Large Scale Solar Assisted Hot Water Heating Systems invested at Green Hospital

POORYA OOSHAKSARAEI, KAMARUZZAMAN SOPIAN
Solar Energy Research Institute
Universiti Kebangsaan MALAYSIA
43600 Bangi Selangor
Malaysia
poorya@eng.ukm.my ksopian@vlsi.eng.ukm.my

Abstract: - Concerns over the impact of the environment on the massive usage of fossil fuels, combined with soaring energy prices, triggered increased interest in the use of solar energy. One of the most attractive applications of solar energy is for hot water usage in the public and commercial sector. The available building surface for the residential, commercial and industrial sector is approximately 110,000,000 m^2. Hence, the potential for solar heaters for Malaysia is 75 GW(thermal). There are over 100 hospitals and hotels throughout the nation that the existing hot water system can be converted to solar assisted system and hence increase the market of the solar energy systems. Hospitals and hotels utilized over 30 % of the total energy consumption for water heating. A case study of such facilities is the Hospital University Kebangsaan Malaysia (HUKM)) was presented. Presently, cold water enters the calorifiers directly, which are heated by LPG boilers. Larger amount of LPG is used and much amount of greenhouse gases is released. The hot water system for the hospital is provided by a boiler, total of eight calorifiers. The unit used to run 24 hours a day. The average solar radiation for Kuala Lumpur is 16.92 MJ / m^2 / day. The evacuated tube collectors with all the required controls system have been proposed and installed. Simple calculations on the energy output, savings on LPG and reduction of CO2 have been conducted. Preliminary results indicated that the saving on LPG based on proposed system was more than 20%. With a prospect of 100 hospitals and hotels throughout the nation, this project shall improve public awareness in energy conservation in the hot water production of their buildings and increase the market of the solar energy systems.

Keywords: large scale, solar assisted, water heater, energy savings, greenhouse gas reduction

1. INTRODUCTION

Solar energy applications are oriented toward the applications of solar energy for domestic hot water systems, solar distillation of sea and brackish water, water pumping, drying of agricultural produce, solar industrial process heat, photovoltaic for remote applications, space heating and cooling (passive and active design), building integrated photovoltaic systems and products, delighting, solar thermal electricity generation, and solar refrigeration [1,2].

The main objective of installing the solar assisted hot water heating system are (a) supplying solar thermal collectors to preheat hot water for existing commercial hot water service (b) demonstrating the use of solar heat pipe energy as an economical alternative compare to water heating by fossil fuels (c) reducing the amount of LPG used (d) reducing greenhouse gases emission (e) providing an advanced practical platform for solar thermal research.

In Malaysia, there are huge potential for the use solar hot water heating in hotels where 24.62% of the total energy consumption is for water heating. Other promising applications are the use of solar industrial process heat in textile factories, hospitals, food processing industries, animal husbandry, dairy, aquaculture, swimming pool heating and other manufacturing facilities [3]. This paper presents the feasibility of the use of large scale solar hot water heating system for hospitals. A case study was conducted using the existing system in Hospital Universiti Kebangsaan Malaysia, a modern teaching and R&D hospital.

2. *SOLAR IRRADIATION IN MALAYSIA*

The monthly average daily solar irradiation in Malaysia is 4000 - 5000 Whr/m2, with the monthly average daily sunshine duration ranging from 4 hr to 8 hr [4]. It can be seen, that the region Klang valley

(Kuala Lumpur, Putrajaya, Seremban) has the lowest irradiance value. Penang (Georgetown, north-west coast) and Kota Kinabalu have the highest values. Figure 1 shows the annual average daily global solar irradiation for Malaysia.

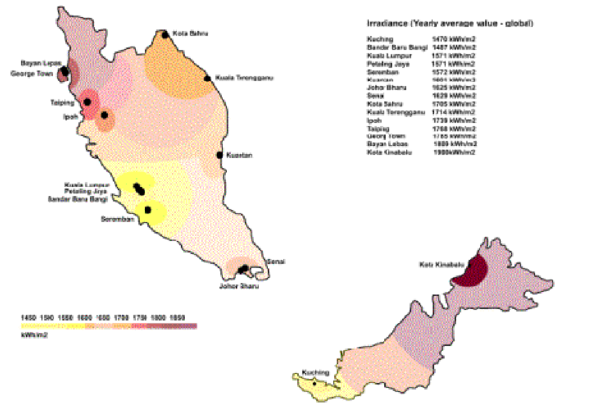

Figure 1: Estimates of the Annual Average Daily Global Solar Irradiation

3. POTENTIAL FOR SOLAR HOT WATER HEATING IN MALAYSIA

There are huge potential for the residential, commercial and industrial sector. We are able to determine the Monthly average daily utilize ability of the system by applying the equation below [8]:

$$\bar{\phi} = \frac{\sum_{days}\sum_{hours}(I_T - I_C)^+}{\bar{H}_T \; N}$$

There are over 100 hospitals and hotels throughout the nation that the existing hot water system can be converted to solar assisted system and hence increase the market of the solar energy systems. Hospitals and hotels utilized over 30 % of the total energy consumption for water heating.

4. EXISTING HOT WATER HEATING SYSTEM

The Hospital Universiti Kebangsaan Malaysia (HUKM) is situated in Cheras. HUKM is about 10 km from the Kuala Lumpur city centre. It is one of the most modern state-of-the-art teaching hospitals for the Faculty of Medicine, University Kebangsaan Malaysia. The hot water system for the hospital is provided by a boiler with a capacity of 2.1 million kcal/hr. The fuel used is LPG. A total of eight calorifiers are used. Each calorifier has a capacity of 13,500 litre/hr. The unit is running 24 hours a day. The existing HUKM hot water systems use a boiler and a calorifier to produce a hot water. The systems has made with two loops as shown in Figure 2.

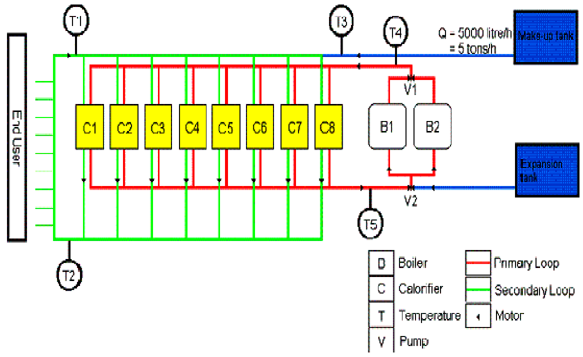

Figure 2: Schematic of Existing Hot Water Heating System in HUKM

Primary Loop: Consist of circulation of hot water within the boiler and the calorifier, plus the expansion tank to replace the water loss during the circulation.

Secondary Loop: Consist of calorifier and end user distribution pipeline. Plus a make-up tank the replace the water loss during the circulation.

In the current system, each calorifier is dedicated to different user such as laundry, kitchen, wards, toilet and etc. The water consumed during the circulation is then replaced by the water stored in the make-up tank. All 8 calorifier simultaneously operate based on the demand from the end user. An average of 5000 litter of water is consumed every hour (based on energy audit result from 3rd ~ 9th March '04). The water distributed to the user, point T2, must between the ranges of 50°C ~ 60°C. While the hot water fed in to the calorifier from the boiler known as Primary Hot Water Supply (PHWS), point T4, must be at 90°C. The water from the make-up and expansion tank is town water with temperature in the region of 25°C (point T3).Whenever the calorifier detects a temperature drop in the SHWR (< 50°C), point T1, it will send a signal to pump V1 to feed in a hot water with the temperature of 90°C. At the same time the boiler will start to burn water until the water flow in the Secondary Hot Water Supply (SHWS) reach the set temperature of 60°C. The water loss during this process in the boiler will be replaced by the expansion tank, while the water consumed in the calorifier will be replaced by the makeup tank. B1 will operate regularly and will always be in Hot-

ISBN: 978-1-61804-175-3

standby Mode when not operate while B2 will always on Cold-standby Mode and act as a backup boiler in case if B1 fails to operate.

5. PROPOSED SOLAR HEATING SYSTEM

Similar settings applied to this mode except the function of the make-up tank is replaced by the Solar Water Heater (SWH) as shown in Figure 3. It increases the temperature of secondary loop as much as possible; then, calorifier boosts it up to pre-set value that is 80^{oC}. If the temperate to the user is high enough, the boiler remains on standby mode. In case of high water demand temperature drops and it trigger the boiler. This process, which is similar to the current system, will continuously occurred until the SWH able to supply the hot water. Initial proposed system consists of 5 Ton pressurised and 10 Ton non-pressurised storage tank [8], which has been merged to a 15 Ton non-pressurised thank, imposed by existing hospital construction limitations.

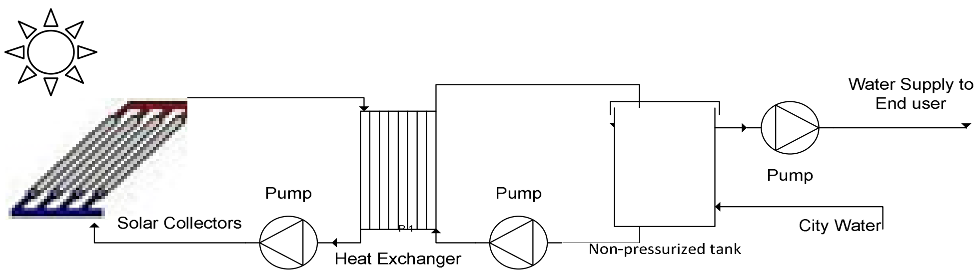

Figure 3: Proposed Solar Assisted Heating System

6. Evacuated Tube Sola Collector

A solar thermal collector uses the sun's energy to heat the water directly. Typically, it consists of a manifold and a collector. The solar thermal collector module recommended in this proposal consists of series of evacuated U-type pipe solar thermal collectors housed in high-vacuum glass tube.

The tube has large dimensions with an outer diameter 100 mm and a length 2000 mm. It is made of borosilicate glass, which is clear and has high transmittance more than 90% for solar irradiation. The tube is evacuated to 1 MPa to eliminate convection thermal heat lost through the glass. The U-type pipe is made of copper and mounted in absorber plate.

The heat transfer rate in each riser tube is calculated using the following equation [5,6]:

$$Q=mc_P (T_{out}- T_{in}) = U_0A_0(T_{out}- T_{in})$$

Where

$$\frac{1}{U_oA_o} = \frac{1}{h_iA_i} + \frac{\ln (D_o/D_i}{2\pi k_w L}$$

The thermal performance of the solar water heater is calculated using the (Hottel and Whiller, 1958; Bliss,1959) equation as follows:

$$\eta = F_R(\tau\alpha) - F_R U_l \frac{T_{in} - T_a}{H_t}$$

7. The Collector Array

U-type solar evacuated collector manufacturers recommend that the maximum number of solar panels in series should not exceed more than 6 (16 Tubes in each panel). The system is to be split into *rows*; each *row* consists of 12 strings solar collectors. Each string consists of 4 solar collector panels, and each panel consists of 16 sets of evacuated vacuum tube. This make up a solar thermal collector system consisting of 2,304 evacuated vacuum tube in total.(Figure 4)

Figure 4: installed evacuated solar collectors at HUKM hospital

Splitting the system into 36 strings increases the overall efficiency. Besides, it gives a high flexibility to trace and evaluate the performance of the system. These blocks are to be connected to a heat exchanger. The heat from the solar collectors is transferred here, only when the water temperature at collector outlet increases at least than 2 degree Celsius more than the temperature of storage tank.

8. Experimental Result

According to before mentioned proposal, construction has been done.

Main component have been installed are as below:

144 panels. 16 Tubes per panel

3 Circulation Pumps

1 plate heat exchanger

15 Ton pressurised storage tank

2 pressurised expansion tank

Weather station

Automated Control unit equipped by data acquisition and Data transition system

2 weeks hot water feeding to the hospital has been monitored. At this period, Solar Water Heater (SWH) provides hot water from 10:00 AM to 10:00 PM. From 10:00 PM to 10:00 AM water boiler covers the hospital demand.

Before solar water existence, hospital used to trigger 2 boilers to provide required hot water. At 2 weeks test run, they shot down 1 boiler and replaced it with SWH. The other boiler has been used to bust up the temperature oh hot water provided by SWH to a certain temperature (80oC) for applications such as sterilization.

Figure 5 represent the average temperature delivered to the hospital in 24 hr. As the average temperature never drops below 40 degree Celsius and the end user use mixing tap, this water is appropriate for low temperature applications. Meanwhile, one boiler is always on mode to cover any unexpected weather changes or catastrophic frailer in SWH.

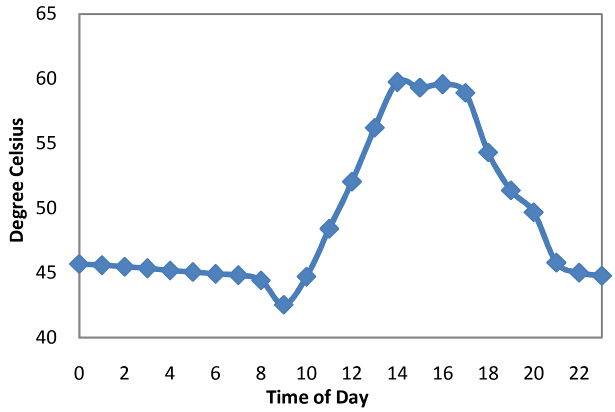

Figure 5: hourly average storage tank water temperature (base on 2 weeks data collection at Aug 2011)

Parts of hospital divisions such as sterilization, kitchen, and laundry require slightly higher temperature (80oC for sterilization) that could be boost up by existing boiler and calorifier.

Solar radiation has been measured by piranumiter that has been used to calculate the efficiency of the first loop of SWH as figure 6

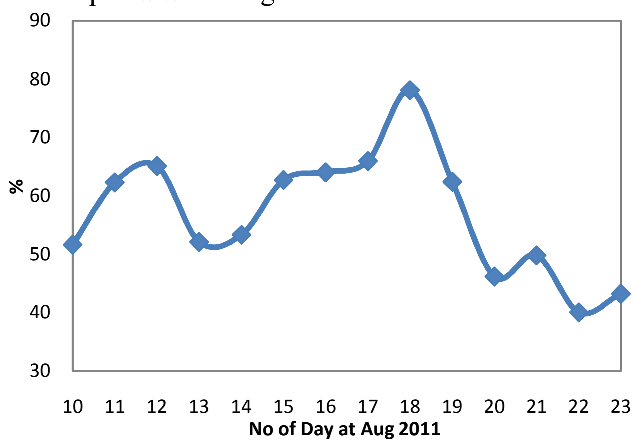

Figure 6: daily average efficiency for 2 weeks data collection at Aug 2011

9. Conclusion

One of the most promising applications for solar energy is the production of hot water for commercial and domestic usage. It will provide hot water for many years, at minimal energy costs. It reduced the LPG consumption of one boiler up to 80%, and will

ISBN: 978-1-61804-175-3

also avoid the production of many tonnes of greenhouse gasses. The efficiency varies from 40% to 80% depending on the weather condition and water consumption profile. At the same time, temperature of water delivered to the hospital rarely drops below 45^{oC} that is appropriate for most of hospital end users. Parts of hospital divisions such as sterilization, kitchen, and laundry require slightly higher temperature that could be boost up by existing boiler and calorifier. There are over hundreds hospitals and hotels throughout the world. Hence, the use of solar water heaters shall improve public awareness in energy conservation in the hot water production of their buildings and increase the market of the solar energy systems.

References

[1]. Truly, R.H.. . (2000). The Clean Energy Century: The Path Forward for Renewable Energy in the New Millenium, World Renewable Energy Congress VI, Brighton, 1 - 7 July, pp 10 – 15

[2] Ebenhack, B.W. (1995). Nontechnical Guide to Energy Resources: Availability Use and Impact. Tulsa, PennWell Publishing Co. 290pp.

[3]. Sopian, K. M. Y. Othman, B. Yatim, and A.H. Shamsuddin, (2000). Potential Application of Environment Friendly Renewable Energy Systems, Journal of Environmental Management, Vol. 1, pp. 3 - 19.

[4]. Sopian K. and Othman M.Y., (1992). Estimates of Monthly Average Daily Global Solar Radiation in Malaysia. Renewable Energy, Vol 2(3). pp 319-32.

[5]. S. Jaisankar, T.K. Radhakrishnan, K.N. Sheeba (2009) Experimental studies on heat transfer and friction factor characteristics of forced circulation solar water heater system fitted with helical twisted tapes Solar Energy 83 pp.1943–1952

[6]. H.D. Ammari, Y.L. Nimir., (2003). Experimental and theoretical evaluation of the performance of a tar solar water heater. Energy Conversion and Management 44 pp. 3037–3055.

[7]. P.ooshaksaraei , B.Ali, S.Mat, M.YAHYA, K.Ibrahim, A.Zaharim, K.Sopian (2010) Large Scale Solar Hot Water Heating Systems for Green Hospital, Recent Advances in Applied Mathematics, American math 2010, ISBN: 978-960-474-150-2

[8]. John A.Duffie, William A.Beckman 1991. Solar Engineering Of thermal Processes