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On the Potential of Solar Energy for Chemical and Metal Manufacturing Plants in Malaysia

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***Abstract*—The manufacturing sector constitutes a cornerstone of Malaysia's economic landscape, significantly contributing to the nation's Gross Domestic Product (GDP). This pivotal role, however, is accompanied by substantial energy requirements, placing the manufacturing sector among the highest energy consumers across various industries in the country. This study primarily focuses on assessing the solar energy potential within the manufacturing sector. The objectives encompass two key facets: firstly, simulating the attainable energy yield from a photovoltaic (PV) system integrated into manufacturing industry facilities, and secondly, evaluating whether the PV system's generated electricity aligns with the energy requirements of selected manufacturing sectors, namely chemical and metal manufacturing plants. Sixteen companies have been selected from the chemical and metallurgical sectors for this study. The design process for the solar photovoltaic systems within these facilities necessitates determining the factory's location and rooftop area. Additionally, assessing the total savings is imperative to gauge the viability of the solar energy generated by these manufacturing plants. Among the 16 companies analyzed, intriguingly, 5 companies have demonstrated the capacity to fully transition to solar energy to cater to their energy needs. Notably, one of these companies can harness solar power to meet an impressive 179.91% of their energy demand by optimizing available space for solar power generation. This transition could potentially translate into substantial savings exceeding RM1 million in electricity costs.**

***Keywords*—Solar energy; chemical plants; renewable energy; metal manufacturing; sustainable energy.**

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I. INTRODUCTION

Conventional power plants such as steam engines, steam turbines, and nuclear power plants use fossil fuels such as natural gas and coal, which are non-renewable resources. The reference scenario predicts that between 2002 and 2030, the world's primary energy demand will increase by around 60%, equal to 1.7% annually [1]. As opposed to the 10.3 billion tons of oil equivalents (toe) of demand in 2002, there will be a total of 16.5 billion toe in 2030. Nevertheless, compared to the preceding three decades, when demand climbed by 2% annually, the predicted rate of growth is lower. Because of the use of these non-renewable resources, the problems with global warming and climate change are escalating. The global average temperature has risen by 1.1°C since the pre-industrial period, and a further increase of 0.2°C has been recorded from 2011 to 2015, according to the World Meteorological Organization (WMO) study on The Global Climate in 2015-2019 [2]. Among the ASEAN countries, Malaysia has the fourth highest emission of greenhouse gases, and this is largely driven by its high economic growth [3]. The contribution of carbon emission by Malaysia was up to 0.52%, which is only behind Indonesia, Vietnam, and Thailand.

According to the Energy Commission of Malaysia, the percentage of the industrial sector's contribution as the source of power demand was as high as 49% of the total in 2017 [4]. Residential and commercial demand were 21% and 30% respectively. Transportation and agriculture have contributed less than 1% of the power demand. The demand for energy usage in the world is increasing over time, and non-renewable resources are not sufficient to provide energy in the long term [4]. Besides, with the increasing rate of industrialization, energy consumption, especially electric consumption, has increased to 337%, from 19,932 GWh in 1990 to 87,164 GWh in 2007. The demand for energy usage in the world is increasing over time, and non-renewable resources are not sufficient to provide energy in the long term. A situation can be foreseen that coal, oil, and gas would run out in 107, 35, and 37 years, respectively [5]. Based on this information, an estimation can be made that coal will be the only fossil fuel left after 2042 and will also run out after 2117. Therefore, according to energy experts, between 50% and 80% of all electricity might be produced using renewable energy in 2050 [6]-[10]. The Ministry of Energy and Natural Resources Ministry stated that the renewable energy installation rate has reached 23%, and this installation rate is planning to hit 40% by 2035. According to the Department of Statistics Malaysia, a policy vision states that Malaysia's renewable energy installation aims to achieve 31% capacity by 2025 [11].

The manufacturing industries in Malaysia contributed 49.5% to the electricity consumption in Malaysia in 2019, according to the National Energy Balance 2019 [12]. The manufacturing industry's machines, lighting, and power points consume much electricity, and this power demand will increase in the future. This will cause insufficient power supply from the power plant in the future if there is no other alternative resource that can be used to generate electricity. Based on the International Energy Outlook 2016 [13], among the Organization for Economic Cooperation and Development (OCED) countries, the chemical manufacturing sector consumed the most energy, followed by the iron and steel manufacturing sector for 10%. Fig. 1 shows the energy-intensive sectors of total OECD industrial sector energy consumption, 2012 and 2040. These serve as the primary motivation to evaluate the feasibility of meeting the energy needs of the chemical and metal manufacturing industries with solar energy.

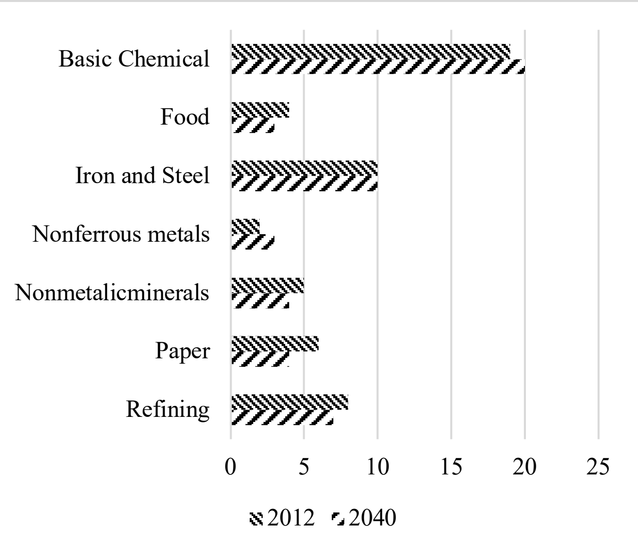

Fig. 1 Energy-intensive Industry Shares of Total OECD Industrial Sector Energy Consumption, 2012 and 2040. [13]

In 2018, the energy consumption of the chemical subsector was as high as 37%. The petroleum and coal products manufacturing industry also has a high percentage, which was 22% [14]. Fig. 2 shows the percentage of manufacturing energy consumption by subsector in 2018. Among all the industries, some fields that contribute the most energy consumption are manufacturing bulk chemicals and petrochemicals, iron and steel, non-metallic minerals, and non-ferrous metals [15]. The energy consumption of chemical and petrochemical industries had come to 1078 Mtoe, equivalent to 12,537,140,000 MWh in 2016. The annual increase in carbon dioxide (CO_2) emission is 2.5% between 2000 to 2016 because of the 2% annual increase in energy consumption. In the USA, bulk chemicals are the largest energy consumer, contributing 28% of the total industrial sector energy consumption in the USA. Iron and steel industries also contributed to energy consumption of up to 819.23 Mtoe in 2016. To address the substantial energy consumption associated with metal-related and chemical industries, there is a need to increase fuel supply, which exacerbates global warming. Therefore, an alternative approach to balance energy supply and mitigate CO_2 emissions is to utilize resources with minimal CO_2 emissions for energy generation.

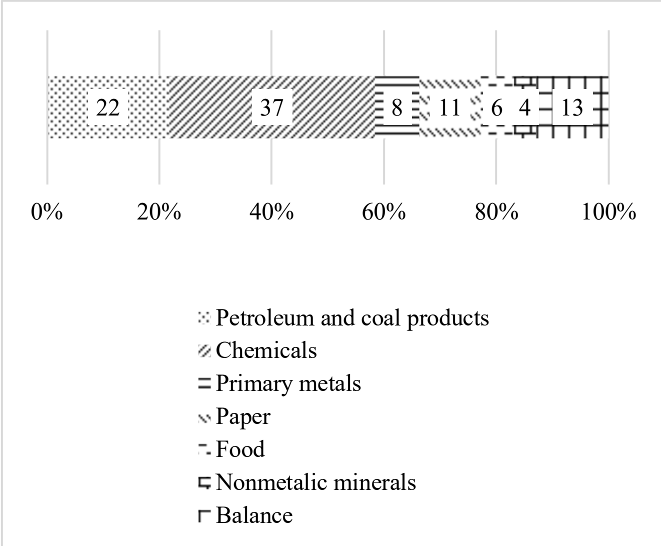

Fig. 2 Manufacturing energy consumption by subsector, 2018. [14]

The photovoltaic (PV) system is one of the alternative ways to generate electricity for the manufacturing industry as the technology of the PV system matures. A recent study in West Papua echoed the strong potential of solar energy in lowering the global warming potential by reducing carbon emissions in power generation [16]. However, the performance of the PV system is still a big challenge as many factors need to be considered, such as the factory's location, which will cause the shading effect. Therefore, the electricity provided by the PV system might not be sufficient to cover the usage of the manufacturing industry, especially for the high energy consumption industries like metal-related and chemical industries.

Hence, the two objectives of this paper are (1) to simulate the energy yield that can be generated by the PV system installed in the manufacturing industry factory and (2) to determine if the electricity generated by the PV system meets the electricity usage demand of the chosen manufacturing industries, i.e., chemical and metal manufacturing plants.

A. Manufacturing Industries and Renewable Energy in Malaysia

As the Department of Statistics Malaysia announced, Malaysia's Industrial Production Index has improved to 3.6% in February 2023 compared to 1.8% in January [17]. The increasing IPI also indicated that the energy consumption by the manufacturing sectors is increasing. From 1980 to 2009, the emissions of per capita CO_2 increased dramatically with the increase of per capita GDP [18]. According to [19], the total installed capacity in Malaysia is 20,493MW, with an energy reserve margin of 47% [19]. Four sectors of manufacturing sectors are energy-intensive industries which are "cement", "industrial chemical", "glass and non-metal," and 'basics metal" [20]. The government restructured the national energy strategy, increased the capacity of the electricity supply, and encouraged efficient energy use to ensure that the environmental harm caused by power production was minimized. The Sarawak Corridor of Renewable Energy and the Small Renewable Energy Program were responsible for achieving this [21].

An ambitious target was set by Malaysian Government to increase the share of renewable energy in the Malaysian energy mix [22]. In 2019, Malaysia utilized approximately 2% of the renewable energy as the source of energy compared to the total generation mix and wishes to achieve 20% penetration by 2025. This target has been updated to 31% as per the Population and Housing Census Malaysia 2020. Malaysia has access to renewable energy sources such as solar, hydropower, wind, biogas, and biomass. Malaysia will continue to rely on conventional energy sources like coal and natural gas generation in the future. However, as the system's penetration of renewable energy rises, the conventional plants' roles may change from base load to standby generation sources.

B. Solar Photovoltaic System in Malaysia

The geographical location of Malaysia makes it suitable for the PV power generation system. Malaysia's government has also taken several actions to encourage the use of solar energy, focusing particularly on building integrated PV (BIPV) systems [23]. On the other hand, power production is negatively impacted by solar cell temperature. Investigations have been done into the initial investment costs and cost-effectiveness of building integrated grid-connected solar PV power plants in different Malaysian [23]. An investigation was conducted on how the temperature of PV solar cells affects the payback time (PBP). As a result, the PBP ranges from 9.70 years in Sabah (Kota Kinabalu) to 12.38 years in Selangor. The PBP of PV plants is greatly increased by solar cell temperature, with Penang and Sarawak experiencing the highest 14.64% and lowest 13.20% increases in PBP, respectively.

Sivaraman and Rawool [24] mentioned that in India, the installation capacity reached 26GW in 2018, 8 times more than in 2014. The mainland of India has an average of 300 sunny days a year, which means there is a potential to generate up to 500 trillion kilowatt hours of energy per year. By calculating the capacity that can be generated by the solar photovoltaic system and the cost of it, the cost per unit of energy was cheaper than the cost compared to the non-renewable resources [24].

Six factors will affect the efficiency of the solar photovoltaic system [25]. These factors are temperature, cable thickness, shading effect, inverter, battery, and charge controller. A place that receives a long period of sunshine in a year, such as Palembang makes installing the solar PV system feasible. However, the PV power plant's output and efficiency are still insufficient. Theoretically, silicon-based solar panels can achieve up to 29% efficiency, but this efficiency is only less than 27% [25].

Tilt angle is also one of the factors that will affect the efficiency and the performance ratio of the solar panel system [26]. Belmahdi and Bouardi [26] conducted a solar panel system in northern Morocco. The result of this study showed that the performance ratio of the fixed tile angle structure was higher than the seasonal adjustment structure, which was 77.3% and 76.9%, respectively. A tilt degree of 0-5º for solar panels was most suitable in Malaysia [27]. Coupled with a tracking system, solar energy yield can be even higher [28]. A simple way of calculating the solar panel required for a solar panel system was introduced. The formula required data such as Peak Sun Hours (PSH), efficiency of the panels, and derating factor of the panels [29]. In case the energy consumption is known, the solar panel array size is just the product of the division of the Energy consumption with the PSH and the efficiency. In [30], the authors mentioned that the energy generated by the solar PV system can be calculated by using the Equivalent Hours of Full Sunlight (EHFS), which is also known as Peak Sun Hours (PSH). After defining the per-day average global horizontal irradiance (GHI), multiply it by the day length and divide it by 1000 W/m^2. The output energy of the solar panels can be obtained by multiplying the module-rated power with the EHFS.

C. Solar Photovoltaic Systems in the Manufacturing Industry

Hussain mentioned that having a combination of rooftop solar PV and industrial infrastructure is good. Industrial buildings normally have large enough roof areas with minimal shading effect, and substantial power consumption makes it a suitable site for solar PV [31]. Financing the scenario with 50% debt was recommended by [32]. According to the author, medium-sized businesses must invest in energy generation to cover their needs at least partially as energy costs rise and industrial demand increases globally. For places with high solar radiation, the scope of rooftop solar energy installation is particularly alluring. The solar panel system may offset a large amount of energy, around 10-20% annually, for medium-sized factories. Given today's global energy and economic situation, this huge sum will save millions of capital. The technologies have advanced to the point that they are cost-effective enough to be used in the industrial sector for independent power generation, even without local government subsidies and incentives. This is advantageous for the overall economy, and the energy and industrial sectors often use some of the greatest shares of any economy's total energy consumption.

Grid-connected solar panel systems for both residential and commercial buildings were examined for their financial sustainability using payback period (PBP) and return on investment (ROI) metrics [33]. Feed-in Tariff (FiT) and revised Net Energy Metering (NEW) schemes were used to determine the PBP and ROI. The study also attempted to demonstrate that in 2017, a solar panel per watt cost decreased from $101.05 to $0.37. In Malaysia, the cost of the solar panel system of 1kWp capacity is around RM10,000 – RM15,000. The study used two scenarios, which are: i) there is simply a total annual saving available, and the solar panel system does not produce any extra electricity, and ii) the solar PV system does produce excess electricity, resulting in annual savings equal to the precise amount of yearly electric bill payments and annual total profit is calculated. The study indicated that the payback period for domestic consumers' monthly electricity expenditures of RM2500 and RM5000 was 8.7 years for both plans. The quickest payback period for both plans was 8.2 years for commercial buildings with an average bill of RM5003.43.

II. MATERIAL AND METHOD

Fig. 3 shows the overall methodology of this research. The chemical subsector and metals-related subsector consume the most energy among all of the subsectors. Therefore, this project will mainly focus on these two subsectors. Eight publicly listed manufacturing companies were chosen from the chemical subsector and another eight from the metal subsector. These companies were chosen based on the availability of the energy consumption data in their published annual report. The company's annual report only provides information on the overall energy consumption without specific details such as energy usage patterns, peak periods, and off-peak periods. Consequently, when designing the solar PV system, the focus will be on ensuring that the total energy generated exceeds the annual energy consumption rather than considering the specific energy usage patterns.

The location of the factories can be determined by using Google Maps and Google Earth to calculate the roof area of those factories. The reason for determining the location of those factories is that the solar panels will be installed on the rooftops of those factories. In this step, the shading on the roof will not be considered in this project. Google Earth can provide a 3-dimension (3D) view of the location and a measuring tool to measure the area of the particular location. As the primary goal of this study is to gain an overview of the said industries, the authors deemed information obtained from Google Earth and the companies' annual reports as sufficient without going into the details which can only be elicited from the companies, and this may prolong the progress of this study which is urgently required.

This investigation uses Monocrystalline solar panels for their higher efficiency than polycrystalline solar panels. Although it has a higher price than polycrystalline solar panels, the difference in terms of the cost has no significant value [33]. Therefore, a monocrystalline solar panel model was randomly chosen based on the availability of the price. Note that the brand and model of the panel were omitted to prevent any potential conflict of interest. The specification of the solar panel used is shown in Table I:

The formula used in this project is similar to the equation provided in [29] and [30] and is globally used. The equation is:

$$E = A \times H \times r \times PR \quad (1)$$

E is the energy generated by the solar panel system, A is the area of the particular site, H is the average irradiation, r is the efficiency of the solar panel, and PR is the system's performance ratio. In this project, the area will be the useable rooftop area of the factories. The average irradiation will be based on the different locations of the factories. When the estimated energy generated by the solar panel system is calculated, an analysis will be made by comparing the energy generated and the energy consumed by that company to determine if the energy generated meets the demand. While it is acknowledged that the orientation and inclination of solar PV is a significant factor [34], this study assumes that the solar PV panels are already optimally placed.

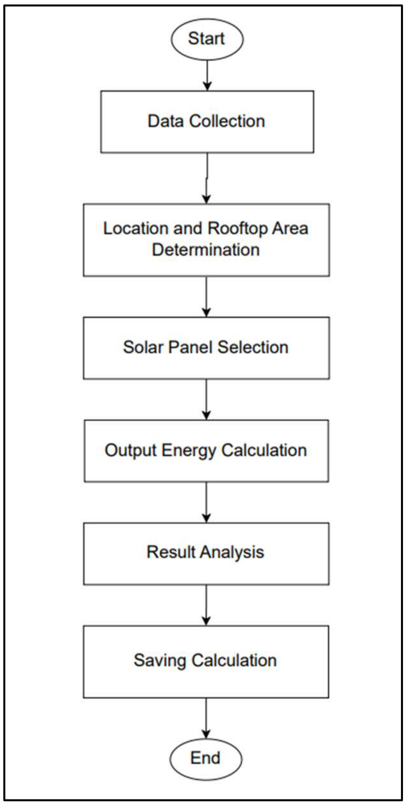

Fig. 3 Overall Methodology

TABLE I
SOLAR PANEL SPECIFICATION

Solar Panel Specification	
Technology	Si -Mono reference item (partial)
Pnom STC Power (manufacturer)	545W_p
Module Size (W x L)	2 x 72
Max. Power Point Voltage (V_{mpp})	41.1V
Open Circuit Voltage (V_{oc})	49.7V
Efficiency	21.10%

The maximum amount that those companies can save is the amount of their electricity bill. The electricity bill can be known by multiplying the energy consumption with the electric tariff. A class E1 tariff was used for all types of companies to simplify the calculation process. The Tariff Schedule on the TNB Website states that tariff E1 is a medium voltage general industries tariff. The tariff rate is 33.70 cents/kWh. The solar PV system's excess energy would not be considered a profit in this project. If the energy generated by the solar panel system cannot cover all the energy usage of the particular company, then the maximum amount that those companies can save would be the energy generated by the solar PV system multiplied by the tariff rate.

III. RESULTS AND DISCUSSION

The total rooftop area of each company was measured by using Google Earth. Tables II and III show the business nature and chemical and metal companies' total solar module area, respectively. For chemical industries, solar panel systems designed for the rooftop of Company A, Company C, and Company G can generate the energy yield capable of meeting their annual electricity demand. The electricity generated by the designed solar panel system for Company A, C, and G was up to about 179.91%, 283.40%, and 320.01%, respectively. One explanation for this is the large rooftop area of the companies.

TABLE II
DETAILS OF CHEMICAL COMPANIES

Company	Business Nature	Solar Module Area (m²)
Company A	Original Design Manufacturing for Hygiene Care and Air Care Products while still manufacturing products based on the product designs and specifications provided by its customers	19,356.00
Company B	manufacturing of agricultural chemicals, industrial chemicals polymers, herbicides etc.	36,638.00
Company C	Specialize in pipe recovery and downstream specialty chemicals	4,839.00
Company D	Supply palmitic and lauric-based products, oleochemical products, and non-oleochemical products	100,260.00
Company E	Manufacturing and selling of cast acrylic products	6,746.00
Company F	manufacturing and trading of polyvinyl chloride ("PVC") compound, plastic additives and industrial chemical products	8,077.00
Company G	producer of polyolefin, olefins, and polyolefins	100,384.00
Company H	manufacturing, marketing, and selling a diversified range of chemical products, including olefins, polymers, fertilizers, methanol and other basic chemicals, derivative products and specialty chemicals	197,736.00

TABLE III
DETAILS OF METAL COMPANIES

Company	Business Nature	Solar Module Area (m²)
Company I	comprised of manufacturing and distribution of steel pipes, hollow sections, scaffolding equipment and accessories, and other steel products	118,827.00
Company J	Manufacture aluminum sheets and coils for fin stock, roofing products, heavy gauge foil, and specialties products	29,274.00
Company K	manufacturing and marketing of aluminum billets and aluminum remelt, suppliers of secondary aluminum extrusion billets	16,220.00
Company L	aluminum extruder, aluminum smelter, aluminum producer	314,768.00
Company M	manufacturing, marketing, and trading aluminum extrusions and their relevant products	44,519.00
Company N	specialist in carbon, stainless, and alloy steel trading and processing, focusing on flat steel products and long steel products	24,570.00
Company O	integrated producer of tin metal and tin-based products	19,516.00
Company P	producer and supplier of tinplate	20,578.00

Additionally, these companies' relatively small energy consumption contributes to the achievement. For companies with high energy consumption, such as Company D and Company H, the designed solar panel system could not meet even 10% of their usage demand. Table IV provides a detailed overview of the electricity generated by the solar panel system for each chemical industry company.

TABLE IV
ELECTRICITY GENERATED BY SOLAR PANELS ON CHEMICAL INDUSTRY FACTORIES' ROOFTOP

Companies	Energy Consumption from report (kWh)	Energy Generated by Manual Calculation (kWh)	Can energy generated by solar panel system cover the demand?
Company A	3,451,692.00	6,201,256.39	Yes (179.91%)
Company B	14,591,903.00	10,578,307.72	No (72.57%)
Company C	494,359.00	1,403,293.49	Yes (283.40%)
Company D	2,662,281,380.56	28,929,278.45	No (1.09%)
Company E	2,680,990.00	1,948,090.53	No (72.73%)
Company F	7,405,928.00	2,364,151.11	No (31.96%)
Company G	9,143,506.00	29,222,845.41	Yes (320.01%)
Company H	28,405,555,555.60	62,248,983.47	No (0.22%)

Among the metal industries, Company I and Company N were able to exceed their electricity usage demand with the designed solar panel system, reaching 286.78% and 168.59%, respectively. One explanation is that these companies are primarily used for storage rather than production, resulting in lower electricity consumption in those areas. However, the remaining companies were still unable to fully utilize the electricity generated by the solar panel system to meet their usage demands. Company L had the lowest coverage, with only 0.9% of its electricity usage being met. Table V provides a detailed breakdown of the electricity generated by the solar panel system for each metal industry company.

TABLE V
ELECTRICITY GENERATED BY SOLAR PANEL ON METAL INDUSTRIES FACTORIES' ROOFTOP

Companies	Energy Consumption from report (kWh)	Energy Generated by Manual Calculation (kWh)	Can energy generated by solar panel system cover the demand?
Company I	11,963,917.00	34,279,735.68	Yes (286.78%)
Company J	28,778,000.00	8,443,597.88	No (29.36%)
Company K	13,003,844.00	4,740,975.27	No (36.50%)
Company L	10,650,000,000.00	95,934,242.11	No (0.90%)
Company M	36,844,336.00	12,980,079.24	No (35.26%)
Company N	4,205,590.00	7,081,279.93	Yes (168.59%)
Company O	34,000,000.00	5,654,238.03	No (16.65%)
Company P	24,533,620.00	5,988,552.96	No (24.46%)

For the energy saving of chemical industries, three companies can achieve 100% saving on their electric bill: Company A, Company C, and Company G. The lowest saving percentage is Company H, which is only 0.22%. The average savings is 59.82%. Fig. 4 shows the saving percentage chart of the chemical industries.

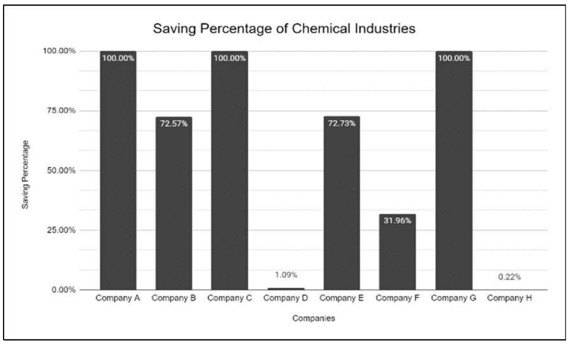

Fig. 4 Saving Percentage of Chemical Industries

For the metal industries, Company I and Company N are able to save up to 100% on their electric bill due to the energy generated by solar PV system is high enough. For company L, it can only save 0.9% of the electric bill. The average savings in metal industries is 42.89%. Fig. 5 shows the saving percentage chart of the metal industries.

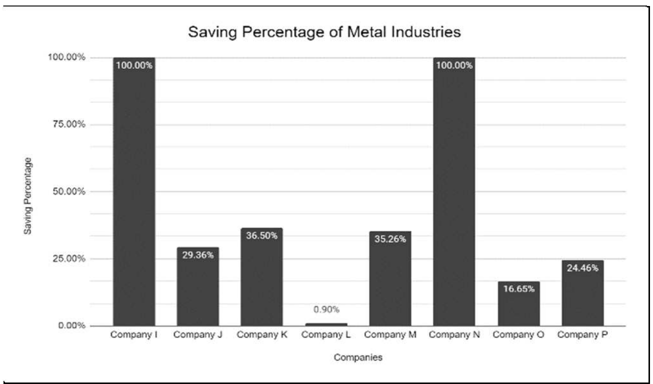

Fig. 5 Saving Percentage of Metal Industries

Fig. 6 shows the pie chart of the ability of solar panel systems to meet the electricity demand for both the chemical and metal industry. Moving forward, alternatives such as small wind turbines can be explored together with solar PV panels to meet the energy demand of the manufacturing plants [35] – [36].

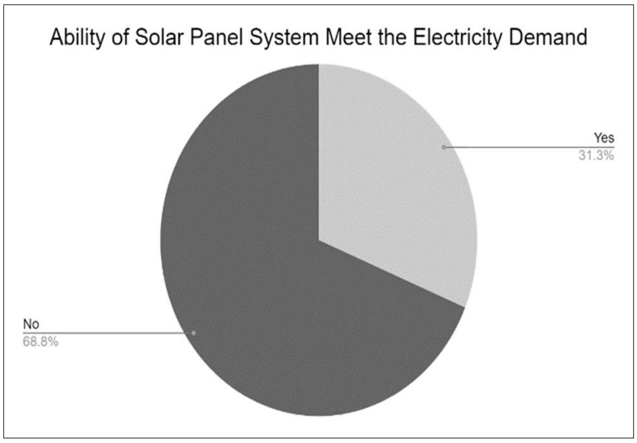

Fig. 6 Ability of Solar Panel Systems Meet the Electricity Demand

In addition, energy efficiency improvement measures should also be taken as it has been simulated that as much as 20% reduction in electricity consumption can be achieved in a fast-moving consumers' goods plant by doing the aforementioned [37]. Manufacturing plants may also consider adopting ISO 14000, which was found to lower the energy intensity of low energy-intensive industries in India [38].

IV. CONCLUSION

In summary, only 5 out of 16 companies were able to fully meet their energy demands via solar, namely Company A, Company C, Company G, Company I, and Company N. In other words, these five companies were able to save 100% of their electric bill and operate without the electric supply from the grid. The huge energy consumption of the manufacturing industries, the small area of the factories' rooftop, and the efficiency of the solar panels are the main reasons that most of the manufacturing plants in this study cannot fully rely on the solar panel system to supply the electricity. Therefore, manufacturing industries will still require the combination of the grid and solar panel system to ensure a sufficient and stable energy supply. However, with the growing demand and attention for renewable energy and advanced technology, all of the manufacturing industries may be able to rely more on the solar panel system. Coupled with energy efficiency improvement measures, the need for energy can certainly be reduced.

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References

[1] Z.Liu *et al.* "Challenges and opportunities for carbon neutrality in China,". *Nature Reviews Earth & Environment.* vol. 3, 141–155, 2022,. doi:10.1038/s43017-021-00244-x.

[2] WMO," The Global Climate in 2015–2019," Accessed: Jan. 15, 2023. [Online].https://library.wmo.int/doc_num.php?explnum_id=9936.

[3] S. N. Abdul Latif *et al.*, "The Trend and Status of Energy Resources and Greenhouse Gas Emissions in the Malaysia Power Generation Mix," *Energies.*, vol. 14, no. 8, p. 2200, Apr. 2021, doi: 10.3390/en14082200.

[4] "Independent Statistics and Analysis - Malaysia," *International - U.S. Energy Information Administration (EIA).* Accessed: Feb. 01, 2023 [Online]. Available: https://www.eia.gov/international/analysis/country/MYS.

[5] S. Shafiee and E. Topal, "When will fossil fuel reserves be diminished?," *Energy Policy.*, vol. 37, no. 1, pp. 181–189, 2009. doi:10.1016/j.enpol.2008.08.016.

[6] L. Runkun, and Y. A. Solangi. "An Analysis of Renewable Energy Sources for Developing a Sustainable and Low-Carbon Hydrogen Economy in China." *Processes.,* vol 11, no. 4, pp. 1225, 2023.

[7] M. Saida, S. Khennas, S. Bouchaib, and A. H. Arab. "Multi-objective cuckoo search algorithm for optimized pathways for 75% renewable electricity mix by 2050 in Algeria." *Renewable Energy.,* vol. 185, pp. 1410-1424, 2022. doi: 10.1016/jrenene.2021.10.088.

[8] K. Anzhelika, E. Magaril, and H. H. Al-Kayiem. "Review and Comparative Analysis of Renewable Energy Policies in the European Union, Russia and the United States." *International Journal of Energy Production and Management.*, vol. 8. no. 18, 11-19, 2023. doi: 10.18280/ijepm.080102.

[9] J-W. Arnulf. "Snapshot of Photovoltaics− May 2023." *EPJ Photovoltaics.,* vol. 14, no. 23, 2023. doi: 10.1051/epjpv/2023016.

[10] W. Radoslaw, P. Daniluk, T. Kownacki, and A. Nowakowska-Krystman. "Energy system development scenarios: Case of Poland." *Energies.,* vol. 15, no. 8, pp. 2962, 2022. doi: 10.3390/en15082962.

[11] A. A. F. Husain, M. H. Ahmad Phesal, M. Z. A. A. Kadir, U. A. Ungku Amirulddin, and A. H. J. Junaidi, "A Decade of Transitioning Malaysia toward a High-Solar PV Energy Penetration Nation," *Sustainability.*, vol. 13, no. 17, pp. 9959, 2021, doi: 10.3390/su13179959.

[12] "National Energy Balance 2019," *Suruhanjaya Tenaga (Energy Commission),* 0128 – 6323, 2022. Accessed: Feb. 06, 2023 [Online]. Available: https://www.st.gov.my/en/contents/files/download/111/NEB_2019.pdf.

[13] IEA, "World energy outlook 2016 – analysis," *IEA*. Accessed: Feb. 10, 2023 [Online]. Available: https://www.iea.org/reports/world-energy-outlook-2016.

[14] EIA, "2018 Manufacturing Energy Consumption Survey," December 2021. Accessed: Feb. 13, 2023 [Online]. Available at: https://www.eia.gov/consumption/manufacturing/pdf/MECS%202018%20Results%20Flipbook.pdf

[15] R. Vooradi, et al, "Energy and CO_2 Management for chemical and Related Industries: Issues, opportunities and challenges," *BMC Chemical Engineering.*, vol. 1, no. 1, 2019. doi:10.1186/s42480-019-0008-6.

[16] E. K. Bawan and R. A. Al Hasibi,"Contributing to Low Emission Development through Regional Energy Planning in West Papua," *International Journal on Advanced Science, Engineering and Information Technology.*, vol. 12, no. 6, pp. 2203-2210, 2022. doi:10.18517/ijaseit.12.6.14505.

[17] "Index of industrial production, Malaysia February 2023," *Department of Statistics Malaysia Official Portal.* Accessed: Feb. 06, 2023 [Online]. Available: https://www.dosm.gov.my/portal-main/release-content/index-of-industrial-production-malaysia-apr-2023.

[18] R. A. Begum, K. Sohag, S. M. Abdullah, and M. Jaafar, "CO_2 emissions, energy consumption, economic and population growth in Malaysia," *Renewable and Sustainable Energy Reviews.*, vol. 41, pp. 594–601, 2015. doi: 10.1016/j.rser.2014.07.205.

[19] Solangi, et al. "Current solar energy policy and potential in Malaysia", *3rd. In Proceedings of the International Conference on Science and Technology,* Pulau Pinang, Malaysia, Dec. 12–13, 2008.

[20] R. Mahadevan, "Assessing the output and productivity growth of Malaysia's manufacturing sector," *Journal of Asian Economics.*, vol. 12, no. 4, pp. 587–597, 2001. doi:10.1016/s1049-0078(01)00104-x.

[21] D. H. Husaini, "Does electricity drive the development of manufacturing sector in Malaysia?," *Frontiers in Energy Research*, vol. 3, 2014. doi:10.3389/fenrg.2015.00018.

[22] W. S. Abdullah, M. Osman, M. Z. Ab Kadir, and R. Verayiah, "The potential and status of renewable energy development in Malaysia," *Energies.*, vol. 12, no. 12, p. 2437, 2019. doi: 10.3390/en12122437.

[23] M. A. Islam, M. Hasanuzzaman, and N. A. Rahim, "Design and analysis of photovoltaic (PV) power plant at different locations in Malaysia," *IOP Conference Series: Materials Science and Engineering.*, vol. 358, p. 012019, 2018. doi: 10.1088/1757-899x/358/1/012019.

[24] K. Sivaraman and A. Rawool, "A brief study of an installation of a rooftop solar PV system in India," *SSRN Electronic Journal.*, 2019. doi: 10.2139/ssrn.3468654.

[25] T. Dewi, P. Risma, and Y. Oktarina, "A review of factors affecting the efficiency and output of a PV system applied in tropical climate," *IOP Conference Series: Earth and Environmental Science.,* vol. 258, p. 012039, 2019. doi: 10.1088/1755-1315/258/1/012039.

[26] B. Belmahdi and A. E. Bouardi, "Solar potential assessment using PVSYST software in the Northern Zone of Morocco," *Procedia Manufacturing.*, vol. 46, pp. 738–745, 2020. doi: 10.1016/j.promfg.2020.03.104.

[27] M. Fadaeenejad, et al, "Optimization and comparison analysis for application of PV panels in three villages," *Energy Science & Engineering.*, vol. 3, no. 2, pp. 145–152, 2014. doi: 10.1002/ese3.52.

[28] B. Mahmoud Dawoud and S. Chun Lim, "Performance comparison of fixed and single Axis Tracker photovoltaic system in large scale solar power plants in Malaysia," *Indonesian Journal of Electrical Engineering and Computer Science.*, vol. 21, no. 1, p. 10, 2021. doi:10.11591/ijeecs.v21.i1.pp. 10-17.

[29] Ed. Franklin, "Calculations for a Grid-Connected Solar Energy System," *The University of Arizona Cooperative Extension.*, June 2019.

[30] N. S. Baghel and N. Chander, "Performance comparison of mono and polycrystalline silicon solar photovoltaic modules under tropical wet and dry climatic conditions in east-central India," *Clean Energy.*, vol. 6, no. 1, pp. 165–177, 2022.

[31] M. N. Hussain, et al, "Solar PV implementation in industrial buildings: Economic study," 2017 *International Renewable and Sustainable Energy Conference (IRSEC)*, 2017. doi: 10.1109/IRSEC.2017.8477355.

[32] C. K. Wei and A. Y. Saad, "The potential of solar energy for domestic and commercial buildings in Malaysia," *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, vol. 75, no. 3, pp. 91–98, 2020.

[33] L. Jiang, et al, "Comparison of monocrystalline and polycrystalline solar modules," *2020 IEEE 5th Information Technology and Mechatronics Engineering Conference (ITOEC).,* 2020.

[34] A. Afandi, M. D. Birowosuto and K. C. Sembiring,"Energy-yield Assessment Based on the Orientations and the Inclinations of the Solar Photovoltaic Rooftop Mounted in Jakarta, Indonesia," *International Journal on Advanced Science, Engineering and Information Technology*, vol. 12, no. 2, pp. 470-476, 2022. doi:10.18517/ijaseit.12.2.14812.

[35] S.C. Lim, T. J. Meng, C. Palanichamy, and G. T. Eng. "Feasibility study of wind energy harvesting at TELCO tower in Malaysia." *International Journal of Energy Economics and Policy* vol 9., no. 6, pp. 277-282, 2019.

[36] C. S. Yan, S. C. Lim and K. Y. Chan, "Potential of Small-wind Turbine for Power Generation on Offshore Oil and Gas Platforms in Malaysia," *International Journal of Energy Economics and Policy,* vol. 12, no. 6, pp. 272-282, 2022. doi: 10.32479/ijeep.13433.

[37] L.A. Shihata, A.A. Ghaly, and J. Kiefer. "Potentials of energy efficiency improvement in manufacturing plants." *Procedia CIRP* ., vol 107 pp. 729-733, 2022.

[38] B. Goldar and A. Goldar, "Impact of ISO 14000 on Energy Efficiency: An Analysis of Energy Intensity of Manufacturing Plants in India," SSRN Electronic Journal, 2022, doi: 10.2139/ssrn.4182892.