. INTRODUCTION

Through the Ministry of Energy and Natural Resources Malaysia (KeTSA), Malaysia set new targets in 2021 to reach 31% of RE share in the national installed capacity mix by 2025. This target aligns with the Government's global climate commitment to reducing carbon intensity (relative to GDP) by 45% in 2030 [1]. Hence, as suggested by Malaysian Standard MS 1525:2007, which serves as a guideline for energy efficiency in non-domestic buildings, renewable energy implementation in new and existing buildings will help minimise the non-renewable energy sources, pollution, and energy consumption [2]. In addition, previous Energy, Science, Technology, Environment and Climate Change Minister Yeo Bee Yin had mentioned over 4.12 million buildings with solar rooftop potential in Peninsular Malaysia, where 34,194 MW of electricity potential could be generated [3]. In line with that statement, public buildings such as hospitals and education institutes generally hold a large area of rooftop space and are located in an area reserved for the building itself. Therefore, education buildings serve a significant potential to help Malaysia achieve national energy mix targets to reduce carbon emissions.

Thus, this study investigates solar PV rooftop potential at public skill training institutes with grid-tied solar PV systems without battery storage in Malaysia. Then, we analyse how the solar PV potential can contribute to Malaysia's global climate commitment. The results will guide the associate ministry on the potential of solar PV deployment at the education institution, especially public skill training institutes in Malaysia.

2. DATA AND METHODS

2.1 Case study area

As for this study purpose, eight public skill training institutes under the Ministry of Youth and Sports Malaysia located in eight different states in Malaysia were selected (Fig. 1). All eight institutes are known as the National Youth High Skills Institute (Institut Kemahiran Tinggi Belia Negara:IKTBN) and the National Youth Skills Institute (Institut Kemahiran Belia Negara:IKBN), depending on the certification level offered.

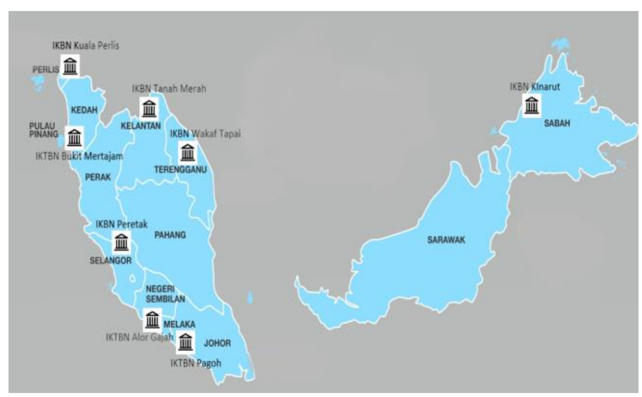


Fig. 1 Location of eight selected IKTBN/IKBN in Malaysia

Each institute consists of several building blocks such as administration, dormitory, dining hall and training workshop. The student capacity for each year is between 500 to 1,000 people.

2.2 Methods

All the building information was collected and provided by the institute administration. The monthly electricity consumption was extracted over 2019 and taken from the electricity bills of the Tenaga Nasional Berhad (TNB) and Sabah Electricity Sdn. Bhd. (SESB), among the primary electricity utility provider in Malaysia. Their monthly load demand ranged from 27.2 MWh to 166.9 MWh, as shown in Fig. 2.

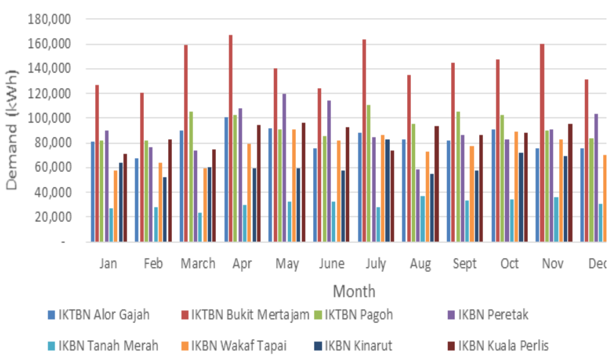


Fig. 2 Energy demand of eight public skill training institutes for over the year 2019

Based on the supplied data, then the available theoretical rooftop for PV installation was estimated using Equation (1) based on previous studies by [5]. Where A_{roof} (m^2) is the available roof area, S_{roof} (m^2) is the total roof area, μ is the utilisation or availability factor, which is a percentage of the useable roof area for PV installations, and *v* is the average building roof slope (degrees). This study considered 60% of roof area availability factors for solar PV installation.

$$A_{roof} = S_{roof} \times \mu \times \frac{1}{\cos(v)} \quad (1)$$

Next, an estimation of potential electrical output, P_T, from the deployment of rooftop PV at the educational building can be calculated based on Equation (2)[6].

$$P_T = P_R \times PR \times Y_R \quad (2)$$

Where P_R is the PV generated power (kW), *PR* is the installation's Performance Ratio, 0.75 was used as a default in this study, and Y_R is the annual reference yield (h).

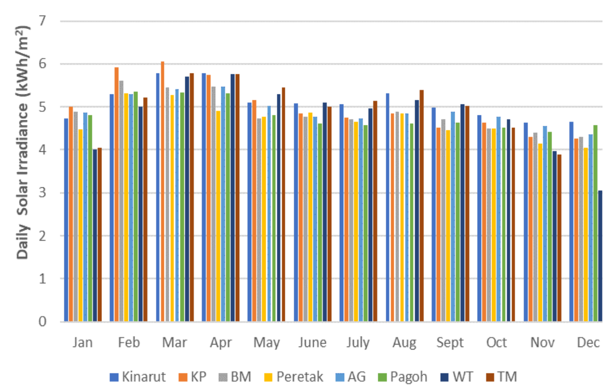
For this study, the shading factor was not considered assuming that all educational buildings are located in locations that are free of shading from other buildings or trees.

Two types of PV modules were used in this study as shown in Table 1 which consist of multicrystalline (c-Si) module and multicrystalline (mc-Si) module. Those PV modules type are widely used and available in the Malaysian market. They are intensively promoted in Malaysia's long-term plans related to the target in increasing the use of renewable energy and reducing carbon emissions.

Table 1. Photovoltaic (PV) module specification

Parameter	c-Si	mc-Si
Maximum Power (Pmax)	375W	340W
No. of cells	120 (6x20)	72 (6x12)
PV module dimensions (mm)	1692×1029	1956×992
Module efficiency STC (%)	21.54	17.52

The one-year solar radiation dataset from Solcast [7] is used in this study (Fig. 3). All of the institutes have a slanted roof and each of the institutes has a different angle tilted roof. Therefore, calculating solar irradiation on existing inclination angles concerning different locations using the Equation from [8]and [9].



KP – Kuala Perlis, BM – Bukit Mertajam, AG – Alor Gajah, WT – Wakaf Tapai, TM – Tanah Merah

Fig 3. Global horizontal irradiance for eight institute

3. RESULTS AND DISCUSSION

As a general assumption for this study, the orientation of PV arrays on the rooftop will not be accounted for as it is less critical for the Malaysia location. Therefore, PV modules can be installed on most of the available rooftops.

From the rooftop surface analysis, approximately 68% of the eight institutes' 227.7 thousand m^2 of the total roof area is suitable for installing PV modules with a total of 155.9 thousand m^2. Individually, all institutes have more than 60% of the roof area suitable for PV modules (Table 2). In fact, IKTBN Bukit Mertajam has the smallest total roof area and has 85% of the roof area suitable for solar PV. From the result, the steeper angle of the rooftop, the wider suitable rooftop area for the PV module we can have. This condition could be an advantage for an institute with a small rooftop size like IKTBN Bukit Mertajam, with a total rooftop area of less than 10 thousand m^2.

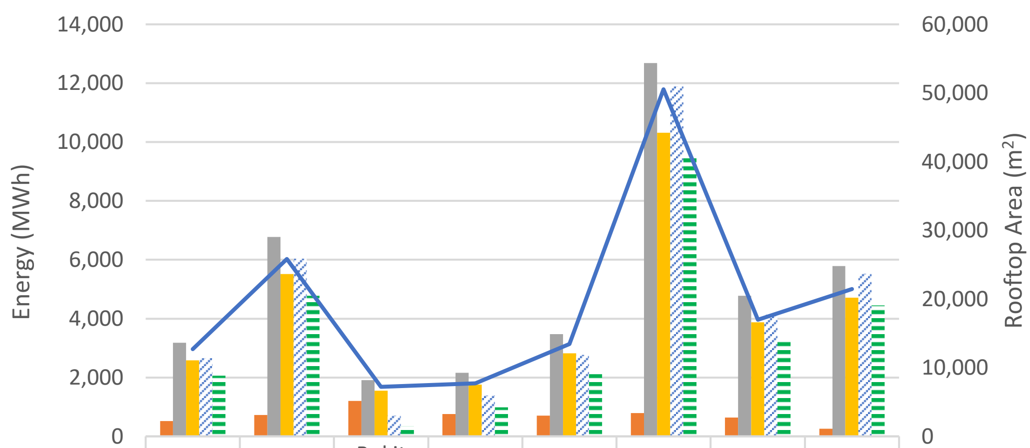
Table 2. Suitable rooftop for solar PV estimation at all eight institutes based on existing rooftop tilted angle

IKTBN/IKBN	Total rooftop area (m²)	Suitable rooftop area (m²)	Rooftop tilted angle (°)	Usable area for solar PV (%)
Kinarut	17,361	12,717	35	73
Kuala Perlis	37,262	25,817	30	69
Bukit Mertajam	8,498	7,211	45	85
Peretak	12,459	7,738	30	69
Alor Gajah	19,417	13,453	30	69
Pagoh	72,947	50,541	15	62
Wakaf Tapai	27,373	17,002	15	62
Tanah Merah	32,406	21,454	25	66

From the total suitable rooftop area for solar PV of eight institutes, an estimated 33.6 MW installed capacity can be achieved from the monocrystalline module, while approximately 27.3 MW installed capacity from the multicrystalline module. Meanwhile, in conjunction with the new Malaysia Renewable Energy Roadmap (MyRER) targets, the estimated total installed capacity at eight institutes can contribute around 0.28% for the monocrystalline module or 0.23% for the multicrystalline module to the national RE sharing capacity target by 2025. This result indicates a positive contribution to the National RE mix target if more public education institutions could install solar PV on their rooftop.

In this study, we assume 70% of the total energy demand of the institute occurred during the daytime based on daily teaching and learning activities [10]. Therefore, as shown in Fig. 4, all of the institutes' demands could be met by the solar PV generation regardless of the PV module type. Although IKTBN Bukit Mertajam and IKBN Peretak have the lowest rooftop PV area, solar PV electricity generation still provides a significant amount of generation.

In relation to the energy demand by the educational institution, a study shows that they consume high energy during the daytime, as shown in Fig. 5 [11]. Since active learning and teaching activities occur almost during the day in educational institutions, the pattern of its energy demand profile fits with the electricity generation curve from the solar PV system. Thus, this indicates that the solar PV system could be a good option for renewable energy technology and suitable for educational



	Kinarut	Kuala Perlis	Bukit Mertajam	Peretak	Alor Gajah	Pagoh	Wakaf Tapai	Tanah Merah
Energy demand (MWh)	521	730	1,204	763	702	794	638	261
PV electricity generation (MWh) c-Si	3,176	6,772	1,908	2,155	3,469	12,682	4,772	5,792
PV electricity generation (MWh) mc-Si	2,584	5,510	1,552	1,752	2,821	10,313	3,881	4,710
Surplus Energy (MWh) c-Si	2,655	6,042	704	1,392	2,767	11,888	4,134	5,532
Surplus Energy (MWh) mc-Si	2,063	4,780	348	989	2,119	9,519	3,242	4,450
Suitable rooftop area (m2)	12,717	25,817	7,211	7,738	13,453	50,541	17,002	21,454

Fig. 4 PV electricity generation compared to energy demand and suitable rooftop PV area for eight institutes

institutions. Furthermore, solar PV electricity generation can be used optimally according to the institute's energy demand during the daytime.

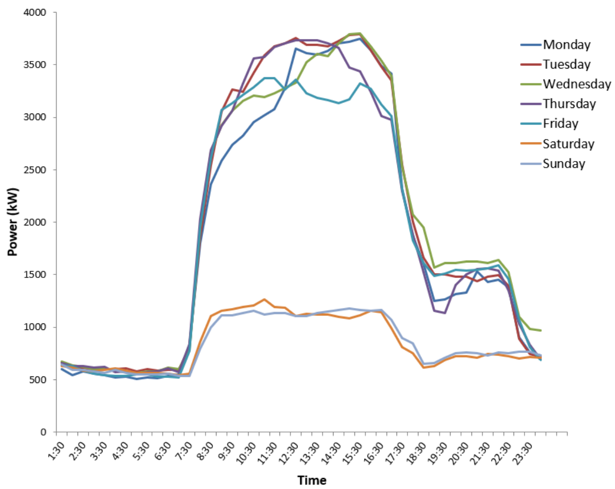


Fig. 5 Energy demand profile of a public education institution for one week [10]

The study results in Table 2 and Fig. 4 show that huge rooftop space at education institutions gives an advantage as solar PV electricity generation could meet all of the institution's energy demands depending on the PV module type. Consequently, approximately 40,727 MWh or 33,124 MWh of electricity generated from monocrystalline or multi-crystal solar PV systems annually can replace energy generated from fossil fuel sources from the electricity grid.

In addition to meeting the electricity demand of the institution, the surplus from solar PV generation, as can be seen in Fig. 4, can be utilized either by the institute itself for income generation or as a centre for the green energy community. The solar PV electricity excess can be an opportunity for the Government to expand green energy access to the communities. Families with limited financial capacity or roof spaces can have access by sharing solar energy with educational institutes. As a comparison, suppose the average load of 250 kWh per month is considered for low to medium-income housing. In that case, all eight skill training institutes can supply green energy to about 8,000 to 10,000 houses yearly.

As for 2019, the total CO_2 emissions related to grid supply to eight training institutes reached approximately 4.65 kt-CO_2. In contrast, all eight institutes could help in CO_2 emission mitigation by a total of approximately 23 kt-CO_2 or 19 kt-CO_2 annually through implementing monocrystalline PV or multicrystalline PV. To highlight the study results that educational institutions have an

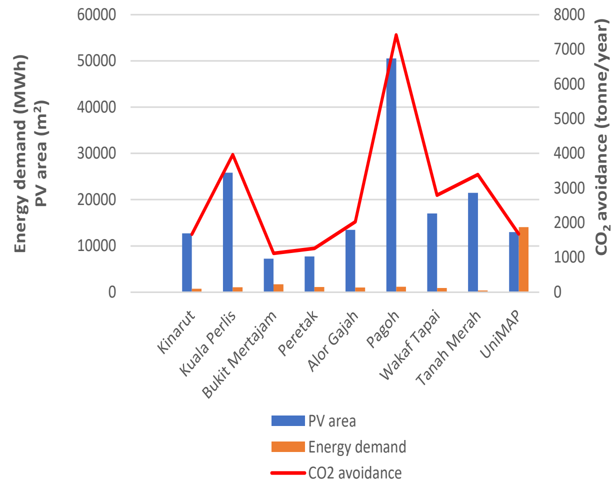


Fig. 6 CO_2 avoidance compare to energy demand and solar PV area between skill training institutes and a university

advantage for solar PV generation and CO_2 mitigation, Fig. 6 compares the public skills training institutes and a university, UniMAP (Universiti Malaysia Perlis) [11].

Since the university has a high demand load and a large rooftop size, this feature gives the advantage of allowing a significant amount of solar PV to be installed. Thus, the energy produced from solar PV and self-consumed by the university help mitigate CO_2 emissions to the environment. Therefore, this demonstrates the potential of the rooftop solar PV at any educational institution to be deployed as it will provide various benefits.

4. CONCLUSIONS

This paper studies the potential of rooftop solar PV at education institutions. All selected public skill training institutes show significant potential in electricity generation regardless of PV module technology and location. This potential gives an advantage to any educational buildings in a different place in Malaysia to install solar PV on their rooftop, especially with the advantages of large roof space and energy demand profile that fit the solar PV generation curve. The Malaysian Government should consider the potential of rooftop solar PV in educational institutions in order to support the national target of 31% share of RE in the energy capacity mix and CO_2 emissions mitigation plan.

ACKNOWLEDGEMENT

This research was supported by JSPS Grant-in-Aid for Scientific Research 20H02677.

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