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# Heating outdoor swimming pools using flat panel solar collectors and evaluating the economic feasibility

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**Abstract**
Conversion from traditional heating systems is being developed to address greenhouse gases in the environment, global warming, growing expenses, and probable limitations of fossil fuels, as well as all accessible energy source alternatives. Solar water heating devices require little upkeep.In this research paper, the feasibility of designing a solar collector for heating an outdoor home swimming pool in the city of Kirkuk - Iraq was studied, and the effect of placing several types of covers to reduce and limit losses to reduce working hours with the solar collector in order to bring the complex to thermal comfort, with a feasibility study within a limited period. The year and a half is the initial cost recovery period.

**Keywords:** Solar energy, swimming pool, feasibility assessment, heating system

## Introduction

Today, the most promising technologies for heating water and air are thermal solar panels and heat pumps The development of equipment for more efficient energy use is driven by environmental factors such as global warming, growing costs, potential limitations of fossil fuels, and the need for more effective biofuel conversion [1]. Standard heating approaches, such electric heaters or diesel/gas boilers, are often used to raise and sustain the temperature for uses like swimming pool heating, which has comparatively significant initial and ongoing costs [2]. There by, developing a renewable heating system is crucial**.** Solar water heating (SWH) is a clean and cost-effective way to effectively harness solar energy in order to meet 50-80% of water needs. SWH technology is currently used in many major countries for everyday electrical bills and homes [3]. By using renewable energy, pool owners can enjoy comfortable water temperatures while reducing energy consumption and cutting costs. Solar collectors for swimming pools come in different types, including flat panel collectors (FSC), evacuated tube collectors (EVC), and unglazed collectors (UGSC). Each type has its own design and performance characteristics, allowing pool owners to choose the most suitable option based on their specific requirements and environmental conditions [4]. Many researchers have been interested in studying the best performance of pools in heating swimming pools. In 2015, researcher Mousia and Dimoud [5] conducted a study of the performance of the energy consumed in swimming pools operating in Greece, and studied and analyzed the characteristics of all swimming pools and emissions from each type of heater used. Most types are traditional boilers that operate with oil and gas to cover their heat needs, and it became clear that there is a wide scope. To implement the necessary measures to preserve and achieve financial and environmental benefits, the annual consumption of electrical and thermal energy and carbon emissions from each type of swimming pools has been calculated for all regions. In 2020 researcher Li *et al.* [6] conducted a theoretical study by conducting simulations in the TRNSYS program to study improving the performance of SAHP air source heat pumps in terms of economic performance by knowing the annual life cycle costs (ALCC) to achieve thermal comfort and performance of the technology by using tanks containing. Phase change materials (PCM). The results showed that energy savings can reach 72% and economic savings 81% when compared with traditional design, and that economic and technical study is important for swimming pool heating projects and the optimal design of components. Hang *et al.* (2012) [7] conducted a theoretical study on the environmental and economic impacts of means of heating water in various ways, the most important of which are solar collectors, flat panels, and solar collectors with vacuum tubes in the presence of additional energy sources such as electric energy, natural gas, and traditional heaters that operate with natural gas and electrical energy. The study was conducted in three cities in the United States of America (Los Angeles, Atlanta, and Chicago) and the results showed that solar collectors with flat panels in the presence of natural gas are the best performing of all types, with a payback period of less than half a year. In this study, the feasibility of replacing swimming. A solar swimming pool heating system was presented and analyzed. Thermal performance and energy cycle life cost of using solar energy for a home outdoor swimming pool in central Iraq, Kirkuk, was presented. A swimming pool with an area of 0.35 $m^3$ was taken into consideration and possible ways to reduce losses were studied.

## 2. System description

Flat solar collector without glass was created. The absorbing, insulating, and supporting layers make up the solar collector. The absorbing layer is constructed of metal that has been selectively coated to maximize absorption. Oval-shaped tubes with a 0.5 cm diameter are there to enhance the absorption surface, and it is located behind the pipes and insulation. The cover and the layer that insulation is made of polycarbonate material, pool was 50-100 cm and its depth was 70 cm. The glass cover was placed on the main surface of the pool, which was devoid of penetration and radiation. Through experiments, it is possible to know the simple isolation mode of furniture or placing a glass cover during the night and night uses, or group accommodation without a cover, mounting, and adjusting the temperature via sensors shown in Fig 1.


**Fig 1:** Solar collector with swimming pool and accessories

### 2.1 Heat loss from pool

Swimming pool heat transfer model is the fundamental requirement for researching the effectiveness of swimming pool heating system Evaluation of eight outdoor pools with solar heating energy balance given by [8, 9].

**Evaporative heat loss**

$$Qeva = Ap.\ h_{eva}\,(p_w - p_a).\,m_{occupancy} \quad (8)$$

$$heva = a + b.v \quad (9)$$

Where a, b are constant [9]

a = 0.0506 w / $m^{-2}pa^{-1}$

b = 0.0669 w $sm^{-3}pa^{-1}$

Occupancy = 4.27 × N / Ap + 1 (10)

The saturated vapor pressure is pw at the surface at pool water temperature; pa is the partial vapor pressure in air; v wind speed (m/s), $h_{eva}$ is the heat transfer coefficient (KJ/kg) of evaporation and N number of swimmer.

### 2.2 Heat loss due to radiation

Heat loss by radiation occurs between pool water to the top surface of the ambient atmosphere through long-wave radiation. ($Q_{rad}$):

$$Qrad = \cdot\, \varepsilon_w \cdot \sigma_s \cdot Ap\left((T_p + 273)^4 - (T_{sur} + 273)^4\right) \quad (11)$$

Where εw is the water's emissivity; σs is the Stefan-Boltzmann constant, which is 5.67×10-8 KW/($m^2$.K4); and Tsur is the ambient environment's r surface temperature. model. Tsur is the sky temperature (Tsky) in the OSWPs [10, 11].

$$T_{sky} = (T_a + 273)\cdot \varepsilon_s^{0.25} - 273 \quad (12)$$

### 2.3 Convective heat loss

The heat transfer generated by the movement of the pool water and ambient air causes convective heat loss ($Q_{conv}$).

$$Qconv = h_{conv.} * Ap * \ (T_p \ - \ Ta) \quad (15)$$

h (conv.) = (3.1+4.1V) (14)

Where $h_{conv}$ is convective heat transfer coefficient and *v* is wind speed m/s

### 2.4 Conductive heat loss
The temperature difference between the pond water and the soil caused conductive heat loss (Qcond). Contributes very little to the total loss in pool heat which he then watched [3].

$$Q\ cond = 0.05\,(Q\ eva + Qrad + Qconv) \quad (15)$$

### 2.5 Water heat loss due to refilling
The temperature difference between pool water and fresh water replenishment results in heat water loss ($Q_{mak}$). Since pool water is lost due to evaporation and drainage, new water is necessary to replenish the pool:-

$$Q_{mak} = m\ cpw \cdot (T_p - T_{mak}) \quad (16)$$

Where m fresh water flow rate (kg/s), $T_{mak}$ the temperature of the fresh Calculate the Solar Energy Absorbed:

To calculate the solar energy absorbed by the collector, use the following formula [12-16].

$$\text{Solar Energy Absorbed } (Q) = \eta \times A \times I \times t$$

- $\eta$ represents the collector efficiency (expressed as a decimal).
- $A$ is the collector area in square meters (m²).
- $I$ is the solar radiation in watts per square meter (W/m²).
- $t$ is the duration of exposure in hours (h).

### 3. Experimental setup
After heating the swimming pool throughout the first day, three test cases were used throughout the night to determine its effect in reducing losses and retaining heat. In the case, it was left uncovered, in the second case a glass cover was placed, and in the third case complete insulation was used and temperatures were recorded through the use of thermocouples.

**Table 1:** Features of measuring devices

| Parameter | Sensor | Accuracy |
|---|---|---|
| Wind speed | Cup anemometer | ±5% $m.s^{-1}$ |
| Ambient Relative humidity | Capacitive sensor | .±0.3% |
| Ambient air temperature | Pt-1000 | ±0.05 |
| Pool temperature | Pt-1000 | ±0.05 |
| Horizontal Solar irradiance | pyranometer | ± |
| Inlet & outlet collector temperature. | Pt-1000 | ±0.05 |
| Indoor heating unit | Pt-1000 | ±0.05 |
| Mass flow rate | Magnetic flowmeter | ±0.5% |

**Table 2:** Radiation distribution in Kirkuk -Iraq

| Months | Solar radiation $W.hr/m^2.day$ |
|---|---|
| October | 7120 |
| November | 6150 |
| December | 5430 |
| January | 5530 |
| February | 6530 |
| March | 7530 |

### 3.1 Economic analysis
The system's economic viability is evaluated using the simple payback period process, which is a measure of time it takes for the system to recoup its initial cost from the fuel savings that arise from operating this system. The following assumptions are assumed in these calculations:

System cost = 1MD.

Fuel used in conventional heating system was diesel.
Efficiency in summer season 100and in winter season 50%.
Diesel cost = 750I D/liter
Diesel heating value = 44 MJ/kg
Diesel density = 0.72 kg/Liter

The electricity consumption of the solar system pumps is considered negligible.
$Q_{saving} = m_{deisel} \times Qcv \times ή_{H.E}$ (10)
100000kJ = mdiesel ×44000 (kJ/kg) × 0.7
diesel= 3.24 kg per day

The amount of fuel that can be saved during the six months in which we need a heating device can be calculate through the following equation:

M (in months) = 3.24×6×30 =584.4kg

Total saving for pool=584.4kg×750ID/kg =438311 ID
= Total cost for solar system used = 800 .000 ID

Payback period= 800.000(ID) /438311 (ID/year) = 1.8 year

### 4. Results and discussion
The experiment took place out in the Iraqi city of Kirkuk (latitude 35.46 longitude 44.39). From December 2022 to February 2023. In order to study the effect of a cover in maintaining the temperature of the aquarium from the beginning of the night from 8 to 6, using three cases of covers, and from Figure 1, the first case becomes clear if a surface is left without any cover from any cover The difference from the beginning of the test to the end was within the range of 18˚C. However, when using the glass cover, the difference was within the range of (10) °C, as shown in Figure (3). However, when using complete insulation, the heat loss was within (5) °C degrees, as shown in Figure 4. It is clear in Figure 5 that the largest percentage of losses were due to evaporation, while when using the glass cover it was a result of convection, but when using complete insulation, the losses were minor due to conduction.

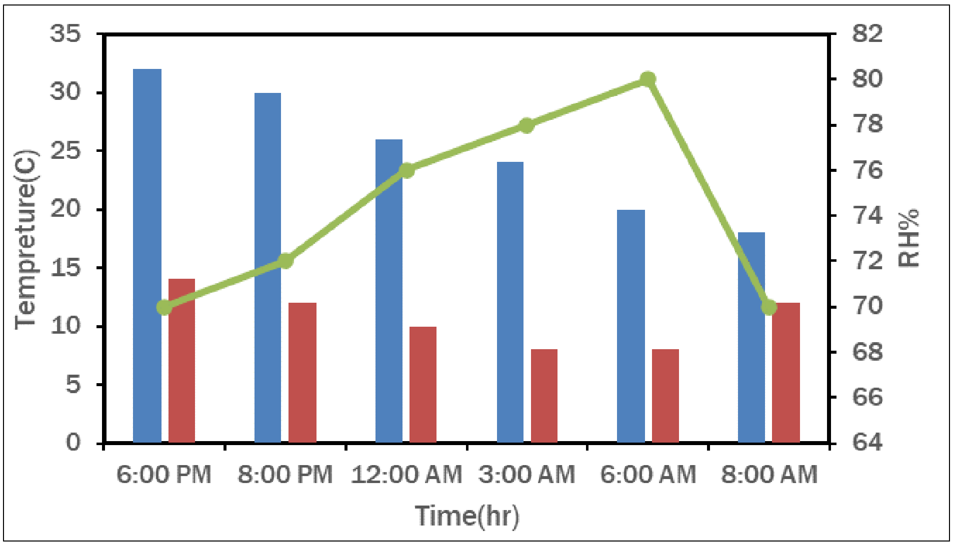


**Fig 2:** The temperature of the pool with humidity levels and air temperatures for the night periods after heating it with a flow rate of 0.03kg/s and no cover for the month of December.

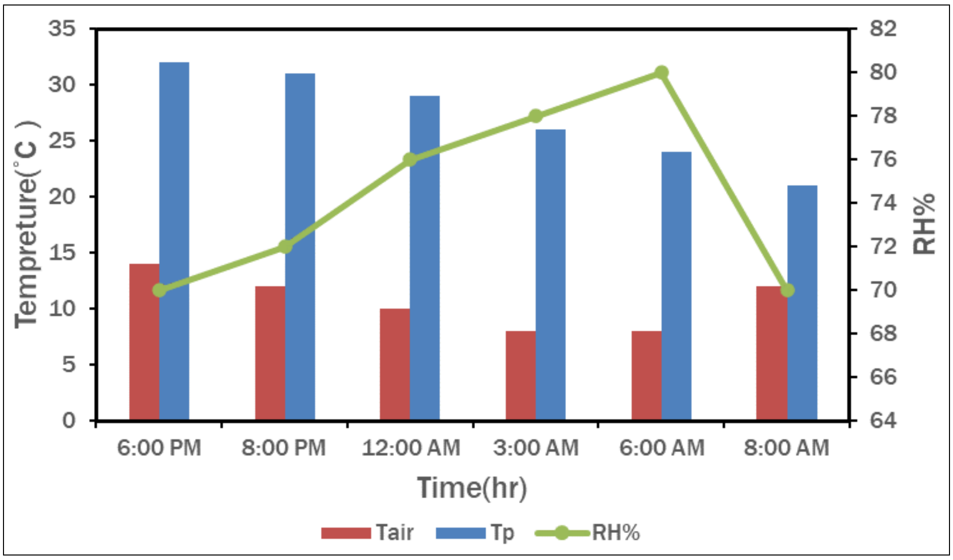


**Fig 3:** The temperature of the pool with humidity levels and air temperatures for the night periods after heating it with a flow rate of 0.03 kg/s and the presence of a glass cover for the month of December.

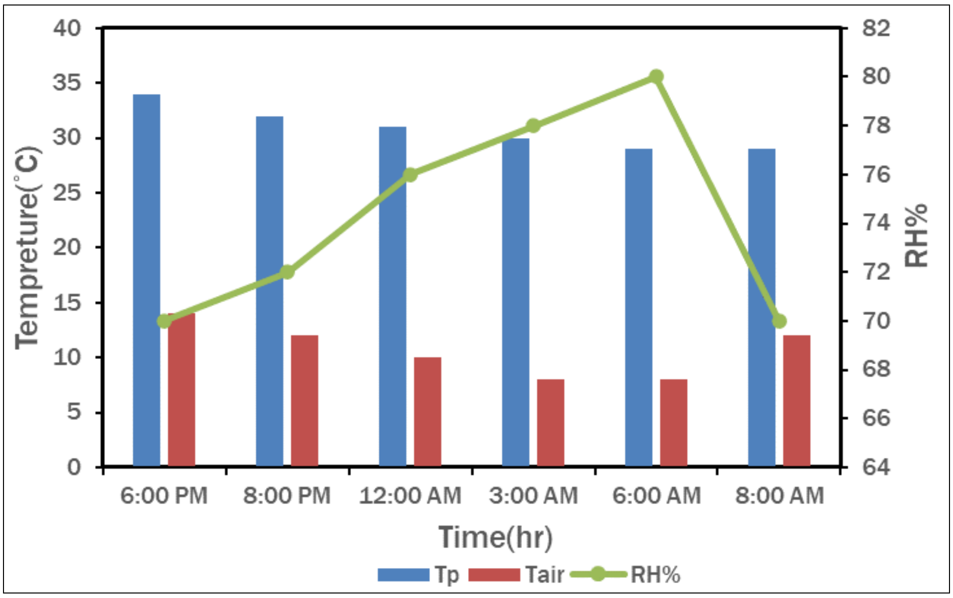


**Fig 4:** The temperature of the basin along with the humidity levels and air temperatures for the night periods after heating it with a flow rate of 0.03 m and the cover being completely insulated for the month of December.

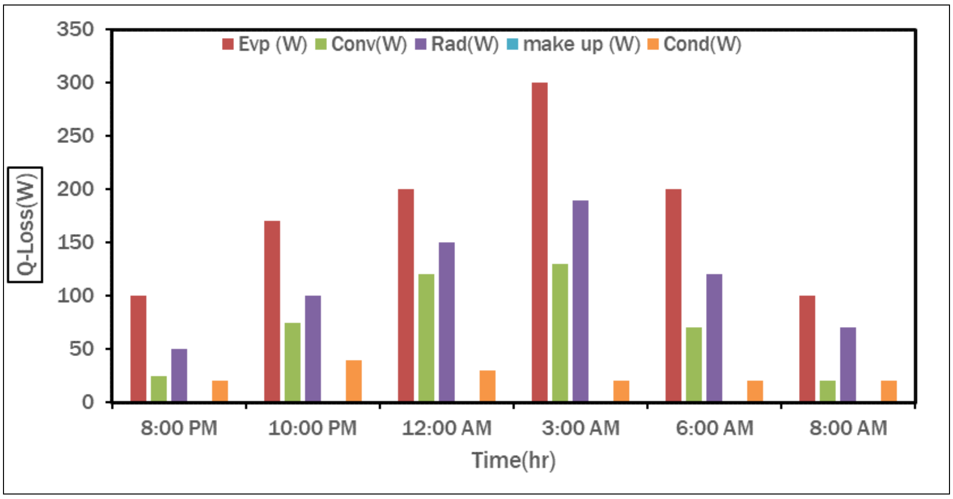


**Fig 5:** The rate of loss of the pool during the night hours with air temperatures of 8 C in the case without a cover 12/13/2022 Kirkuk/Iraq.

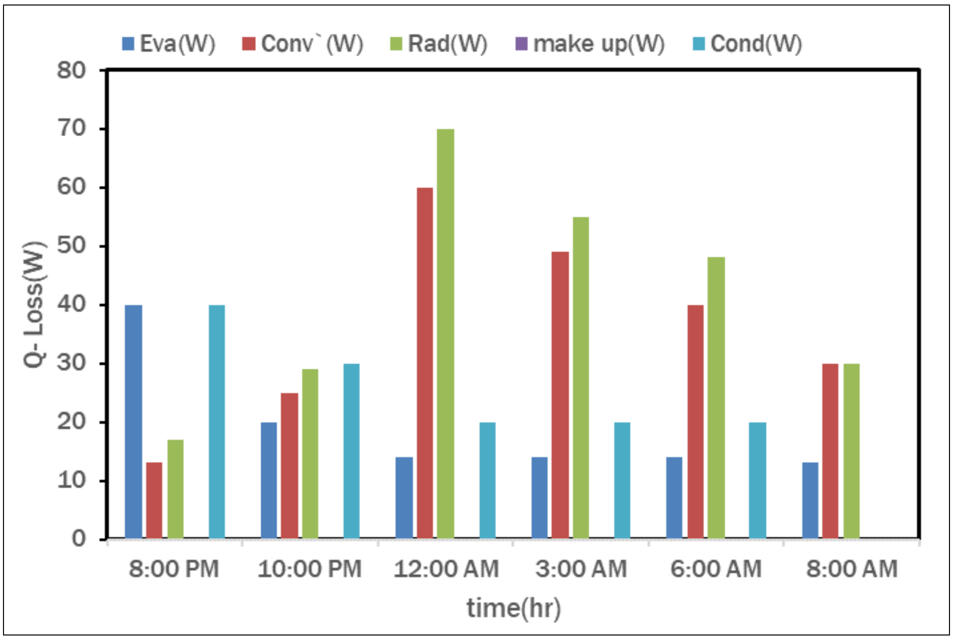


**Fig 6:** The rate of losses for the pool during the night hours with air temperatures 8 ˚C in the case with a glass cover at night 12/14/2022

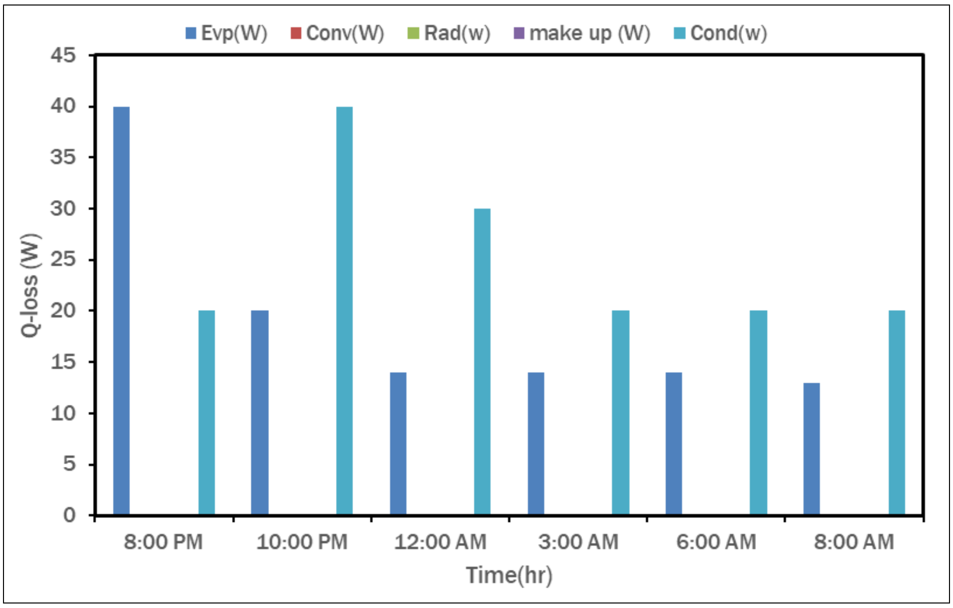


**Fig 7:** Loss rates for the swimming pool during the night hours with air temperatures of 8 C in the case of complete isolation during the night periods 12/15/2022

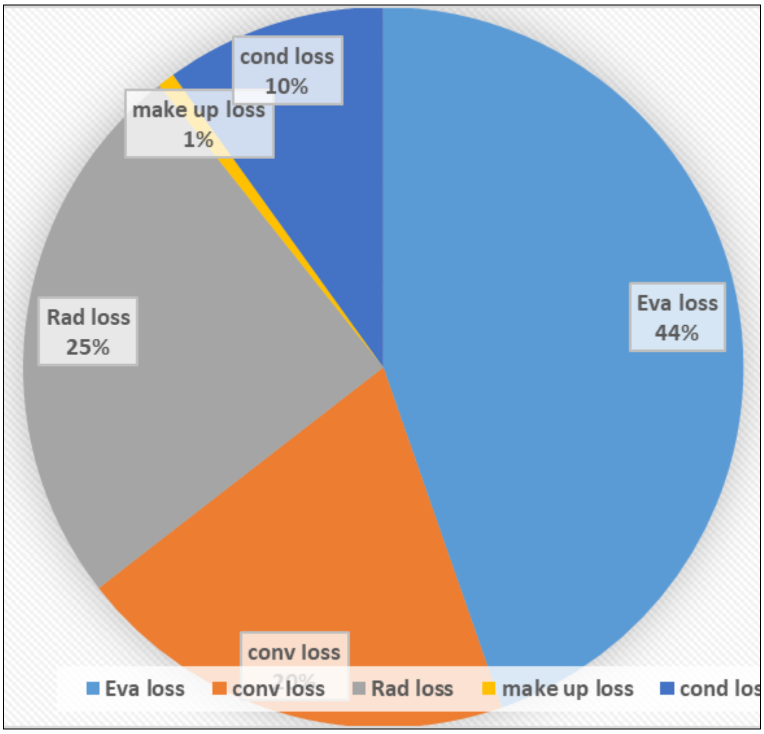


**Fig 8:** Percentage of losses

## 5. Conclusion

This research studied the feasibility of installing a solar system or heating outdoor swimming pool flat solar collectors were chosen. Dimensions of 260 cm/160 cm were used. Installing a solar power system reduced energy by about 100%. It was also found that 44% of the energy is present Lost due to evaporation. Three cases of covers were used, and in the case of complete cover, there was a lower drop in heat equivalents, and thus optimum operating periods for the solar collector to reach thermal comfort the next day. The payback period of the solar system is about a year and a half.

## References


1. Kuyumcu ME, Yumrutaş R. Thermal analysis and modeling of a swimming pool heating system by utilizing waste energy rejected from a chiller unit of an ice rink. Thermal Science. 2017;21(6A):2661-72. DOI: 10.2298/tsci151225148k.
2. Projektovanja I, Privredu ZA, Al-falahat AM, Jordan A. Economic feasibility of heating source conversion of the swimming pools. 2022;20:276–284. DOI: 10.5937/jaes0-34474.
3. Sadhishkumar S, Balusamy T. Performance improvement in solar water heating systems: A review. Renew. Sustain. Energy Rev. 2014;37:191-198. DOI: 10.1016/j.rser.2014.04.072.
4. Jesko Ž. Classification of solar collectors, 2008, 22-27.
5. Mousia, Dimoudi A. Energy performance of open air swimming pools in Greece, Energy Build. 2015;90:166-172. DOI: 10.1016/j.enbuild.2015.01.004.
6. Li Y, Nord N, Wu H, Yu Z, Huang G. A study on the integration of air-source heat pumps, solar collectors, and PCM tanks for outdoor swimming pools for winter application in subtropical climates, J Build. Perform. Simul. 2020;13(6):662–683. DOI: 10.1080/19401493.2020.1813198.
7. Agricultural H. Feasibility Study Of Using Solar Thermal Energy For (Hungary As A Case Study). 2022;7410(41):72-78. DOI: 10.17676/HAE.2022.41.72.
8. Bayraktar N, Abed M, Hayder H, Ali M. Design, Simulation, Construction of Swimming Pools: A Comprehensive Review, Simulation. 2022;20:8922-8946. DOI: 10.14704/nq.2022.20.8.NQ44914.
9. Poudyal A, Bhattarai RN. Design and Analysis of a Solar Swimming Pool Heating System Statement of Problem Design Formulation, 2014, 131-139.
10. Ruiz E, Martı PJ. Analysis of an open-air swimming pool solar heating system by using an experimentally validated TRNSYS model. 2010;84(1):116–123. DOI: 10.1016/j.solener.2009.10.015.
11. Woolley J, Harrington C, Modera M. Swimming pools as heat sinks for air conditioners : Model design and experimental validation for natural thermal behavior of the pool, Build. Environ. 2011;46(1):187-195. DOI: 10.1016/j.buildenv.2010.07.014.
12. Abed FM, Al-shahery GMY. Performance. 2013;3:48-53.
13. Zarda F, Hussein AM, Danook SH, Mohamad B. Enhancement of thermal efficiency of nanofluid flows in a flat solar collector using CFD, Diagnostyka. 2022;23(4):1-9. https://doi.org/10.29354/diag/156384.
14. Berkache A, Amroune S, Golbaf A, Mohamad B. Experimental and numerical investigations of a turbulent boundary layer under variable temperature gradients, Journal of the Serbian Society for Computational Mechanics. 2022;16(1):1-15. 10.24874/jsscm.2022.16.01.01.
15. Qader FF, Hussein AM, Danook SH, Mohamad B, Khaleel O. Enhancement of Double-Pipe Heat Exchanger Effectiveness by Using Porous Media and TiO2 Water, CFD Letters. 2023;15(4):31-42. https://doi.org/10.37934/cfdl.15.4.3142
16. Qader FF, Mohamad B, Hussein AM, Danook SH. Numerical study of heat transfer in circular pipe filled with porous medium. Pollack Periodica; c2023 https://doi.org/10.1556/606.2023.00869