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# The Challenges and Opportunities of Solar Thermal for Palm Oil Industry in Malaysia

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Renewable energy is the key solution to the growing energy crisis. Renewable energy resources such as solar, biomass, wind, and wave energy are infinite, abundant and environmentally friendly. Solar energy is one of the most promising renewable energy sources in the equatorial zone of Malaysia. Photovoltaic (PV) and solar thermal are the current technology implemented in harvesting solar energy to generate energy. The purpose of this study is to investigate the potential implementation of solar thermal technologies at the palm oil industrial processes in Malaysia. In order to determine the potential, analysis of palm oil processes operational condition is needed, then a solar thermal potential based on irradiation will be assessed. A review of solar thermal potential and process heat requirement in the palm oil industrial leads to the selection of promising unit processes that can be integrated with solar thermal. The palm oil processes in this study includes palm oil refinery and oleochemicals. The challenges and opportunities for integrated solar thermal with palm oil processes are discussed as well. The outcomes of this study facilitate the implementation of solar thermal technologies in prioritized processes in the palm oil industry.

## 1. Introduction

The world relies on fossil fuels to meet its increasing energy demands. Fossil fuels such as crude oil, natural gas, coal, and coke as well as other petroleum products are providing almost 93 % of the Malaysia energy demands in 2017 (Malaysia Energy Information Hub, 2019). The final energy consumption accounted was 730 TWh. This enormous amount of energy being consumed is having adverse implications on ecosystem of the earth. The usage of alternative clean energy which is renewable energy can lessen the impact on carbon emissions and to the environment.

Figure 1a shows the distribution of various type of energy resources in Malaysia in 2017. As illustrated in the Figure 1a, renewable energy such as solar, biodiesel, biogas and biomass only contributing about 0.77 % of the total energy usage, lags far behind renewable energy target in the national power mix to 20 % of installed capacity by 2025 (SEDA, 2019). In 2017, the Malaysia's industry sector energy demand was 203 TWh, representing which is the second largest energy consumers after transportation in Malaysia as shown in Figure 1b. This indicate that there is a huge potential of renewable sources for decarbonizing the industrial sector in the future.

### 1.1 The potential of solar energy in Malaysia

Solar energy is a renewable, environmentally friendly, pollution free and freely available energy source. Solar energy is the direct source of all renewable and indirectly source of all nonrenewable source (Tiwari and Mishra, 2012). The most challenging aspect of using solar energy is its unpredictable climate. The available radiation from the sun varies by hour and day, geographical location and depends on the sky clearness. However, Malaysia are fortunate to have characteristic features of the climate that are uniform temperature, light winds although have high humidity and copious rainfall.

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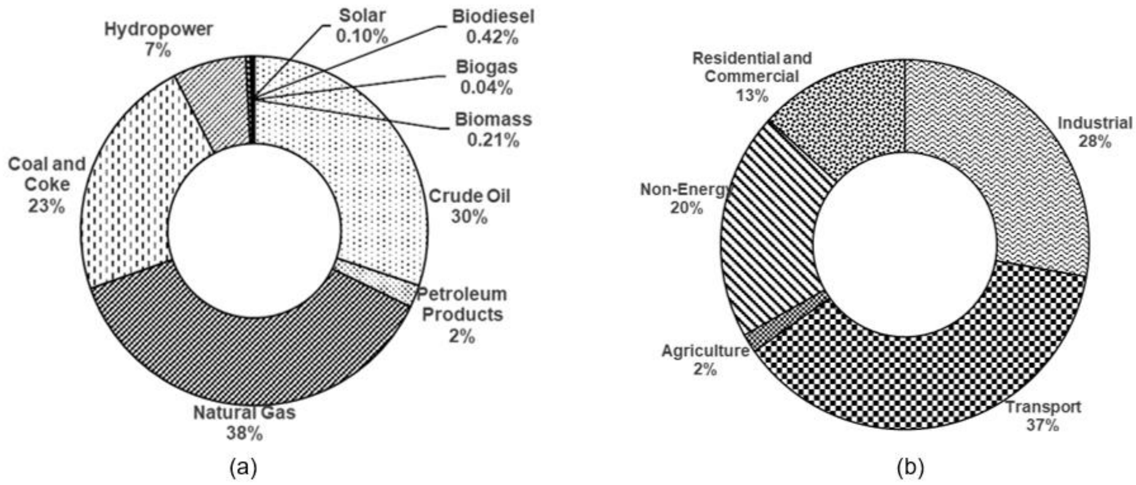


*Figure 1:(a) Malaysia's primary energy supply and (b) final energy demand by sectors for 2017 adapted from Malaysia Energy Information Hub, 2019*

The average sunshine duration was found to be in the range of 4 to 8 h/d and the ambient temperature is stable and varies from 22 °C to 33 °C throughout the year. The monthly global solar radiation is around 400 to 600 MJ/$m^2$ (Mekhilef et al., 2012). The annual average daily solar radiation for Malaysia are from 4.21 to 5.56 KWh/$m^2$ and sunshine duration is more than 2,200 h/y (Tijani and Roslan, 2014). This reflect that the availability of moderate solar energy during the year makes it possible to be used as a heat source for a solar thermal system.

### 1.2 Current studies on solar thermal implementation in Malaysia

Most of recent studies on solar energy in Malaysia has more focused on the development and implementation of PV technologies compared to solar thermal technologies. Fewer research on solar thermal technologies and implementation were carried out in Malaysia because it is still an emerging technology particularly for Malaysia industries compared to PV. There are several studies have been carried out regarding the implementation of solar thermal in Malaysia. Rafeeu and Ab Kadir (2012) carried out experimental models with various geometrical sizes and diameter of solar dish concentrators to analyze the effect of geometry on a solar irradiation and temperature and in maximising the solar fraction under Malaysian environment. However, the work only presented a simple exercise in designing, building and testing small laboratory scale parabolic concentrators. Affandi et al. (2014) performed investigation on the feasibility of implementing Concentrated Solar Power (CSP) in Malaysia by evaluating the CSP technologies, meteorological data as well as Direct Solar Irradiance (DNI). The study did not investigate the other solar technologies for lower heat demand. Furthermore, Tijani and Roslan (2014) simulated the heat losses (radiation and convection) associated with heat collection element (HCE) of Solar Parabolic Trough Collector (PTC). They also investigated the effect of different wind speeds and mass flowrate of the heat transfer fluid (HTF) on thermal losses. It is observed from numerical analysis that the combine effect of radiation and convection heat losses are not significantly affected by changes in wind speed.

Heng et al. (2019) proposed a 50 kW solar cogeneration system which consists of a parabolic trough collector with aperture area of 1,154 $m^2$, thermal storage system and an organic rankine cycle power conversion system. They found that the performance of a small-scale solar cogeneration system in Malaysia and found that the efficiency of the solar to electric was around 8 %. The performance of a photovoltaic thermal collector with parallel plate flow channel under different operating conditions in Malaysia also was investigated through numerical and experimental by Nahar et al. (2017). In addition, Hossain et al. (2019) proposed a hybrid PV thermal collector to enable the extraction of both electricity and heat from the same module, thereby improving the overall efficiency. This was carried out by designed and developed of parallel serpentine pipe flow based PV thermal.

However, currently there is no thorough investigation was carried out to investigate on the feasibility and viability of solar thermal for lower temperature heat demand such as in palm oil industry. This study aims to investigate the feasibility of the solar thermal in Palm oil industry in Malaysia by evaluating the key determining factors such as analysis of palm oil processes operational condition and solar thermal potential based on irradiation. This study provides an overview of prospective scenarios for the solar thermal in Malaysia focusing on the industry. The outcomes of this study help the industry in the selection of solar thermal technologies in prioritized processes.

### 1.3 Potential of solar thermal to satisfy heat demand for processes in the palm oil industry

The oil palm plantation industry has emerged in the last 50 years as a major agricultural activity and important commodity in Malaysia. The natural resource is favorable for the country's climate. Malaysia currently accounts for 28 % of world palm oil production and 33% of world exports (MPOC, 2019). In order to get the various of end products, there are a few main sectors involves namely milling, nuts kernel crushing, refining and oleochemicals. Table 1 shows the number of companies and the total capacities in operation in Malaysia for 2018.

*Table 1: Number and capacities of Malaysia's palm oil sectors in operation as at 2018 (Economics and Industry Development Vision, 2019)*

| Sector | No | Capacity in Operation (t/y) |
|---|---|---|
| Fresh Fruit Bunch Mills | 450 | 112,659,000 |
| Palm Kernel Crushers | 43 | 7,195,300 |
| Refineries | 51 | 26,475,200 |
| Oleochemicals | 20 | 2,668,941 |

There are 450 mills all over the country and the heat demand are in between 32 to 145 °C which is mainly for heating of product in the unloading, and loading, sterilization, and digestion process. Although the temperature requirement considered low, the amount energy for heating are large due to high capacities in operation. Palm kernel crushers using less heat demand because the main process is involving physical activities. The product from palm oil and kernel mill undergo various processes to produce food and non- food applications. Some of the most important processes and their range of the temperatures required outlined in Figure 2.
The heat demand for refineries and oleochemical industries are higher which are in the range of 80 to 260 °C for refining process and up to 300 °C for oleochemical. The unit processing that using higher heat demand are hydrogenation, deodorizing, hydrolysis and distillation. The actual operating temperature may vary because it is depending on the type of raw materials, end products, technology used and as well as the other processing condition such as pressure. There a few types of solar thermal collectors currently used to supply the heat demand ranges from 40 to 450 °C for industries as illustrated in Figure 3. Uncovered collector and standard flat plate collector can be used for heat demand below 80 °C while evacuated tube collector, advanced flat plate collector and compound parabolic concentrator (*CPC*) are suitable for the heat demand in between 80 to 120 °C. Higher design temperature requires the technology such as parabolic trough and fresnel, high vacuum flat plate and advance evacuated tube collectors.
Gupta and Rathod (2019) investigated a laboratory scale for the potential of solar radiation in India for the biodiesel production by esterification of palm fatty acid distillate (PFAD) by using Fresnel lens solar concentrator (FSC). They found that FSC is highly energy efficient in conversion of PFAD to Fatty Acid Methyl Ester than the conventional hotplate heating method.

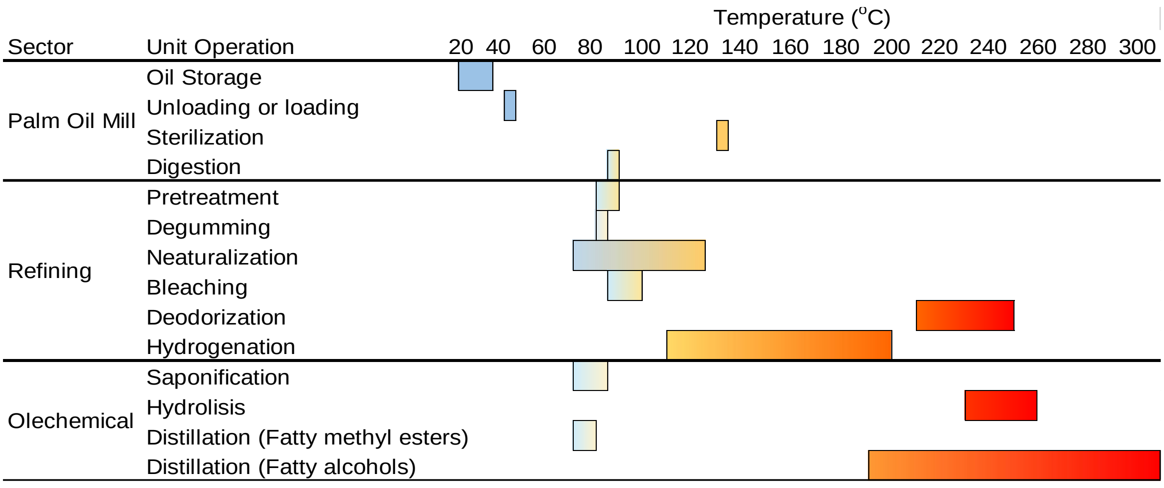


*Figure 2: Palm oil sectors heat demand by temperature ranges adapted from Shahidi (2015)*

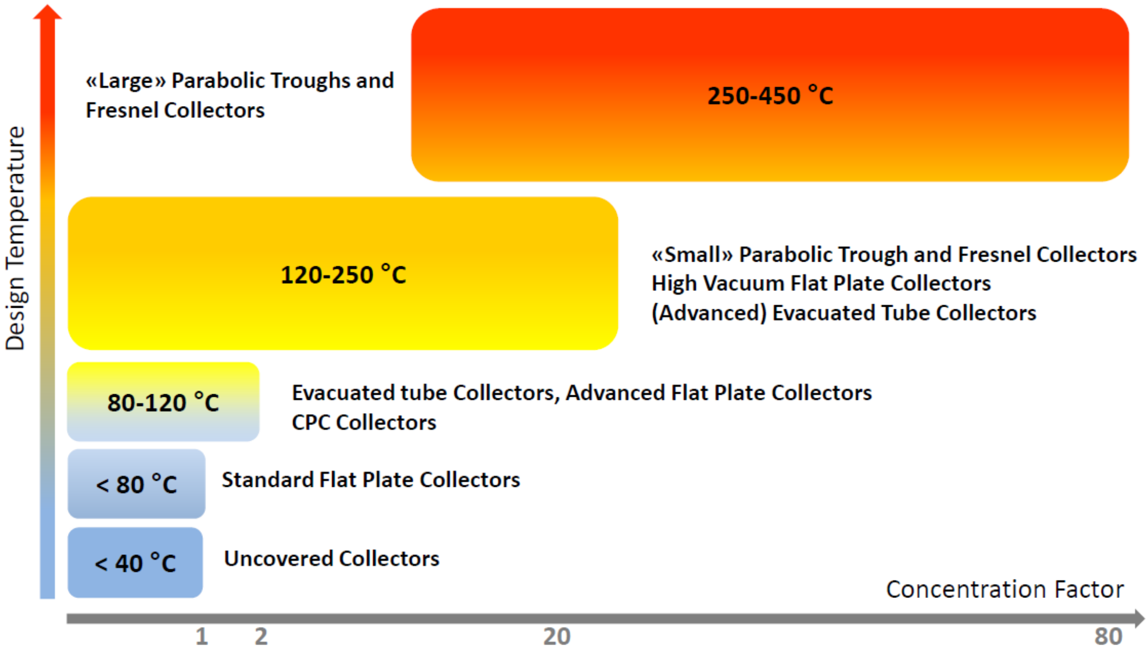


*Figure 3: Types of solar collectors for different design temperature (Frank, 2013)*

By evaluating the heat demand in palm oil industry, the suitable solar collectors for heating demand in palm oil refinery and oleochemical are advanced evacuated tube collector, advanced flat plate collector and *CPC*, small parabolic trough and fresnel high vacuum flat plate. The selection of ideal type of solar collector and the right size of the solar thermal collector are crucial to ensure the design temperature is achieved. For example, a solar thermal project was successfully installed in a poultry industry in Johor, Malaysia by using evacuate tube plate for blanching process to fulfil 70 to 75 °C heat demand for processing of meat products. The solar thermal plant implemented heat integration at scalding tank by solar loop in between 80 to 90 °C as alternative for electrical steam boiler (Solar Heat for Industrial Processes, 2017).

## 2. The challenges of solar implementation for low temperature heat demand

The problem of harnessing energy efficiently from solar radiation is depending on the availability of solar thermal energy. The amount of solar irradiation is related to the geographical location and Malaysia has the advantages because its strategically located near the equator (Affandi et al., 2014). The country also not facing issues related to the ambient temperature and the average temperature of the capture fluid and its mass flowrate. However, the largest hurdles to solar thermal is the high cost for installation. Solar thermal heat expenses are mainly determined by the upfront investment consisting of the solar collector, storage, plumbing, pumps, controller and the installation costs. In contrast, one of the advantages of solar thermal is low maintenance cost.

Sing et al. (2018) evaluated the trade-off between solar utility temperature and system efficiency plus economic feasibility of an integrated solar thermal system by considering different process temperature range, different integration configuration in the context of Malaysia. The payback period for all processes in the illustrative case study vary from 4.7 to 7.6 y. Meanwhile Baharum et al. (2018) investigated PV and CSP by determining Levelized Cost of Electricity (LCOE) and land usage comparison to determining the cost comparative between both solar technologies. The found that Solar CSP generate more energy in an area ($km^2$) with total difference almost 14 % higher than Solar PV. The result is very positive as CSP has the advantage to be the future sustainable energy generation in Malaysia. 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 (Baharum et al., 2018). In addition, Islam et al. (2019) also performed a similar techno-economic analysis of CSP technologies for Malaysia. Three different technologies, PTC, solar power tower (SPT) and solar parabolic dish (SPD) were assessed and the results shows that PTC and SPT type plants are particularly suitable for locations at East and Peninsular Malaysia.

The other factor such as the size of the solar thermal collector also will determine the amount of energy that can be harvested. The heat demand in palm oil refining may vary due to various processing steps and multiple raw materials and end products. The larger size of collector will contribute higher capital cost for the company. This challenge can be solved by carry out optimization for the heat integration to choose appropriate solar thermal collector technology. The designing step for solar thermal system also vital to ensure it can be fulfil the heat demand for future expansion.
The other bottleneck for implementation of solar thermal in palm oil industry is the collector field placement. The palm oil refining and oleochemical in Malaysia mostly build in an industrial area. This may problematic for certain company due to unavailability of suitable space. However, the palm oil mill usually situated in oil palm plantation area in a rural location and have a better opportunity to be install at landed area. The optimum inclination and orientation of the solar thermal collector also need to investigate. The structural analysis of the roof is required to be carried out beforehand in the case of roof mounting is chosen.

## 3. Outlook and prospect of solar thermal

Malaysia has embarked into several key initiatives and renewable energy act was gazetted in 2011. The government targeted the achievement of 20 % of renewable energy in the energy mix by the year 2025. To further encourage the adoption of renewable energy, the Malaysian government introduced the Feed-in Tariffs (FiT) which expedite growth in the renewable energy sector. Solar energy is naturally positioned to play a crucial role in helping to increase RE in the future energy mix of the country. However, the growth of solar thermal in term of development and demand in Malaysia considered lower compared to its counterpart, solar PV. For solar PV, the prices became more competitive in the Malaysia due to the continuous support from the government. In January 2019, the new policies called New Net Energy Metering (NEM) Scheme and Supply Agreement for Renewable Energy (SARE) were introduced by the government to increase solar energy generation in Malaysia. NEM allows self-consumption of electricity generated by solar photovoltaic (PV) system users, while selling the excess energy to Distribution Licensee at prevailing Displaced Cost. NEM is executed by the Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC), regulated by the Energy Commission (EC), with Sustainable Energy Development Authority (SEDA) Malaysia as the implementing agency. Nevertheless, the government does not yet have policies, incentives or standards that specifically aim at larger-scale solar thermal system applications in commercial buildings or in industrial applications. Besides, there is also a need for regulatory authorities to have a specific guidelines and regulations on the relevant requirements, permits, and licenses for the solar energy projects implementation in Malaysia.
As an attempt of lessening the gaps faced by solar thermal in Malaysia, in July 2014, a cooperation in between the Global Environment Facility (GEF) and United Nation Industrial Development Organization (UNIDO) has embarked a national project on GHG Emissions Reductions in Targeted Industrial Sub-Sectors through Energy Efficiency (EE) and Application of Solar Thermal Systems (Dahlan, 2015). In addition, Malaysia Energy Efficiency and Solar Thermal Application Project (MAEESTA) also established to promote program, seminar and workshop to the local industries, suppliers and vendors for solar thermal implementation. MAESSTA also carries out project on GHG emissions reductions through energy efficiency (EE) and application of solar thermal systems in Malaysia. The project focuses on improving thermal EE at manufacturing and processing plants with possible integration of solar thermal systems in targeted industrial sub-sectors.
The energy efficiency and conservation act (EECA) that expected to be regulated early 2020 will be the important instruments for a successful implementation of solar thermal energy in industry and commercial building. The solar thermal is expected to growth further in Malaysia as the uncertainty of future fossil fuel energy prices. The cost reductions for solar thermal are expected to stem from direct building integration (façade and roof) of collectors, improved manufacturing processes and availability of the new advanced materials for collectors.

## 4. Conclusions and recommendations

Malaysia has a huge potential for the implementation of large scale solar thermal in industry and commercial building due to its location at the equatorial region. The continuous supply of sunlight, silent in operation, independent of fuels source, the environmentally friendly factors, made solar energy a good alternative for palm oil industry. The potential implementation of solar thermal technologies at the palm oil industrial processes in Malaysia was investigated and the potential was analysed based on the analysis of palm oil processes operational condition and the assessment of solar thermal solar irradiation. The palm oil refining and oleochemical industrial has the potential due to the heat demand and the suitable solar collectors for heating demand in palm oil refinery and oleochemical are advanced evacuated tube collector, advanced flat plate collector and *CPC*, small parabolic trough and Fresnel high vacuum flat plate. With payback period estimated in between 5 to 8 y, the implementation of solar thermal in palm oil industry is promising considering the latest trend and current development on the technologies. Therefore, more efforts in research and development on solar thermal are required in order to overcome the barriers to enhance the solar thermal market in the country.

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