2015 International Conference on Advances in Environment Research
Volume 87 of IPCBEE (2015)
DOI: 10.7763/IPCBEE. 2015. V87. 17

Heating Indoor Swimming Pool Using Solar Energy with Evacuated Collectors

Ahmad Aboushi [1 +] and AbeerAbu Raed [2]

[1] Al-zaytoonah Private Universuity of Jordan, P.O.Box 130, Amman 11733, Jordan

[2] Department of Architecture Engineering, American University of Ras Al Khaimah, 10021 UAE

Abstract. Solar energy is often used to heat swimming pools so that conditions of comfort can be obtained. The water temperature in swimming pools can be regulated using solar water heating systems, extending the swimming pool season and saving on the conventional energy costs. Solar water heating systems need very little maintenance.

This paper presents the work on evaluating the thermal performance and life cycle energy cost of using solar energy for indoor swimming pool in west Amman-Jordan. A swimming pool of 50 m^3 was considered in this work. 150 evacuated tubes, 47*1500 mm each, were used to achieve comfort conditions. It was found that thermal comfort is achieved using solar energy over 9 months. To reach comfort temperature in December till February Diesel or electric heater can be used in addition to solar energy system.

Keywords: Solar energy, energy efficiency, evacuated tube

1. Introduction

The demand for energy increases rapidly with economic and population growth In Jordan. The demand for primary energy in 2007 was about 7438 million tons of oil equivalents, with a growth rate of 3.5% against a growth rate of 2.3% in 2006. The cost of importing energy creates a heavy financial burden on the national economy.

The total contribution of renewable energy in Jordan is about 1% of the total energy mix. Renewable energy applications in Jordan includes solar water heaters of more than 300,000 units, solar photovoltaic of more than 200 kW peak, wind farms of 1.5 MW, hydropower of about 5 MW and biogas of more than 3 MW. Recently, policy has been adopted for the integration of renewable energy in the energy system by allocating 5% of the total energy from renewable energy sources within the next 10 years.

According to Jordan' Energy Master Plan [1], the share of RE must be increased. The aim is to reach a 3% share of Jordan's primary energy consumption by the year 2015. Also a high carbon emissions will be introduced which is against the world trends to reduce these emissions to face the Global Warming Potential (GWP) and Ozone Depletion Potential (ODP) and many other hazardous effects to both the environment and mankind. The water temperature in swimming pools can also be regulated using solar water heating systems, extending the swimming pool season and saving on the conventional energy costs. The basic principle of these systems is the same as with solar service hot water systems, with the difference that the pool itself acts as the thermal storage. For outdoor pools, a properly sized solar water heater can replace a conventional heater; the pool water is directly pumped through the solar collectors by the existing filtration system.

Jordan lies in the so-called earth-sun belt area and has a high potential of solar energy, where the annual averages of global solar energy is about 1800 kWh/m^2/year. (Yearly average solar radiation on a fixed tilted surface is more than 6 kwh/m^2 day).

[+] Corresponding author.
E-mail address: A.Aboushi@zuj.edu.jo.

Solar energy is mainly used in Jordan for domestic solar water heating (about 30% of the houses in the country). More than 25 manufacturers are producing locally designed solar water heaters systems. These systems cover different applications such as water pumping, telecommunications, schools and others with a total capacity of 184 kW. Many Jordanian authors considered different RE options for implementation in Jordan. Sakhrieh *et. al.*, presented an experimental investigation of overall performance, efficiency and reliability of five types of solar collectors which are available in the Jordanian local market [2]. Experimental and theoretical evaluation of the performance of a tar solar water heater and comparison with that of a conventional type collector was carried out by Ammari *et al.*, [3]. Mohsen *et. al.*, [4] carried out Extensive experimental studies on a compact solar water heater, in order to evaluate the performance of the heater and determine the optimal depth of the storage tank. Worldwide, the use of solar energy has been presented by several researches. For example a survey of the various types of solar thermal collectors and applications is presented by Kalogirou [5]. Furthermore, he presented an analysis of the environmental problems related to the use of conventional sources of energy and the benefits offered by renewable energy systems are outlined. Sateikis *et al.*, [6] studied the possibilities to satisfy 50% of the energy demands to heat the individual houses in rural areas of Lithuania with the utilization of the wind and solar energy. A new design of roof-integrated water solar collector is presented by Luis Juanico [7]. In this research the feasibility of replacing swimming pool heating system with a solar one is presented and analyzed. Thermal performance and life cycle energy cost of using solar energy for indoor swimming pool in west Amman-Jordan was presented. A swimming pool of 45 m3 was considered in this work.

2. System Description

The swimming pool is shown schematically in Fig. 1 and Fig. 2. The surface area of the swimming pool is 30 m^2. The depth of the swimming pool is 1.5m. The swimming pool is placed in a 67 m^2 room. The inside design temperature of the room is taken as 24 ^{O}C.

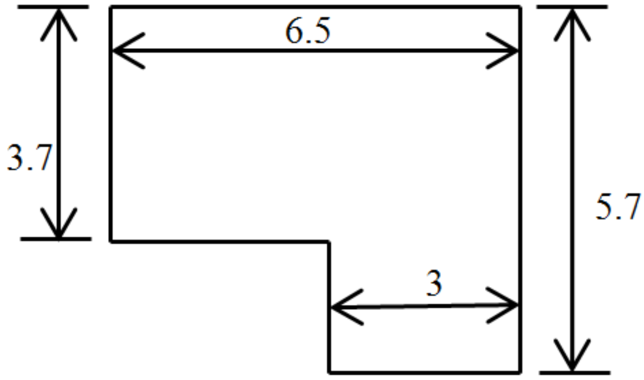

Fig. 1: Schematic diagram of the swimming pool

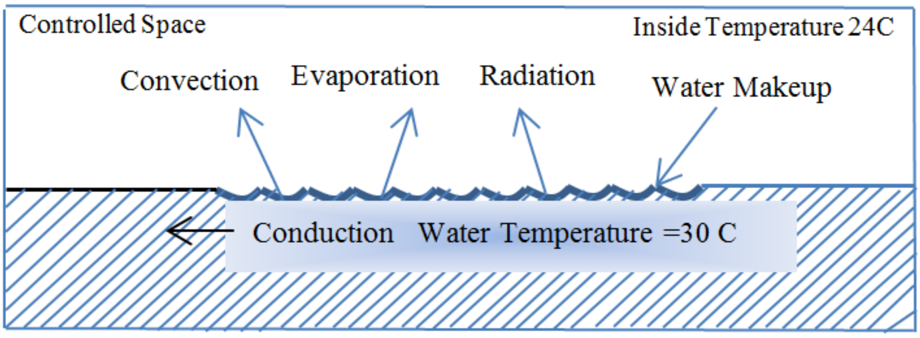

Fig. 2: Schematic diagram of the heat loss

3. Heat Losses

The total heat losses from swimming pool were consisting:

- Heat loss by conduction from walls of the swimming pool.
- Heat loss by convection.
- Heat loss by evaporation.
- Heat loss by radiation.
- And heat loss by water makeup.
- The following assumptions are made to install the solar system:
- The pool is operating all year around.
- The expected proportion saving about 100% in summer, and 50% in winter.

The size of the solar system was calculated and implemented using evacuated tube solar collector. The required parts are presented in Table I.

The system's feasibility is calculated using the simple payback period method, which is the time required for the system to recover its initial cost from the saving the fuel resulting from using this system. In these calculations the following assumption are made:

- System cost = 2740 JD.
- Fuel used in conventional heating system was diesel.
- Efficiency in summer season 100% and in winter season 50%.
- Diesel cost = 0.5 JD/liter
- Diesel heating value = 44 MJ/kg
- Diesel density = 0.72 kg/Liter
- The solar system pumps electricity consumption is considered negligible.

Table I: Parts needed for the swimming pool

Piece	Product name	Quantity	Single price (JD)	Total price (JD)			
1	Heat pipe	150	7	1050			
2	Controller	1	145	145			
3	Extension ball 25 liter	1	25	25			
4				Pump	1	120	120
5				Heat exchanger	1	320	320
6				Cab installation	1	350	350
7				Pieces of solar heater	1	500	500
8				Pressure gage	10	7.5	75
9				pump "1 ½	1	155	155
Total price							2740 JD

3.1. Heat Loss by Conduction

Heat loss from walls inside the swimming pool

$$Q^{\bullet}_{loss}=U\,A\,(Ti-To) \qquad (1)$$

$$U=\frac{1}{Rth.}=\frac{1}{Ri+Ro+\frac{X}{K}} \qquad (2)$$

where; A (Area) = (20.9) ×1.5 m^2, Ti=30 ℃, To =24 ℃, K=1.75W/m. ℃, x=3 m, Ri=0.12 m^2. ℃/W and R_O=0.08 m^2. ℃/W

$$Q^{\bullet}_{loss}=0.5224\times(20.9\times1.5)\times(30\text{-}24) = 98.28\ W$$

3.2. Heat Loss by Convection

Heat loss by convection from the surface area of the swimming pool:

$$Q^{\bullet}_{loss}= h\,A\,(T_{water\,-}\,T_{air}) \qquad (3)$$

$$h = 2.8 + 3.0\,v \qquad (4)$$

where; A=30 m^2 , and v=0.12 m/s, h= 3.16 W/m^2. ℃

$$Q^{\bullet}_{loss} = 3.16 \times (30) \times (30 - 24) = 568.8 \text{ W}$$

3.3. Heat Loss by Evaporation

The heat loss by evaporation from the surface area of the swimming pool was calculated by the following equation:

$$Q^{\bullet}_{loss} = h_{water}\, g \qquad (5)$$

$$g = \Theta\, A\, (x_s - x) \qquad (6)$$

$$\Theta = 25 + 19\,v \qquad (7)$$

g: is the amount of evaporated water

where; h_{water} = 2430 kJ/kg, $v=0.12$ m/s, A=30 m^2, x_s =0.0272 $kg/kg_{d.a}$ from Air Psychometrics at 30 ℃, x= 0.009299 $kg/kg_{\,d.a}$ from Air Psychometrics at 24 ℃ and the amount of evaporated water = 4.068×10^{-3} kg/h

By applying the heat loss equation

$$Q^{\bullet}_{loss} = 2431 \times 4.068 \times 10^{-3} = 9.89 \text{ kW}$$

3.4. Heat loss by Radiation

The heat loss from water to the ambient temperature can be calculate

$$Q^{\bullet}_{loss} = \epsilon\, \sigma\, A\, (T^4_w - T^4_A) \qquad (8)$$

where; Є=1, $\sigma = 5.67\times10^{-8}$ W/m^2K^4 , T_w=30 ℃, and T_A=24 ℃

$$Q^{\bullet}_{loss} = 1 \times 5.67\times10^{-8} \times 30 \times (303^4 - 297^4) = 1.1022 \text{ kW}$$

3.5. Heat Loss by Water Makeup

The mass flow rate for makeup water is:

$$m^{\bullet}_{makeup} = m^{\bullet}_{eva} + (f_{makeup} \frac{\rho\, Vp}{7\times86400}) \qquad (9)$$

where; $m^{\bullet}_{eva}$ = 4.068×10^{-3} Kg/s, ρ_{water} = 1000 kg/m^3 , Vp = L × W × D =30 × 1.5=45 m^3

$$m^{\bullet}_{makeup} = 4.068\times10^{-3} + 0.1 * (1000*45/7*86400)((1000*80)/(7*86400)) = 0.0115 \text{ Kg/s.}$$

The rate of energy requirement corresponding to water makeup, $Q^{\bullet}_{makeup}$, is:

$$Q^{\bullet}_{makeup} = m^{\bullet}_{makeup}\, Cp\, (Tp - Tc) = 0.0115 * 4.186 \times (30-8) = 1.156 \text{ KW}$$

Finally the total heat loss from swimming pool is

$$Q^{\bullet}_{Total} = 0.09828 + 0.5688 + 9.89 + 1.1022 + 1.156 = \mathbf{12.81528} \text{ KW}$$

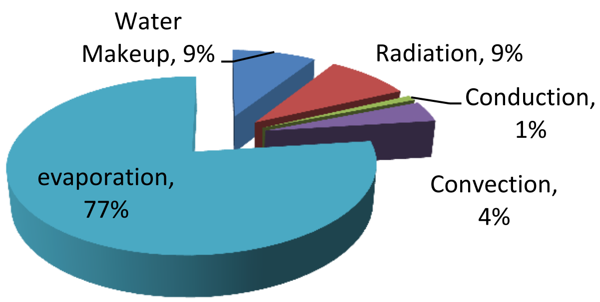

Fig. 3: The percentage of heat loss.

Fig. 3 shows that evaporation has the largest percentage heat loss from the total heat loss of the swimming pool, that indicate the most energy required to heat the pool to recover that loss. By reducing the evaporation loss, the energy required has been reduced

The amount of fuel saved can be estimated by the following equation

$$Q_{saving} = m_{deisel} \times Q_{cv} \times ή_{H.E} \quad (10)$$

$$1107240.192 \text{ kJ} = m_{deisel} \times 44000 \text{ (kJ/kg)} \times 0.7$$

m_{deisel}= 35.94 kg per day

The amount of fuel saved in summer and winter season.

From supplier, it will save 100% in summer (from May-September) and 50% in other months

m_{deisel}(in summer) = 35.94 (kg / day) × 100% × 5 (month / year) × 30 (day/month)

= 5392.4 kg / year.

m_{deisel}(in winter) = 35.94 (kg / day) × 50 % × 7 (month / year) × 30 (day/month)

= 3773.7 kg / year.

Total fuel saved = 5392.4+ 3773.7 = 9166.1 kg/year.

The cost of 1 kg diesel is 0.5/0.72 = 0.7 JD/kg

Total saving for one pool = 0.7 (JD/kg) × 9166.1 (kg / year) = 6416.27 JD/year.

Total cost for solar system used = 2740 JD

Payback period= 2740 (JD) /6416.27 (JD/year) = 0.43 year.

4. Conclusions

This research studied the feasibility of installing a solar system or heating an indoor swimming pool. Evacuated tube solar collectors were chosen. 150 evacuated tubes, 47*1500 mm each, were used. The installed solar system resulted in energy reduction by about 75%. It was found also that 77% of the energy is lost due to evaporation. So it is recommended to cover the pond during the night in order to reduce energy loss by evaporation. This can be achieved using a thin film cover. The payback period for the solar system is less than year.

5. References

[1] MEMR. Jordan’s energy master plan. Amman: MEMR Press; 2005.

[2] Sakhrieh A, Al-Ghandoor A. Experimental investigation of the performance of five types of solar collectors. Energy Convers Manage (2012), http://dx.doi.org/10.1016/j.enconman.2011.12.038

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

[4] Mousa S. Mohsen, Ahmed Al-Ghandoor, Ismael Al-Hinti, Thermal analysis of compact solar water heater under local climatic conditions, International Communications in Heat and Mass Transfer 36 (2009) 962–968.

[5] Soteris A. Kalogirou, Solar thermal collectors and applications, Progress in Energy and Combustion Science 30 (2004) 231–295.

[6] Ignas Sateikis, Stefa Lynikiene, Bronius Kavolelis, Analysis of feasibility on heating single family houses in rural areas by using sun and wind energy, Energy and Buildings 38 (2006) 695–700.

[7] Luis Juanico, A new design of roof-integrated water solar collector for domestic heating and cooling, Solar Energy 82 (2008) 481–492.