Nanofluid based photovoltaic thermal (PVT) incorporation in palm oil production process

Ali H A Alwaeli, K. Sopian, Adnan Ibrahim, Sohif Mat, and Mohd Hafidz Ruslan

***Abstract*—The palm oil industry is very important and affects other industries and markets around the world. The two most dominant countries in palm oil production are Malaysia and Indonesia. More solutions are proposed by researchers to increase the sustainability aspect of the palm oil process. This paper presents an idea of emerging the solar energy industry and the palm oil industry to achieve higher levels of sustainability. PVT panel in particular are high efficiency energy conversion systems that allow to produce electricity and thermal energy in the same area. The thermal energy produced could be used for pre-heating the water for the sterilization process. The system, if implemented, can help investors save energy, time and money. Above all, reduce the carbon footprint of the process.**

***Index Terms*—Palm Oil; photovoltaic; carbon footprint; PVT;**

I. Introduction

PALM oil based products are used everywhere today, forming 50% of packaged products in local supermarkets which demonstrate its importance for consumers [1]. As it's known Palm oil accounts for 35% of the world's vegetable oil market [2]. The process of creating this palm oil from palm trees is very intensive, yet relatively simple. Malaysia is considered the second higher producer of palm oil in the world following Indonesia with about 19.9 million tonnes of palm oil annually. The negative aspect to this massive production is high carbon footprint, use of chemical elements in production and damage of eco systems. This is why global standards for sustainable palm oil were created such as the RSPO certification which ensure protection of eco-systems, higher safety measures and more sustainable solutions in plantation and extraction of palm oil [3]. Therefore, many work have been done to link the palm oil industry to renewable energy and sustainability; either by sustainable plantation, extraction and refining or by converting it to electricity or biodiesel. This essay will introduce the idea of incorporating photovoltaic thermal (PVT) collectors to the sterilization process allowing to produce hot water for the process and electricity from solar panel to power all active components. However, it is important to begin with explaining the processes in palm oil production, then concept of photovoltaic thermal collectors.

The process begins with plantation of palm trees and harvesting of fresh fruit bunches (FFB), these palms contain palm kernel oil in its kernel and palm oil in its Messocarp. The collection process is done by the local farmer and supplied to the transportation truck. The FFB is taken to the mill where it goes through grading, separation and selection. Once suitable FFBs are selected they are inserted in a saturated steam gauge in a large pressure vessel to be sterilized. This process contains different active components such as various pumps and heaters. The FFBs then are rotated in a rotation drum to confirm their sterilization, as they are dislodged. Next step is to homogenize and mesh them to produce the oil, which is done using digester and screw press. Final step is extraction and purification which is carried out using a vibrating screen clarifier and purifier. Further processes include refining of this produced crude oil to be a refined, bleached and deodorized (RBD) palm oil [4].

The photovoltaic thermal collector on the other hand is a hybrid system that utilizes the capabilities of both solar thermal systems (ST) and photovoltaic panels (PV). PV is a semiconductor device which converts the solar radiation of sun, only visible spectrum; as in light, into electricity [5]. While, ST is a collector with tubes that are designed in a way that allow it maximum absorption of solar radiation's heat to produce thermal output [6]. The reason these two collectors are mixed is because that PV panels have lower efficiency at high temperature, while the opposite is true for ST collectors. Therefore, the two systems are connected to each other, allowing heat transfer to occur form PV to ST and so maintain PV voltage and increase thermal output of ST [7]. An added advantage is to save space for the consumer as the two systems are setup in same area, instead of separate locations. PVTs are classified based on type of collector and working fluid, for example air, water and nanofluid based PVT collectors. The difference in use between these fluids is their thermal properties and capacitance. The highest in terms of heat transfer is the nanofluid [8]. The proposed PVT for this essay is SiC nanofluid based PVT system, which is illustrated in schematic diagram in fig. 1.

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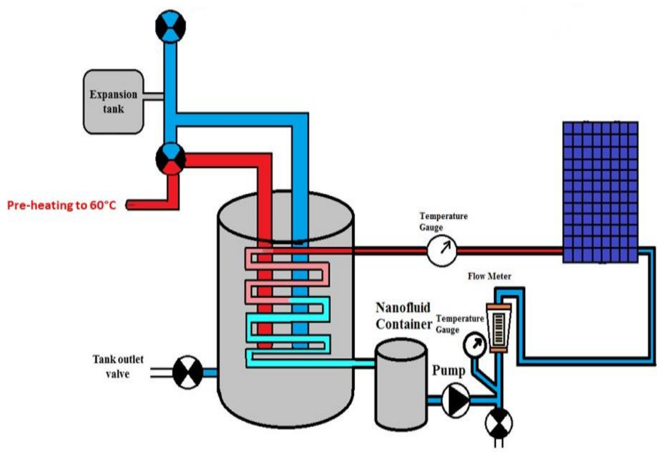

Fig. 1: Schematic diagram of proposed SiC-nanofluid based PVT

The PV panel produces electric power while the collector attached to it absorbs the heat and transmit it to the fluid within the pipes. The nanofluid gets heated, therefore cooling down the PV, and it circulates in the system. The nanofluid enters the heat exchanger, with water simultaneously, and get cooled down to be used for next cycle. The water absorbs the heat in the heat exchanger and is then either stored in a separate container or directly used. This rig was installed in the Green Innovation and Technology Park, UKM. Several tests were conducted to ensure optimum output and performance enhancement. The experiments concluded that using 3% volume fraction of SiC nanofluid based PVT for Malaysian climate has great potential and the achieved thermal efficiency is around 64.8% [9]. References [10 & 11] show further work on this proposed collector for the interested reader.

The use of nanofluid comes from its superior thermophysical properties which are a resultant of the Brownian motion of the nanoparticles in suspended fluid. As for the volume fraction, which is simply the ratio of Nano powder to base fluid, it is tested for different concentrations. The criteria depend on element of enhancement in thermal conductivity and its relation to cost increase [12-13].

The use of PVT to produce thermal output can be very beneficial in the sterilization process which requires both electricity for active components and saturated steam. Fig 2. Shows how PVT will now be a part of the palm oil production scheme. The incorporation of a high efficiency conversion scheme within the processes of palm oil making is an attractive idea and can mobilize and promote solar energy applications and technology. This idea is very important and helpful as turning any aspect of the palm oil process green could be very helpful to limiting the carbon footprint it produces while keeping production at moderate levels for the market.

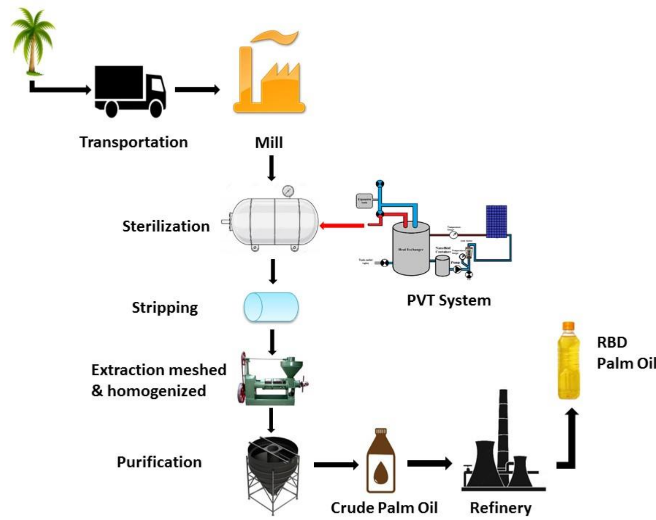

Fig. 2: The palm oil production with PVT

II. STERILIZATION PROCESS

It is important to note that the power and steam demands influence the overall energy efficiency of the system, and so by lowering those demands the carbon footprint can be reduced as well. However, the issue is that in the sterilization process, which generally consumes around 30% to 60% of the total steam process, to achieve good bleachability of BFF's the requirements must be fulfilled. As the amount of steam consumption depends on the type of cylindrical pressure vessel utilized (for example; vertical, horizontal etc.). Most common type used in the palm oil industry is the horizontal type. Conventional horizontal pressure vessels consumes around 360 to 400 kg process steam per tonne FFB, 4 Bar Abs pressure in triple-peak cycles and require a temperature of around 143 °C for a duration of 90-120 minutes. More recent innovation for this type of sterilization cylinders shows a steam consumption of a 110 kg to 130 kg, 1.5 Bar Abs pressure and a temperature ranging between 100-120 °C for a duration of 40 minutes in single peak cycle. The pre-heating element of the added PVT system, which can supply up to 60 °C of hot water which will in turn reduce the temperature requirements and hence less energy is needed to complete the process and also less time is required as well. However, there are still some issues that needs to be investigated in this solution; such as the carbon footprint of the PVT system itself. Which can also be solved by installing the PVT arrays at the rooftop of the refinery. Another issue is that fluctuation of performance of PVT depending on the weather variations throughout different times of the year [14-15]. This could deem the solution to be a secondary source, not a primary one. In any case, the solution will continue to provide the palm oil industry with electricity and heat for long periods of time and a good economic incentive. As for sterilization process, this will ensure to use as much as needed without trading off the efficiency of the FFBs but at the same time maintaining the element of sustainability in the palm oil process.

III. CONCLUSION

This idea could be applied at the final stages as well; at the refinery. Even though it is suggested in this work to utilize PVT for sterilization process, it is important to understand it can expand to other steps like implementation in meshing and drying processes. The thermal output might change depending on the requirement of each process. This system will encourage palm oil refineries and mills to invest in solar energy and make the process more sustainable. The incentive is that this system is cost-effective and can compete with net metering systems, over extended periods of time. The proposed PVT offer better energy generation per area than conventional PV or ST systems. Another element, as discussed above, is the reduction on GHG emissions, carbon footprint and water footprint of the company and so the industry. Overall it will have a positive effect on solar energy awareness in society and preserving of nature while maintaining industrial growth.

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