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Mini Solar Water Heater

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Abstract

This study presents the design and development of a cost-effective mini solar water heater intended to reduce electricity consumption while maintaining water temperature in a storage tank. The project addresses the high market price of conventional solar water heaters by creating an affordable solution for rural or remote areas with limited access to electricity. A flat-plate collector system was selected for its simplicity and efficiency, using recycled materials to minimize cost. Prototype testing demonstrated that the system could heat water up to 42 °C during peak sunlight hours and maintain a gradual temperature decrease over time. Although the target temperature of 50 °C was not achieved, the results confirm the feasibility of the design for low-cost water heating applications. The proposed system offers an environmentally friendly, user-friendly, and low-maintenance alternative for domestic water heating, with potential improvements including enhanced insulation, increased copper circulation, and integration of auxiliary heating to improve performance.

1. Introduction

Solar energy is one of the renewable energy sources like wind, geothermal and hydro. Renewable energy utilizes naturally regenerated energy sources [1]. Solar energyenergy, which is radiation emitted by the from the sun can produce heat, cause chemical reactions and generate electricity [2]. Solar thermal systems and photovoltaic systems are both referred to as "solar power" [3]. In this case, solar energy will be used to heat water. Solar energy, being a type of renewable energy, is expected to become increasingly important as a green energy source. It has potential, and its radiation can be converted into either thermal energy (heat) or electrical energy [2]. Currently, the world still relies on fossil fuels for heating and powering automobiles and homes. This reliance contributes to rising sea levels and may lead to more frequent floods and heat waves, according to scientists [1].

Traditional water heaters were powered by local gas from nearby gasworks or by solid fuels. For centuries, solid fuels like coal and wood were used to heat water [4]. Among modern systems, the solar water heater is a newer development. Applications for solar water heaters include supplemental water heating, industrial uses such as boiler-feed water generation as an economizer and competitive solar electricity production [5]. Solar water heaters can be used in homes, businesses, communities and hotels for heating water for cooking, baking, drying and cleaning kitchenware .

The developed product, named the Mini Solar Water Heater, is designed to heat water using solar energy only, without relying on electricity, while maintaining the water temperature in the storage tank. This project applies the concept of a flat-plate solar water heater, where copper pipes are directly heated by solar radiation. A reflective metal plate placed behind the copper pipes enhances heat absorption, and the insulated water tank helps retain the stored water's temperature.

1.1 Literature Review

Solar water heaters use energy from the sun to heat water [6]. They are designed to save electricity and reduce the greenhouse effect. The two most popular markets for solar water heating are swimming pools and service hot water [7]. The performance of a solar water heating system is affected by factors such as the environment, collector tilt, and orientation. Ongoing research has led to many new and improved technologies for solar water heaters [8].

Often called tankless or on-demand water heaters, instantaneous water heaters heat water using electricity, propane or natural gas [9]. These heaters do not require a storage tank, eliminating tank energy losses and theoretically providing an endless supply of hot water. Most homes in Malaysia have "instantaneous" or "tankless" electric water heaters [10]. These systems detect water flow over the heat exchanger with a sensor, which activates the heating element, instead of storing heated water in a tank. While these water heaters have advantages, they also have drawbacks. For example, they consume a significant amount of electrical power. Most electric water heaters in Malaysia have power outputs of 3kW 3 kW or more, leading to a minimum monthly energy consumption of 90kWh 90 kWh with an hour of daily use [10]. Heating water quickly requires more electricity, resulting in higher operating costs. Figure 1(a) shows an example of an electric water heater system, which includes components such as a safety thermal cut-off, a display, a heater, an electronic control module, a temperature sensor, a flow sensor, and a wiring block. Each component has a specific function to ensure the electric water heater operates correctly.

In solar water heaters, heat transfer fluid or water is heated by the sun in the collector [3]. The heated water is then stored in a tank until needed, with a traditional system providing additional heating necessary. There are two main types of solar water heaters: active and passive [11]. Active systems are more common and use electric pumps and controllers to circulate water through the collectors [3]. They are divided into direct circulation systems and indirect circulation systems. In passive systems, the water tank is above the solar collector, and heat is transferred through natural circulation [12]. Passive systems are typically more reliable, easier to maintain, and may last longer than active systems due to the absence of electrical components [3]. However, they have disadvantages, such as high heat losses on cold days and the risk of water freezing at night, which can damage the panels. Examples of passive systems include integral collector storage systems and thermosyphon systems.

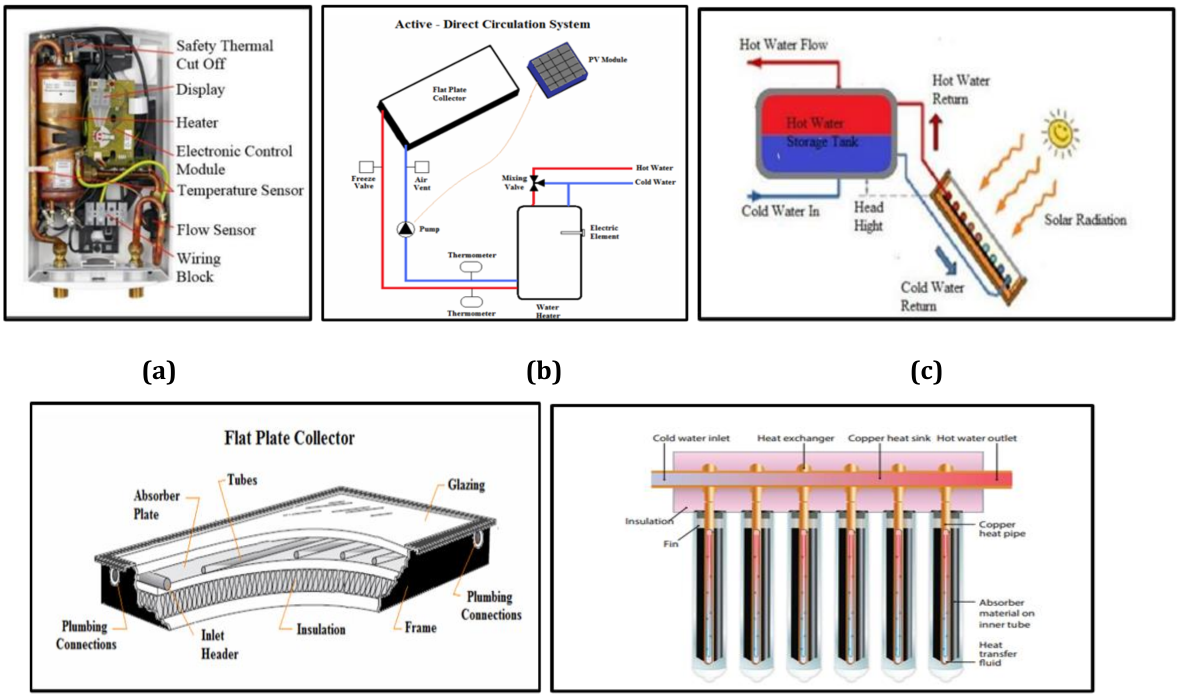
Pumps in direct circulation systems move pressurized potable water through the collectors. Due to its sensitivity to weather, this technology is less suitable for areas with consistently low temperatures [12]. The system uses a single tank and a solar cell to power the pump. Figure 1(b) below shows a direct circulation system diagram.

Thermosyphon systems are a cost-effective and reliable option, especially for new homes. These systems cycle water through the collectors and into the tank as warm water naturally rises [3]. As water in the solar collector heats up, it becomes lighter and rises into the tank above. Cooler water sinks to the bottom of the hot water and moves by convection to the lowest point of the collector. The hottest water rises to the top of the tank [13]. Gravity then draws the colder, heavier water from the tank into the collector inlet [14]. Figure 1(c) below shows a diagram of how the thermosyphon system heats water from the tank.

A solar energy collector uses incident solar radiation to heat a working fluid, such as water or a glycol-water mixture [14]. Solar collectors are the main component of solar heating systems. They capture electromagnetic energy from the sun and convert it into thermal energy [13]. The two most popular types of collectors in solar water heaters are flat plate collectors and evacuated tube collectors.

The most popular type of solar collector for residential solar space heating and water heating systems is the flat plate collector [3]. A typical flat plate collector consists of an insulated metal box with a plastic or glass cover and a dark-coloured absorber plate. Flat plate collectors can heat water to temperatures up to 100°C [13]. In these systems, fluid is pumped through the collectors to absorb heat from the absorber plate and transfer it to an insulated water tank, where it can be used directly or indirectly on a heat exchanger or other device [3]. Flat plate solar collectors are an affordable option for low-temperature thermal energy applications such as room heating and industrial process heating [14]. A specific type of flat plate collector is the air flat plate collector, which can use metal sheets, screen layers, or non-metallic materials as absorber plates. The average lifespan of a flat plate collector is over 25 years [3]. Figure 1(d) below shows the structure and main components of a flat plate collector.

Evacuated tube collectors with heat pipes are typically configured in parallel rows of glass tubes [15]. The inner tube has an absorptive coating, while the outer tube provides protection. Sunlight passes through the outer glass tube and heats the absorber tube inside [3]. The cylindrical design of these collectors optimizes performance and efficiency by maintaining a normal angle to sunlight more frequently, ensuring consistent energy production throughout the day and year [12]. As vapor rises to the tube into the tank, it condenses and absorbs heat from the colder water in the tank. The condensed liquid then travels back down the pipe to be vaporized again, repeating the cycle [13]. Evacuated tube collectors perform better than flat plate collectors in cold areas since they rely on light rather than the outside temperature. However, they are more expensive and delicate compared to flat plate collectors [3]. Figure 1(e) below shows the interior of an evacuated tube collector and the main components that ensure the water heater functions effectively.



(a) (b) (c)

(d) (e)

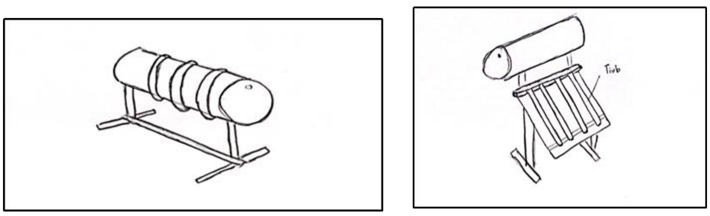
Fig. 1 *Figure description (a) Example of Electric Water Heater System(b)Direct Circulation System Diagram(c)Thermosyphon System Diagram (d) Flat Plate Collector Diagram(e)Evacuated Tube Collector Diagram*

2. Methodology

The most important factor in this project is material selection. Some of the materials have been selected due to the efficiency and low cost.

2.1 Methods

The project aims to produce a reliable, visually appealing product using durable, easily available materials while keeping construction costs reasonable. Ensuring safety and having market potential are critical aspects. Fig. 2 below shows all the sketches of the concept designs. The first concept features a solar collector wrapped around a non-insulated water tank, which could lead to heat loss and high construction costs. The second concept is a smaller version of an evacuated-tube collector, which is efficient but prone to overheating, salt accumulation, and maintenance issues like tube failure and gasket leakage. The final design, a mini flat-plate solar water heater, is cost-effective, user-friendly, and easy to install. It operates by passing cold water through a copper rod in a solar tray, where it is heated by sunlight before returning to a water tank. This design prioritizes affordability and simplicity, making it accessible to a wide range of users while ensuring efficient operation.



(a) (b)

Fig. 2 *Sketches of concept designs (a) First concept(b) Second concept*

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2.2 Prototype Specifications

A detailed illustration of the prototype by using SolidWorks is shown in Fig. 3. This stage is important before starting the next process with the fabrication process.

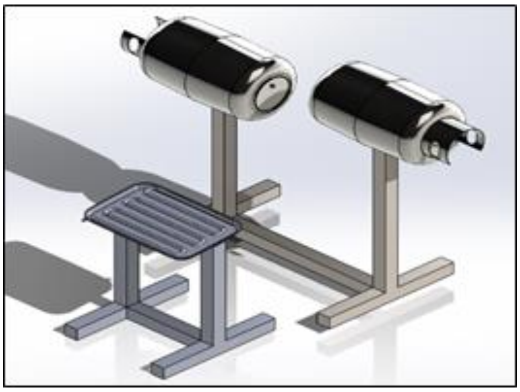

Fig. 3 *A prototype design were developed by using Solidworks Software*

2.3 Components and Functions

Each component of the project serves a certain function. Materials appropriate for the intended purpose are needed in order toto accomplish the desired result.

Table 1 *Components and functions*

Components	Function
Solar tray	To hold the copper rod and help the water-heating process
Stand	To hold the water tank and the solar tray copper rod
Tube	To connect water from the water tank to the rod water tank
Copper rod	As a medium-to-heat water that through it
Water tank	To store all the heated and cold water

Table 1 presents the main components of the mini solar water heater and their respective functions. Each part plays a specific role in the heating process: the solar tray supports the copper rod and assists in absorbing solar heat, the stand provides structural support for both the tray and the water tank, and the tube channels water from the tank through the copper rod for heating. The copper rod serves as the primary heat-transfer medium, while the water tank stores both heated and unheated water to ensure a continuous supply.

3. Results and Discussion

This part includes a detailed explanation of the project's implementation results. Everything of these outcomes has been through several tests. Furthermore, this part also includes some observations concerning the problems encountered with this project. The project's advantages and disadvantages are described based on the findings of the project review test, and an overview for resolution is also provided.

3.1 Temperature Measurement

The test was performed to evaluate the ability of the copper heating medium to absorb and transfer solar heat. Water temperatures were measured after 10 minutes of copper exposure to direct sunlight. Table 2 shows the recorded temperatures at three different time periods of the day.

Table 2 *Result of temperature testing*

Time of day	Initial temperature (°C)	Final temperature (°C)
Morning (09:00–11:00)	31.6	35.7
Afternoon (12:00–15:00)	33.4	42.0
Evening (16:00–18:00)	32.1	37.5

Based on table 2 above, the highest temperature (42 °C) occurred during the afternoon when solar radiation was at its peak. Morning and evening temperatures were lower due to reduced solar intensity. These results indicate that the copper rod can effectively transfer solar heat to the water, but the maximum temperature achieved was below the target of 50 °C.

3.2 Tank Heat Retention Test

The second test measured how long the water tank maintained its temperature at room conditions after heating. Table 3 shows the temperature drop over 30 minutes.

Table 3 *Result of water tank maintained*

Time (min)	Temperature (°C)
0	37.5
5	36.8
10	35.7
15	34.9
20	33.2
25	32.0
30	32.1

The water temperature as shown in Table 3 decreased from 37.5 °C to 32.1 °C within 30 minutes, with the largest drop occurring in the first 20 minutes. The slight increase at 30 minutes may be due to ambient temperature fluctuations or measurement error. The results indicate that the current insulation of the tank is insufficient to retain heat for extended periods.

The mini solar water heater successfully heated water using solar energy, achieving a maximum temperature of 42 °C. However, the target temperature of 50 °C was not achieved. Factors limiting performance include insufficient solar intensity during testing, limited surface area of the copper rod, and heat loss from the uninsulated tank. To improve efficiency, the use of better insulation materials, an electric booster heater, or an auxiliary water pump is recommended to enhance heat transfer and reduce losses.

4. Conclusion and Recommendations

In conclusion, the mini solar water heater successfully achieved most of the objectives set for this project. The system was designed to be economical, affordable, and easy to use, with a total cost of only RM122.00, partly due to the use of recycled components such as the water tank. The prototype was able to supply approximately 12 litres of warm water per cycle, demonstrating its potential for practical use in rural or low-electricity areas.

However, the project did not achieve the target water temperature of 50 °C. Several factors contributed to this limitation, including insufficient heat absorption by the copper tubing and limited water circulation, which reduced overall thermal efficiency. The findings from the heat retention tests also revealed that the current tank insulation is inadequate for maintaining high water temperatures over extended periods.

To improve the system's performance and user-friendliness, several recommendations are proposed. First, integrating a small auxiliary electric heater inside or around the copper tubing could boost heating efficiency during low-sunlight conditions. Second, wrapping the water tank with better insulating materials, such as fiberglass or high-density foam, would help reduce heat loss. Third, redesigning the stand to allow easy removal of the water tank would simplify installation and maintenance. Finally, increasing water circulation—either by enlarging the copper piping or incorporating a small, solar-powered pump—would enhance heat transfer and result in higher output temperatures.

These improvements would enable the mini solar water heater to achieve higher temperatures, improve thermal retention, and remain cost-effective for households in rural or off-grid areas.

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Conflict of Interest

This publication has no conflicts or issues regarding the data, as it relies on references from the internet and research.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design****: Muhamad Addin Muqaffa Azman, Sharil Haziq Shahnizan, Nurmina Abdullah;* ***data collection****: Muhamad Addin Muqaffa Azman, Sharil Haziq Shahnizan;* ***analysis and interpretation of results****: Muhamad Addin Muqaffa Azman, Sharil Haziq Shahnizan, Nurmina Abdullah;* ***draft manuscript preparation****: Nurmina Abdullah. All authors reviewed the results and approved the final version of the manuscript*

References

[1] L. Tripathi, A. K. Mishra, A. K. Dubey, C. B. Tripathi, P. Baredar, "*Renewable energy: An overview on its contribution in current energy scenario of India,"* Renewable and Sustainable Energy Reviews, vol. 60, pp. 226-233, 2016.
[2] N. Kannan, D. Vakeesan, "*Solar energy for future world:-A review*," Renewable and sustainable energy reviews, vol. 62, pp. 1092-1105, 2016.
[3] M. R. Islam, K. K. S. U. Sumathy, S. U. Khan, "*Solar Water Heating Systems and Their Market Trends,"* Renewable and Sustainable Energy Reviews, vol. 17, pp. 1-25, 2013.
[4] G. O'Hara, "*Hot and Cold Water in the Home,"* In The Politics of Water in Post-War Britain, pp. 183-214, 2017.
[5] N. I. Shamsul Azha, H. Hussin, M. S. Nasif, T. Hussain, *"Thermal performance enhancement in flat plate solar collector solar water heater: a review,"* Processes, vol. 8, no. 7, pp. 756, 2020.
[6] P. T. Tsilingiris, *"Solar water-heating design—a new simplified dynamic approach,"* Solar Energy, vol. 57, no. 1, pp. 19-28, 1996.
[7] A., Gastli, Y. Charabi, *"Solar water heating initiative in Oman energy saving and carbon credits,"* Renewable and Sustainable Energy Reviews, vol. 15, no. 4, pp. 1851-1856, 2011.
[8] T. S. Vinubhai, R. J. Vishal, K. Thakkar, *"A review: solar water heating systems,"* In The National Conference on Emerging Vista of Technology in the 21st Century, Limda, Vadodara, pp. 1-8, 2014.
[9] D. P. Jenkins, S. Semple, S. Patidar, P. McCallum, "*Changing the approach to energy compliance in residential buildings–re-imagining EPCs,"* Energy and Buildings, vol. 249, pp. 111239, 2021.
[10] A. T. Din, K. A. Azlan, *"Development of Low-Cost Solar Water Heater Using Recycled Solid Waste for Domestic Hot Water Supply,"* In MATEC Web of Conferences, vol. 150, pp. 04010, 2018.
[11] M. R. Islam, K. K. S. U. Sumathy, S. U. Khan, *"Solar water heating systems and their market trends," Renewable and Sustainable Energy Reviews,* vol. 17, pp. 1-25, 2013.
[12] K. C. Chang, W. M. Lin, K. M. Chung, "*Solar water heaters as a pre-heating system for industrial processes,*" Energy Efficiency, vol. 11, no. 3, pp. 755-760, 2018.
[13] N. H. Afgan, D. Al Gobaisi, M. G. Carvalho, M. Cumo, "*Sustainable energy development*," Renewable and sustainable energy reviews, vol. 2, no. 3, pp. 235-286, 1998.
[14] S. Karki and K. R. Haapala, "*Technical and economic feasibility of solar flat-plate collector thermal energy systems for small and medium manufacturers*," Applied Energy, vol. 254, 2019.
[15] M. Olek, P. Olczak, D. Kryzia, "*The sizes of Flat Plate and Evacuated Tube Collectors with Heat Pipe area as a function of the share of solar system in the heat demand*," In E3S Web of Conferences, vol. 10, pp. 00139, 2016.