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A Framework of Solar Thermal Performance Study for Poultry Industry

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Malaysia is one of the countries aiming to create sustainable energy by using renewable sources as an alternative to reduce consumption of fossil fuel due to the negative impacts to the environment and public health. Solar energy which is free and abundant in Malaysia can be one of the potential renewable sources of energy to meet the energy demand in Malaysia. Some industries consume energy for low heating process, hence solar thermal has a great potential to fulfill the demand. This paper presents solar thermal performance assessment in poultry industry that obtain the heat energy from scalding tank with temperature between 60 – 70 °C for scalding process for efficient removal of chicken leather. The framework has been demonstrated in PPNJ Poultry & Meat Sdn. Bhd. as a case study as it is the first solar thermal incorporated in the industry process in Malaysia. The results reveals that about 88 % of the total energy input for scalding process has been contributed by solar thermal with about 2 % energy loss.

1. Introduction

Heat energy is one of the most important energy needed in the industry. Malaysia's industries required about 27 % of energy consumption where more than half of them are used to generate heat with temperature below 100 °C (Malaysia Energy Commission, 2016). Fossil fuel is no longer a suitable source of energy in Malaysia because of its high price and it contributes to serious environmental problems as it emits high greenhouse gases. Therefore, Malaysia is aiming to produce clean and sustainable renewable sources of energy to replace fossil fuel (Landau, 2019).

Solar thermal technology is one of the developing renewable solar energy that captures solar energy to generate heat energy for heating application especially any application that required temperature below 150 °C (Kaçan et al., 2015). In global, the industrial processes that required low-to-medium temperatures accounts for 33 % of industrial energy consumption (IEA-ETSAP and IRENA, 2014). Malaysia is a Southeast Asian country that has abundant sun resources with average sun irradiation between 1,400 to 1,900 kWh/m^2 annually. Malaysia also has a long sunshine time which is more than 10 h/d (Sabiha et al., 2015). Therefore, solar thermal technology has great potential in replacing the fossil fuel as it provides environmentally and economically sound way to obtain energy as well as it is the best option for industrial heating application in Malaysia. Poultry industry in Malaysia has become the pioneer industry that used solar thermal in its process where it supplements about 80 % of heating that previously supply by electric boiler (Noh, 2018). The simulator used in this study is SHIP (Solar Heat for Industrial Processes) Design Tool. SHIP Design Tool is an online calculator designed by InSun: Industrial Process Heat by Solar Collectors where it provided the annual performance and economic information to the user (Stuttgart, 2015).

While previous research work has been focused on the solar collector and integration of solar thermal system, however there are few studies on performance of solar thermal system in any other paper. One of the works had been done on thermal performance of solar water heating system where the different aspects were analysed such as the inlet and outlet temperature of the solar collector, water temperature in the storage tank, total solar radiation and the change of the heat collection efficiency (Yang et al., 2018). This study was done in the residential area only and not in the industry. The study also only focused on the temperature and total

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solar radiation but there was no performance study done on the solar fraction and solar yield. Other than that, the performance of a solar thermal system in providing heat up to 90 °C at the meat factory had been studied. The maximum and average values of specific energy output for the on-site measurement was compared with the simulation results where both values showed agreeable results (Cotrado et al., 2013). The research work only focused on the energy output by the solar system and total energy demand and energy supply of the whole system was not evaluated. A study on an evaluation of the integration configuration with and without heat exchanger and different solar utility temperature had been done on the both flat plate solar collector (FPC) and compound parabolic collector (CPC) (Sing et al., 2018). However, the study only considered the temperature of solar utility temperature and not the solar energy supply and energy demand.
The aim of the present work is to conduct a measurement and verification on the performance of solar thermal system in a poultry industry where the type of solar collector used in this work is evacuated tube collector (ETC). In this study, the real time heat supply by the solar collector and low temperature required by the process are analysed. The energy demand and energy supply are discussed further and demonstrated. The paper had contributed the first monitoring to the solar thermal system in poultry industry where the improvement can be done after that. This paper will be able to become a baseline and guideline for the solar thermal system in Malaysia as there is lack of studies about this work in the context of Malaysia. Other than that, the paper highlights the importance of using renewable sources to the society.

2. Methodology

Figure 1 shows the general methodology for this case study. Background study on solar thermal system is the basic steps to know the previous or current condition of the solar system in PPNJ Poultry & Meat Sdn Bhd. Besides, it provides the information of the integration point of the solar thermal system at the scalding process. The expected outcomes from the stage 1 are previous data on the energy demand of the scalding tank and the design or simulation data for the solar system. The on-site data collection will be run for a month and the data collected with the specific location are listed in Table 1. After that, the collected data will become the inputs into the simulator which is SHIP Design Tool. The simulator will be used throughout the on-site data simulation and analysis. Last stage is to perform the performance verification process for the solar thermal system.

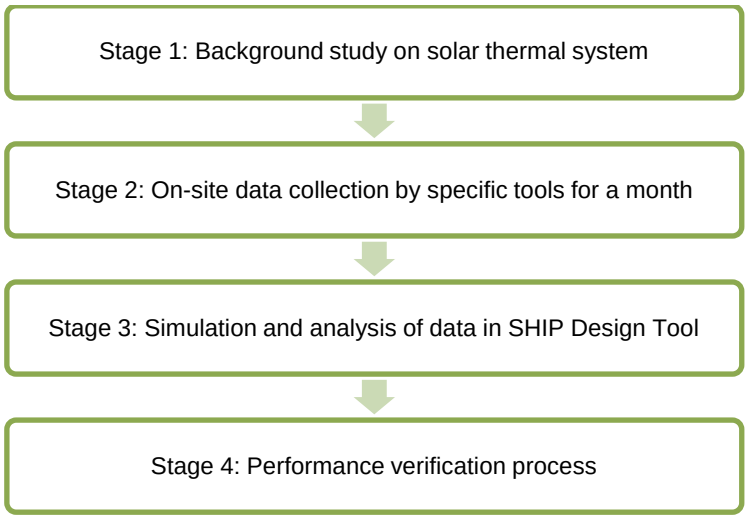

Figure 1: General procedure of methodology

2.1 Measurement

Measurement is a part of data collection activity. The activity was performed at the solar thermal system in PPNJ Poultry & Meat Sdn Bhd for a month. The temperature data were captured by the temperature logger at the panel while the mass flow rate data was captured using IoT (Internet of Things) technology. The data for solar radiation will be provided by SHIP Design Tool. Data that will be collect with the specific location are shown in Table 1.

Table 1: List of data collected

Variables	Location
Temperature	Supply (solar) and Demand (scalding) Streams
Mass Flow Rate	Supply (solar) and Demand (scalding) Streams
Solar Radiation	Go to 'Hourly Radiation Data' Information System of European Union

2.2 Performance Verification

Performance verification is a process in verifying the performance of the solar thermal system with respect to the design specification, energy demand and energy supply. Since the working fluid for the solar system is water and does not involve reaction, the energy balance was made based on Eq(1).

$$\text{Process Energy Demand} = mC_p\Delta T \quad (1)$$

where m represents the mass flow rate of water (kg/h), C_p is the specific heat capacity of the water ($C_{p\ water}$ = 4.18 kJ/kg·°C) and ΔT is the temperature difference of the water (°C).
It is also required to calculate solar fraction of the solar thermal system to determine actual energy provided by solar thermal system. The equation for solar fraction is shown in Eq(2).

$$\text{Solar Fraction} = \frac{\text{Amount of Energy Provided by Solar Thermal System}}{\text{Total Input Energy Required}} \quad (2)$$

After verification process, it can be confirmed whether the installed system is operating as it is intended or not.

3. Result and discussion

3.1 Case study

Solar thermal project in PPNJ Poultry & Meat Sdn Bhd had been operated since January 2017 in cooperation with SIRIM and UNIDO. Figure 2 shows the process flow diagram of solar thermal system in PPNJ Poultry & Meat Sdn Bhd. The components that involve in the solar thermal system are including solar collector system, hot water storage and auto-regulated heat exchangers. The system consists of two main streams which are solar stream and hot water stream. Both streams are closed loop.
The process of solar thermal system is started with heating up working fluid which is water by using evacuated tube solar collector. The water is heated up from 30 °C to 120 °C and flows to plate heat exchanger through pipes. The heat exchanger is used to transfer the heat from the solar collector stream to cold water stream. The storage tank acts as a medium to store heats for usage when it is unsuitable for heat generation by solar thermal system due to some climate conditions such as low irradiation and night time. The set point temperature of water inside the storage tank is at 70 °C. The heat in the scalding tank is supplied by both solar thermal system and electric boiler where electric boiler can be act as a backup for heat generation. The effluent water from scalding process is discharged for water treatment.

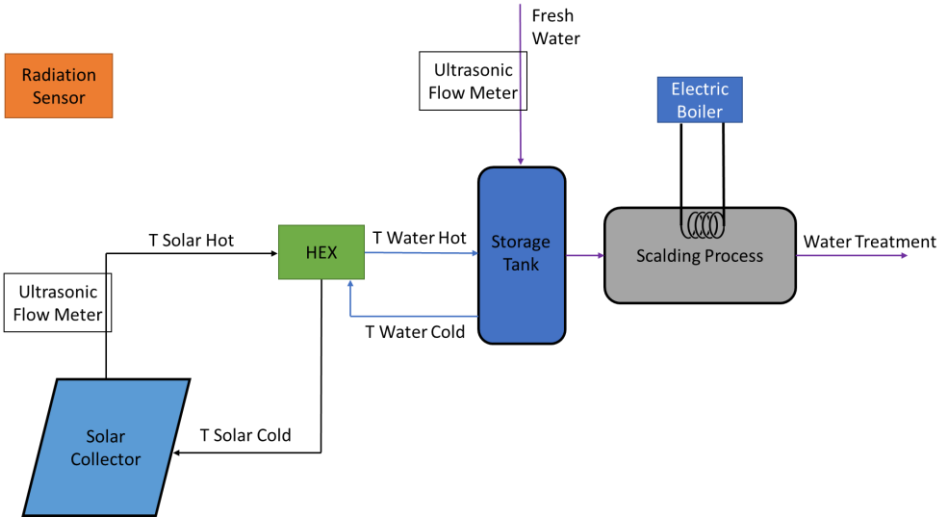

Figure 2: Process flow diagram of solar thermal system in PPNJ Poultry & Meat Sdn Bhd

The temperature data for July 2018 is shown in Figure 3. Distribution, harvesting, generation and scalding temperature are indicated the temperature for storage tank, solar collector, transfer heat and scalding tank respectively. From Figure 3, it shows that the solar collector can reach up to 120 °C or more when it is in good radiation. During the operation of scalding process, the temperature of scalding tank should be maintained at 60 °C for smooth operation. The operation is operating 6 d in a week where it is run up to 8 h/d.

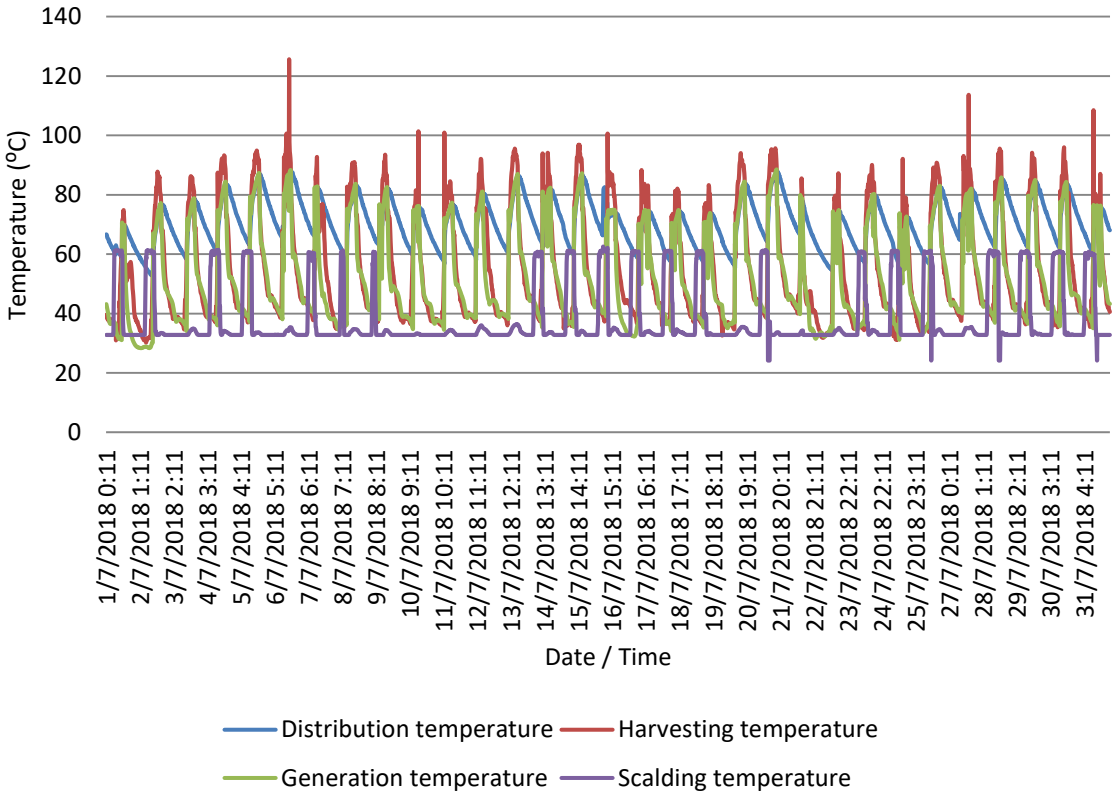

Figure 3: Temperature data for July 2018

The solar thermal system is integrated at scalding process to support the electric boiler by heating. The details of the solar thermal project are shown in Table 2.

Table 2: List of parameters for solar thermal project in PPNJ Poultry & Meat SDN BHD

Parameters	Unit	Value
Energy Demand Daily	kWh	329
Energy Demand Annually	kWh	102,648
Solar Heat Delivery Annually	kWh	99,598
Collector Aperture Area	m^2	118.95
Hot Water Storage	m^3	8
Number of Tube Collector (Evacuated Tube)	units	1,170
Design Capacity	birds	8,000

Figure 4a shows the graph of process heat demand while Figure 4b shows the graph of heat generation from the solar thermal. Both graphs are using actual and simulation data. Figure 4a shows that the process heat demand from the actual data is higher than the simulation data. It is because of the increasing of production. The simulation data was based on 8,000 birds while the actual data was based on 12,000 birds. The higher the production, the higher the heat demand by the scalding process. Meanwhile, Figure 4b shows that the heat generated from the simulation data is higher than the actual data. There are many factors that can affect solar yield which are the weather and shading. The actual data for solar yield does not reach the simulation data is because of unpredictable weather.

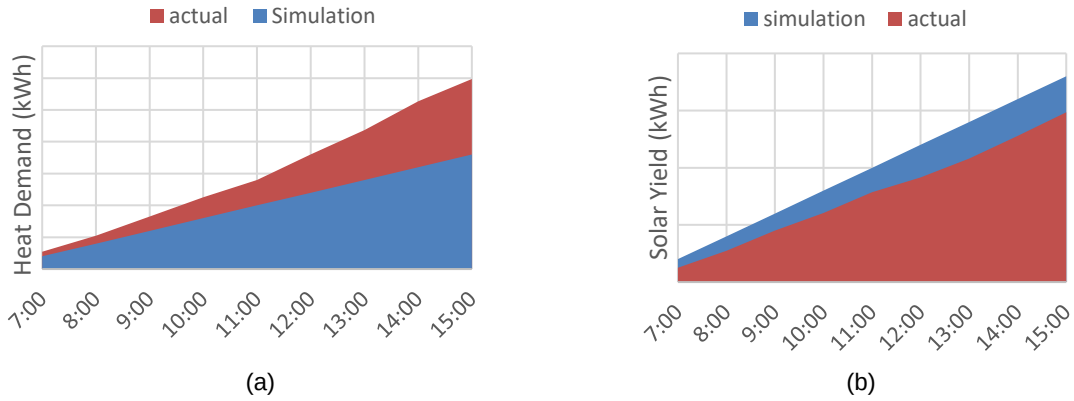

Figure 4: Graph of (a) process heat demand (b) solar heat generation from actual and simulation data

Figure 5 shows the energy supply and demand in solar thermal system. Energy supply is the energy generated by solar thermal and electric boiler for the process. Energy demand is energy needed by the process or losses to the surrounding by various factors. From Figure 5, it shows that the average solar fraction is about 88 %. It means that solar thermal is able to meet 88 % of the energy demand by the process and only 22 % of the energy is supported by boiler.

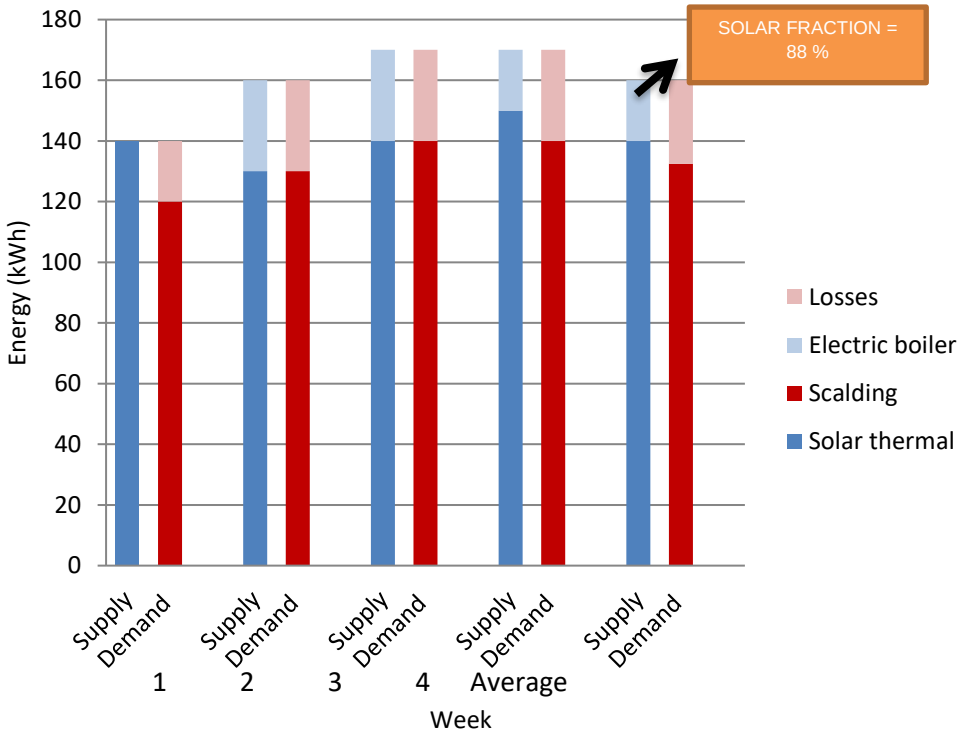

Figure 5: Graph of energy supply and demand in solar thermal system

4. Limitations and future work

A long term study for the performance and economic analysis of solar thermal system at the poultry industry can potentially improve further this present study. Further research can be directly described the economic and environmental impact of the solar thermal system integrated at the process. Comparing the performance study with the other industries that implemented solar thermal system in their process can also be considered

to expand the scope of the present study. It is better if the solar radiation can be captured by the specific tool in order to produce more accurate data and results.

5. Conclusions

Measurement and verification on solar thermal system have been conducted in PPNJ Poultry & Meat Sdn Bhd. All variables needed have been collected such as temperature, mass flow rate and solar radiation. Based on the case study, it shows that the actual data does not meet the simulation data. It is because of the increasing production where PPNJ Poultry & Meat Sdn Bhd had increased their production to 12,000 birds per day. The unpredictable weather shading is also one of the reasons the actual and simulation data does not match. Energy demand and solar fraction have been calculated based on collected data. The solar fraction for the solar system in PPNJ Poultry & Meat Sdn Bhd is about 88 %. It shows that PPNJ Poultry & Meat Sdn Bhd saves 88 % of energy by using renewable energy which is the solar thermal system. The solar fraction has a great potential to be increased if some improvement can be made. The improvements that can be made by PPNJ Poultry & Meat Sdn Bhd are add up another hot water storage tank or enlarge the existing storage, insulate the hot water storage and reuse water out from scalding process to preheat the fresh water going into the storage tank.

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