e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

DESIGN AND FABRICATION OF PASSIVE SOLAR WATER HEATING SYSTEM

Thinley Tobgay[*1], Chimi Dem[*2], Dheynay Zangmo[*3]

[*1,2,3]Jigme Namgyel Engineering College, Department Of Electrical Engineering,
Samdrup Jongkhar, Bhutan.

ABSTRACT

Nowadays solar water heating systems are gaining popularity in sustainable development. This system has become one of the most suitable ways to reduce electricity consumption in the home. It is seen that various types of solar water heating systems are produced and marketed for the consumers with which they can leverage the energy of the sun to heat the water for comfortable living. Although there are many types of solar water heating systems on the market, most can hardly afford this system. The gap always remains for people who can afford and who are in a bad financial situation to afford this system. The question of affordability arises when the solar water heating system uses an active scheme of heating the water, wherein many complicated components are used thereby increasing the cost. To address this issue, this paper presents that the passive solar heating system is suitable for small-scale residential use. It further presents the process of designing and fabrication of a passive solar water heating system using locally available materials. The design work begins with the careful selection of the design requirement of the passive solar water heating system, sizing of the active solar heating system component, selection of the materials available in the locality, fabrication, and testing of the system. With the fabricated solar water heating system in this project, the heating system was able to heat the water up to 800 C.

Keywords: Thermosyphon, Passive Solar Water Heating, Locally Available Materials, Fabrication.

I. INTRODUCTION

Specifically, in colder regions, hot water is considered one of the most important requirements for daily life. Study shows that approximately 40-60 liters of water is being consumed by an average adult daily in a household. Heating water was carried out in different ways starting from using fire to the use of modern electrical means. Although many employs fire to heat water in underdeveloped nations, the use of electric heaters has become rampant as it is easier to install, use, and affordable. However, if the appliance uses electricity generated using non-renewable sources, the operating cost and the environmental impact of these electric solar water heating system is tremendous. This pushes consumers to look for alternative ways to heat water. Solar water heating techniques have all the attributes that electric heaters lack. Solar water heaters are green and help the environment. Since solar energy is free, the operating cost of these systems is a very minimal and safe electricity bill.

Solar water heaters (SWH) are a system that uses solar radiation to heat water which can be used for domestic and industrial purposes. It is not a new technology since its usage date back to 200 BC when Romans used this concept to heat their public baths, wherein the water storage tanks were painted black to absorb solar energy. The commercial development of these solar water heating systems came into reality in 1891 and was introduced by Clarence Kemp [1]. Since then, the solar water system got its popularity, and just in the year 2012, 78 million units of SWH were installed for various utility purposes all over the world [2].

Generally, these solar water heating systems are made of five basic components such as solar collector, storage tank, pump, differential controller, and pipes and valves. The solar water heating system can be divided into two types depending on how the fluid in the system circulates. The fluid in the system can be forced and it can be natural. If the system uses pumps to force the fluid circulation in the system, such a system is called an active solar water heating system. If the circulation of liquid happens naturally, such a system is called a passive solar water heating system.

This paper presents the designing process and the fabrication of a passive solar water heating system for domestic use.

II. OVERVIEW OF THE PASSIVE SOLAR WATER HEATING SYSTEM

This class of solar water heating systems is most used for domestic heating. For this system, the pump is not required to push the water or working liquid in the system rather, the circulation of the liquid happens due to the principle of thermosyphon. This principle is based on the density of water. When water gets warmer, the weight of the water molecule becomes lighter and starts to rise while when water becomes cooler, its weight increases and the water molecule starts to settle down in the bottom of the tank. In the nutshell, natural convection occurs in the system to circulate the liquid in the system.

Unlike an active solar water heater, a passive system has a relatively smaller number of components. A typical passive solar water heating system has three basic components, viz, solar collector, storage tank, and pipes and valves. For this kind of system, the tank must always be kept above the collector. This is to ensure that when water in the collector warms up due to solar radiation, the lighter water particle enters the storage tank and pushes down the heavier and cooler particles of the water.

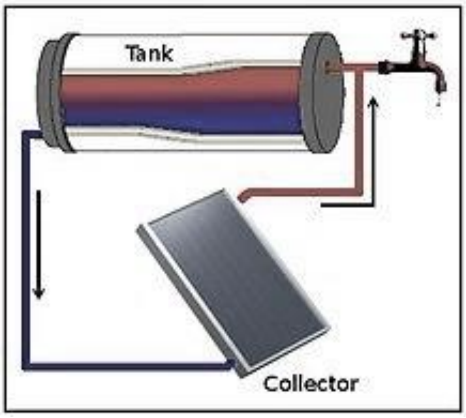

Figure 1: Passive solar water heating system

III. DESIGNING AND FABRICATION

For design consideration, it is important to select a suitable place for the installation of the fabricated solar water heating system. Based on the altitude of the selected location, engineers can select the features for the solar water heating system. In this work, Thimphu was selected for the installation of the fabricated system. The weather data for Thimphu, Bhutan is retrieved from the map in figure 2.

Looking at the map, Thimphu receives sufficient solar irradiance which is favourable for implementing solar water heating system.

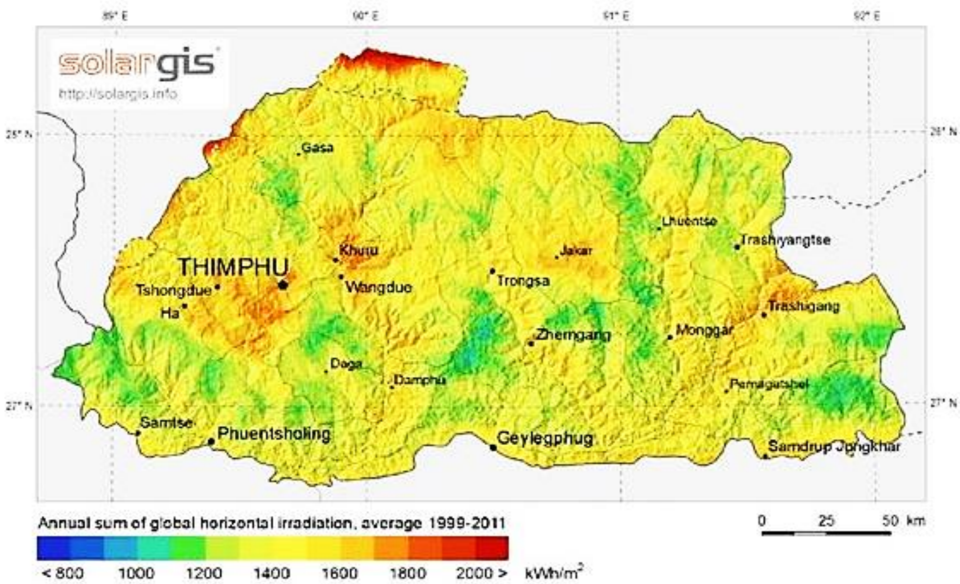

Figure 2: Solar irradiance map of Bhutan

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

Sizing of the storage tank

The storage tank stores both cold and hot water. Normally the cold water settles at the bottom due to its weight and warm water floats. The combination of an auxiliary heating source and solar energy maintains the desired temperature in the storage tank. The determination of the adequate storage tank capacity volume requires the estimation of the monthly and annual value according to volume changes. The required volume of hot water to be produced can be obtained from equation 1.

$$V_{st} = 1.2(B \cdot O \cdot D_{HW} + D_k) \quad \text{Equation 1}$$

Where, B is the number of consumers, O is the percentage occupation, D_{HW} is hot water demand per person and D_K is the hot water demand. Table 1 shows the data for storage size calculation.

Table 1: Variables determining storage tank

Sl No.	Variable	Symbol	Value
1	Number of consumers	B	3
2	Percentage Occupation	O	80%
3	Hot water demand per person	D_{HW}	10
4	Total hot water demand	D_K	20

Using equation 1 with variables determining the size of the storage tank from Table 1, the size of the storage tank is calculated to be 30 L. The tank having capacity of 30 L is required to be fabricated.

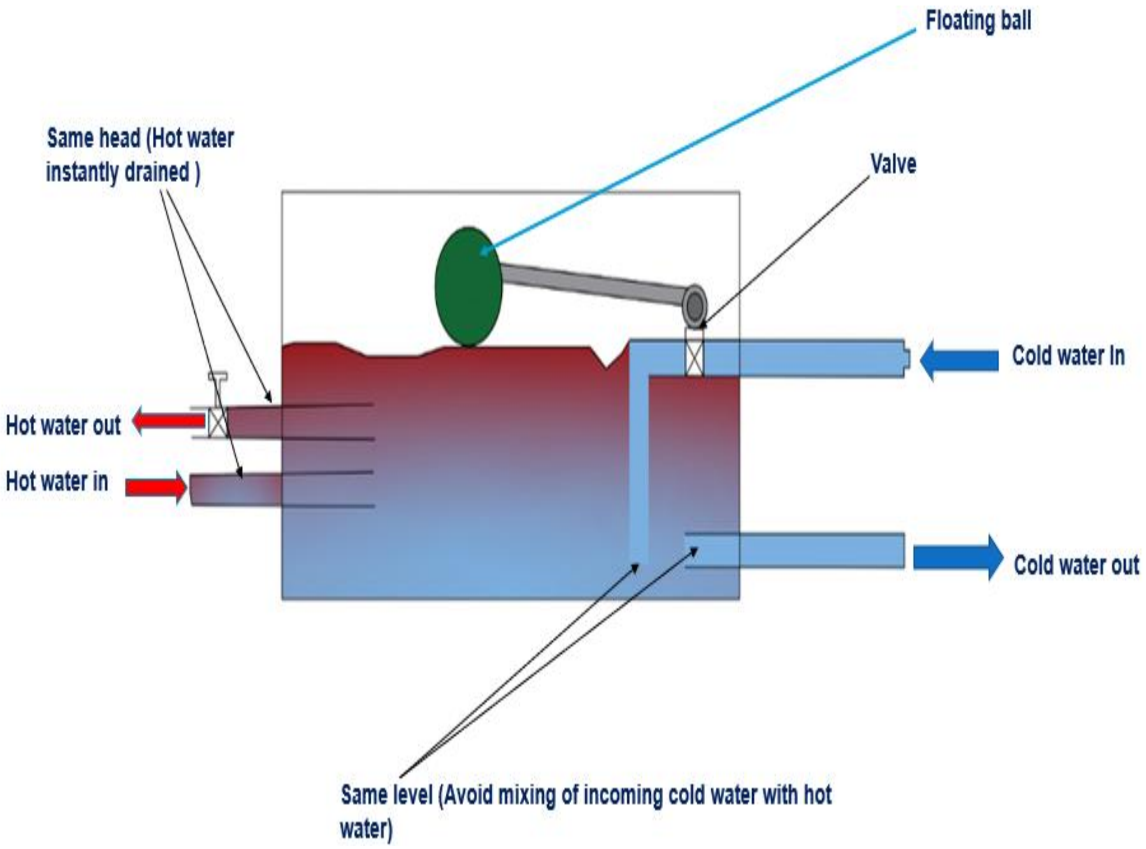

Figure 3: Schematic of the designed storage tank

Fabrication of the storage tank

The tank as per the design was fabricated. A polystyrene box was chosen for housing the storage plastic bucket with a 30 L capacity. Sawdust was used as an insulating material to trap the heat from leaving the storage system.

Firstly, the plumbing work was done on the bucket. Then the bucket was placed inside the polystyrene box which is sealed off later. The fabrication process of the storage tank is shown in figure 4.

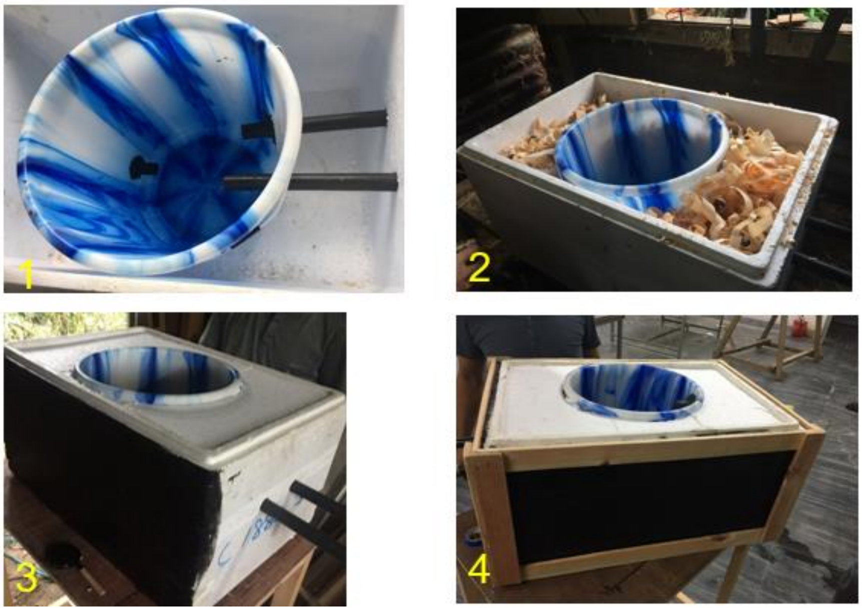

Figure 4: Fabrication process of the storage tank

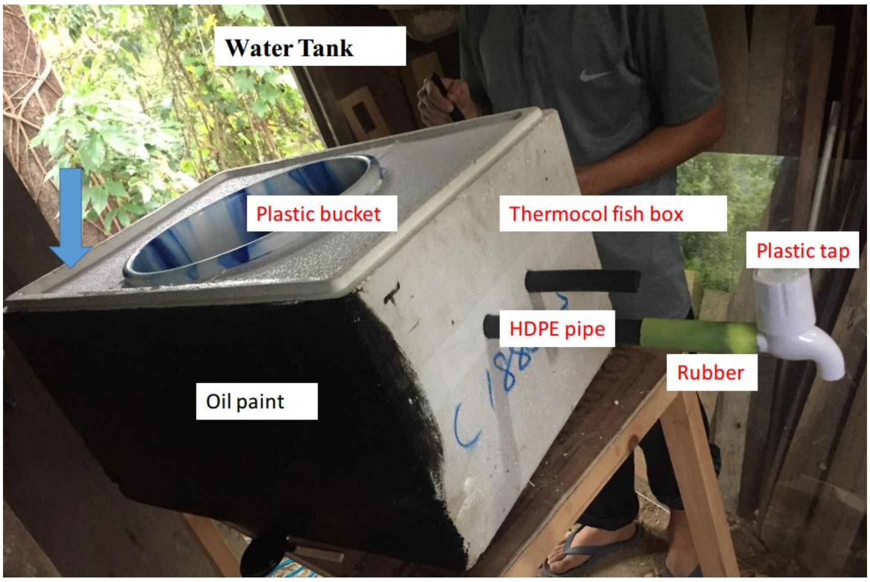

Figure 5: Fabricated water storage system

Sizing of Solar Collector

The solar collector will absorb all the solar irradiance falling on it and transfer it to the water inside the capillary tube through heat conduction. The collector proposed is of flat plate type where the capillary tubes are laid on the plates.

The energy demand for heating the given volume of water i.e 30 L is obtained by using equations 2 and 3.

$$Q_{HW} = \frac{m \cdot \Delta T \cdot C_p}{3600} \quad \text{Equation 2}$$

$$Q_d = 365 \cdot [(1 + k) \cdot Q_{HW} + Q_{HL}] \quad \text{Equation 3}$$

Where k is the assumed loss factor in percentage, m is the mass of water to be heated in kg, C_p is the specific heat capacity of water in kJ/kg-^{0}K, ΔT is the required temperature rise in ^{0}K, Q_{HW} is the domestic hot water in kWh/day, Q_{HL} is the standby heat loss in kWh/day.

The energy enquired to be collected by the collector was calculated to be 14.4 MJ. For this, the collector area must be 0.814 m^2. The collector can have any arbitrary if the area is not altered. Therefore, the dimension of 1 m by 1.3 m was chosen for collector fabrication.

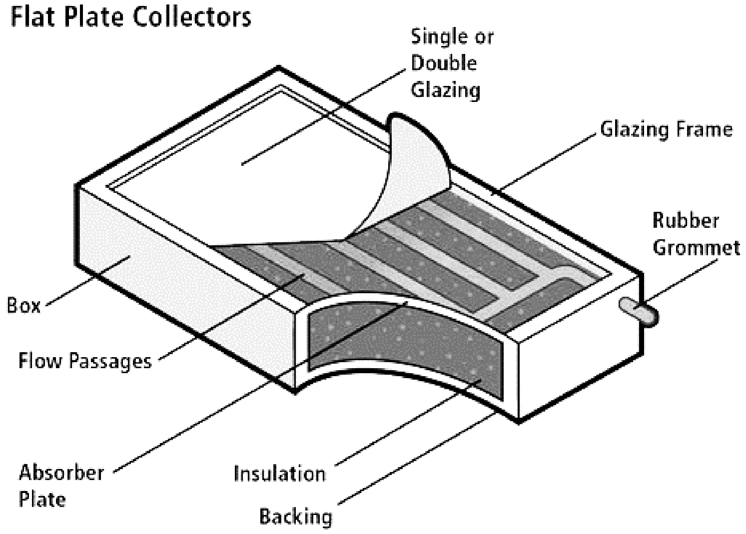

Figure 6: Schematic of suitable solar collector

Fabrication of the solar collector

Solar collector was fabricated with wood, glass, aluminum conduit, aluminum sheet, black plastic sheet, polystyrene, and other miscellaneous items. Each of these materials was carefully chosen to play with the laws of sun rays to maximize solar energy.

First, the frame was fabricated. Then the insulation was installed to prevent the trapped solar energy. The aluminum sheet was laid, and the aluminum conduit was placed. Finally, the collector was completed with the glass glaze cover along with the quality plumbing work.

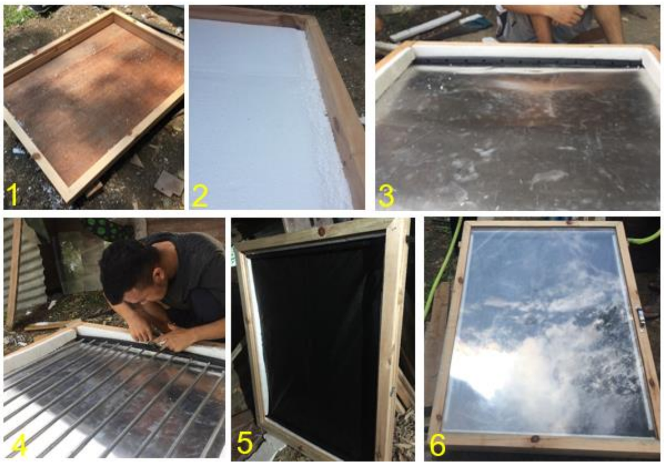

Figure 7: Fabrication process of the solar collector panel

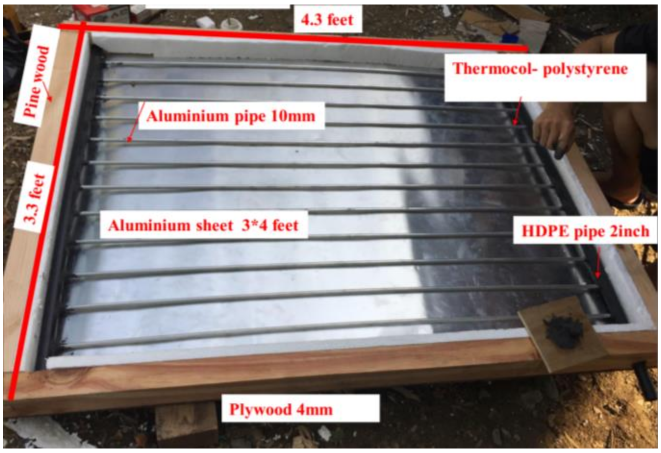

Figure 8: Solar Collector

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

IV. RESULTS AND DISCUSSION

The components designed and fabricated were all connected to form the completed locally fabricated passive solar water heating system. The fabricated system is as shown in the figure 9. The system was put under the sun for about 10 mins and the temperature rise of up to 20 ^{0}C was recorded with even under cloudy weather.

Figure 9: Locally fabricated passive solar water heating system

V. CONCLUSION

A low-cost passive solar water heating system is proposed in this paper. The design process and fabrication of the passive solar water heating system are presented so that readers can easily find the fabrication process and reproduce the design for their use. It was observed that excluding the labour charge, with only the materials of about Rs. 4495 is sufficient for fabrication work. The test indicates that the fabricated system is effective and can heat up the water to the desired temperature.

VI. REFERENCES

[1] Alessandro Franco and Sauro Filippeschi, Closed Loop Two-Phase Thermosyphon of Small Dimensions: a Review of the Experimental Results, ISSN 0938-0108 Volume 24 Number 3 Microgravity Sci. Technol. (2012) 24:165-179 DOI 10.1007/s12217-011-9281-6.

[2] Saleem Raza Samo, Asif Ali Siyal, Zafar Ali Siyal and Abdul Rahman Jatoi, ANALYSIS OF AN ACTIVE AND PASSIVE SOLAR WATER HEATING SYSTEM, IWTC 16 2012, Istanbul, Turkey, IEEE Sixteenth International Water Technology Conference.

[3] Bengt Perers, Simon Furbo, Jianhua Fan, Weigang Ko, Drain back systems in laboratory and in practice, Bengt Perers et al. / Energy Procedia 70 (2015), pp.300 – 310, Denmark, SHC 2014.

[4] N. V. Ogueke, E. E. Anyanwu, and O. V. Ekechukwu, A review of solar water heating systems: JOURNAL OF RENEWABLE AND SUSTAINABLE ENERGY 1, 043106 July (2009)

[5] Ioan Sarbu, Calin Sebarchievici, Solar Heating and Cooling Systems 1st ed , Piața Victoriei 2, Timișoara 300006, Romania 2017.

[6] Noohi. Samira, Rezaei. Davood, OPERATION OF ROOF POND SYSTEMS, CONSIDERING ITS ADVANTAGES AND DISADVANTAGES, The 6th International Green Energy Conference, (IGEC-VI) 5 – 9 June, 2011 Eskişehir, TURKEY.

[7] G. GROSSMAN, Smithsonian Science Information Exchange, Inc., in Summary of International Energy Research and Development Activities 1974–1976, 2013.

[8] The energy website webpage available on https://www.energy.gov/energysaver/water-heating/solar-water-heaters.

[9] A.E. DIXON and J.D. LESLIE, Solar Energy Conversion,1st Ed ,ontario canada ,1979.

[10] Aravind Kumar Chaturvedi, A Review of Solar Flat Plate Liquid Collectors Components, Department of Mechanical Engineering, Kurukshetra University Affiliated College Yamuna Nagar, Haryana, India, Volume 3, Issue 1 (2015) 138-141 ISSN 2347 - 3258 International Journal of Advance Research and Innovation.

[11] Bob Ramlow, Benjamin Nusz, Solar water heating: A comprehensive guide to solar water and space heating systems. Printed in Canada in April 2010 by Friesens.

[12] Chris Laughton, Solar domestic water heating: The earths can expert handbook for Planning, Design and Installation. First published in 2010 by Earthscan.

[13] J.Paul Guyer, P.E, R.A, An introduction to solar collectors for heating and cooling of buildings and domestic hot water heating, 2nd edition. Published in 2017 by authors.

[14] T. Tobgay, C. Dem and D. Zangmo, "Simulation and cost-benefit study of implementing active solar water system in the school mess," IRJETS, vol. 4, no. 4, pp. 1-7, 2022.