

RESEARCH ARTICLE

Design of a Solar Energy Water Heater Tank with High Efficiency for Local Use in Gaza Strip

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ABSTRACT

The traditional sources of energy are considered as a threat to the environment. On the contrary, renewable sources of energy such as wind energy, solar energy, and geothermal energy, etc. are eco-friendly. The main source of renewable energy in our area is solar energy where Palestine is considered as one of the sunny countries, and perceps good solar radiation over the year. The insolation intensity is in the range of $0.5-1\text{kW/m}^2$, and so solar concentrators are required to attain medium and high temperature conditions. In this work, Solar Energy Heater Tank (SEHT) is designed. SEHT uses solar energy to produce hot water for various domestic purposes. By using SEHT, the cost of electric bills reduces dramatically. Moreover, it is a great alternative for regions which do not receive utility services. It does not pollute air or water or soil and is completely eco-friendly. The components used in designing SEHT are taken form junk yards. The tank replaces the currently available ones that are electricity powered supplied by utility company. Though the design is found very useful to Gaza, and it also applicable to any area where solar radiation is abundant, especially for areas suffering from lack of tradition sources of energy or in remote areas where utility services cannot reach them.

Keywords: Solar energy, Thermal heating, Water heater, Renewable energy, Reflecting mirrors.

1. INTRODUCTION

The urge to use clean and environmentally safe sources of energy has become a global demand. There are many advantages resulting from the use of clean energy distributed in the fields of environment, economy and health. The clean energy has benefits including diversity, security, improved quality of life, green environment and human health. It also improves economic gains through avoiding medical costs, higher disposable incomes, and more jobs [1, 2]. Sun is a vital source of renewable energy. Solar energy is used in different aspects including thermal energy production for example to heat water using collector (mirrors or reflectors) or to produce electrical energy for normal use via solar panels. As early as 1970s, due to oil crises, studies about using solar energy to

produce thermal energy are accelerated. Currently, it has become an important task due to the political scenarios in the regions. Different concentrating collectors are proposed in [3-5]. [6] has initiated steam generation at low temperature with a parabolic focuser and has discussed system plan and performance factors. [7] has studied a parabolic reflector and absorber to trace the sun light.

Studies to use solar energy to improve water heating systems are done intensively in country like Hong Kong. These studies considered analyzing annual performance of façade-integrated hybrid photovoltaic/thermal collector system for using in residential building; estimating the potential application of a centralized solar water heating system for high-rise building; studying centralized photovoltaic and hot water collector wall

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system to serve as water pre-heating system; and evaluating conventional solar water heater system and solar assist heat pump system for hot water production [8-14]. The flat plate solar collectors and parabolic concentrators are better to be used under low ($<80^{\circ}\text{C}$) and high ($>300^{\circ}\text{C}$) temperature conditions respectively. Efforts are being made to design a rooftop Linear Fresnel Reflector Solar Concentrator (LFRSC) system. [15] A rooftop LFRSC is used to produce medium temperature heating that can be used in larger scale area. It is more suitable for tall buildings.

In a study conducted in Kenya, a 2-element plane reflector augmented galvanised pipe flat plate collector is used for solar water pasteurization [16]. The system is used only for producing drinking water, in which two tanks are used to collect the infected water and the pasteurized water accordingly. In a range of publications, Phase change materials (PCMs) with high thermal capacity and constant phase change temperature are used to modify performance of water heating systems [17]. In general, commercial systems are used. [18] has used a type of paraffin wax PCM in spherical capsules in jacketed shell typed solar water heater tank. It is observed that the proposed structure produces hot water with specified temperature at 25% longer time. [19] has used paraffin wax contained in small cylindrical aluminum containers packed in a commercially available, cylindrical hot water storage tank on two levels. It is validated that this type of set up can yield additional 13–14 $^{\circ}\text{C}$ in the stored hot water temperature over time. [20] has investigated the thermal performance of a Domestic Solar Water Heater with Solar Collector Coupled Phase-Change Energy Storage (DSWHSCPHEs). The thermal performance of the DSWHSCPHEs under exposure is lower than the Traditional Water-in-Glass Evacuated Tube Solar Water Heaters (TWGETSWH) with an identical collector area. It is also clear that the radiation and initial water temperature influence the system function.

In the above mentioned system, water is used for large scale applications and it requires two tanks to preserve water: one before heating and one to collect the hot water. For domestic use, some researchers have used commercial systems which are not suitable for low income families. Moreover, they are not suitable for tents and small houses. Our system is as simple

as that it does not need to have two water tanks. It uses water from the tap and the output is for immediate use. Moreover, it can be easily fabricated at local workshops from materials collected from junk yard. This makes our system simpler, lighter and portable.

1.1. Description of the situation in Gaza

Gaza strip, a highly populated narrow land area is 41km long and around 6-12km wide. Since it has no conventional energy sources, it has to fully depend on the electricity and fossil fuels from other countries. Due to several reasons, Gaza strip is unable to balance between supply and demand. Gaza strip gets a total of around 197MW electricity from Gaza power plant (60 MW), the Israeli electric company (120 MW) and Egypt (17 MW). But it actually requires around 300MW.

Due to this shortage, power cut is common that even lasts for about eight hours per day affecting economic activities and other prime aspects of the individuals. Furthermore, it experiences annual increase in electricity demand by 10-15MW with respect to population and industrial growth. It is stated that around 70% of electricity consumption is from domestic sector. The national energy policy is unclear owing to incomplete institutional and Palestinian state frameworks. Political stability, economic state of the individual, energy demand and the availability of natural resources have a strong influence over renewable energy market. Moreover large scale investments are impossible due to political risk and uncertainty [21-24]. At the local level, the Palestinian Authority has announced that it will increase reliance on renewable energy to reach 5% of the energy consumed in 2020 [25]. Most of the time, people use small motors and candles during power cuts. Due to this, death or third degree burnings among children are also prevailing. Energy problems occur due to poor water and sewage treatment systems.

Thus the proposed work aims to provide a safe and environmentally friendly source of hot water to the houses held using solar energy using materials found in junk yards. This work helps people anywhere in the globe living in small houses, tents and temporary houses to obtain hot water for daily use without the need to have large roofs. The designed heater is cheap since it could be designed locally. The next section gives details

about the used materials, followed by methodology and results.

2. SEHT CONSTRUCTION

The proposed SEHT is constructed from components that have been collected from junk yard. These components are as follows:

- Three mirrors: 2 mirrors (length, width, thickness) 40cmx40cmx4mm, 1 mirror: 100cmx40cmx4mm
- One glass plate: 100cmx40cmx4mm
- Aluminum frames for glass and mirrors.
- Thermal insulation: Glass wool
- Cylinder: length 90cm, radius 15cm, and thickness 1mm.
- Galvanized steel box (outside) : (length, width, height) 100cmx40cmx30cm
- Galvanized steel box (inside) : (length, width, height) 70cmx30cmx20cm
- Two pipes for water inlet (length 80cm) and outlet (length 70cm).
- Water outlet and water inlet valves.
- Wood pieces

Figure A1 shows the designed system. The outer box (100cmx40cmx30cm) is constructed from galvanized steel and the inner box is placed inside, and the two boxes are separated by wooden pieces as in figure 1.

The copper cylinder with two pipes (water outlet and water inlet) inserted inside is painted black for maximum absorption. Then the cylinder is placed inside the box as in figure 2. The box is then covered by the glass plate. Then the three mirrors are arranged around the box two on each side and one on the long side as in figure 3. In the design, we assume 15litres/person/bath and 5l/person/day, 10l/person/day and 5l/person/meal of hot water demand for bathing, cooking and washing clothes and utensils respectively.

Hence the estimation of total hot water demand is given as 30-35 litres per person per day and hence six individuals would require a minimum of 180-210 litres per day. The designed SHET provide 100 litres of hot water per day. Thus, SHET can easily serve 3 people. The system can be easily installed in the roof, or terrace or window and requires minimum maintenance. It requires 1.5mx0.5m surface area. Cold water is connected to cold water inlet and hot water is obtained from hot water outlet.

3. STEAM OUTPUT ESTIMATION

In the current design, one unit is used. The energy hitting the receiver (glass plate) is given in (3.1).

$$Q_a = I_a A_m \eta_o \alpha \quad (3.1)$$

where I_b is the total radiation on A_m , A_m is the total mirrors area, η_o is the fraction of the solar radiation focused on to the water pipe (receiver), and α is the absorbance of the water pipe [26]. Total energy absorbed by the receiver, Q_a is calculated using solar radiation flux $I_b = 700\text{W/m}^2$; $A_m = 2 (0.4 \times 0.4) + 1 \times 0.4 = 0.72\text{m}^2$ and $\eta_o \alpha = 0.5$ as in (3.2).

$$Q_a = 252\text{Watt (J/s)} = 907.2 \text{ kJ/h} \quad (3.2)$$

Q_s , the heat absorbed by the fluid in the receiver is given in (3.3)

$$Q_s = M_s C_p \Delta T + M_s L = M_s (C_p \Delta T + L) \quad (3.3)$$

In (3.3), M_s refers to the mass flow rate of water at inlet which is assumed to be fully converted to steam at outlet, C_p denotes the specific heat of water, ΔT refers to the temperature difference, and L is the latent heat of steam vaporization. M_s is determined by balancing the heat supplied to heat absorbed ($Q_a = Q_s$), and setting the respective values of $C_p = 4.178\text{kJ/kgK}$, $L = 2257\text{kJ/kg}$ and ΔT in (3.3). For example if steam is produced at atmospheric pressure from water at 25°C $\Delta T = 100 - 25 = 75$, M_s works out to be 0.316kg/hr . The system results have been compared with local available heating systems using traditional source of energy and it proves to be more efficient by almost 25% and will not contribute to the electricity bill. The only cost will be the material used in the construction. The most important outcome is the mobility of the system and that it can serve small houses instead of large solar system that is common in water heating.



Figure 1. Galvanized steel boxes separated by wooden pieces

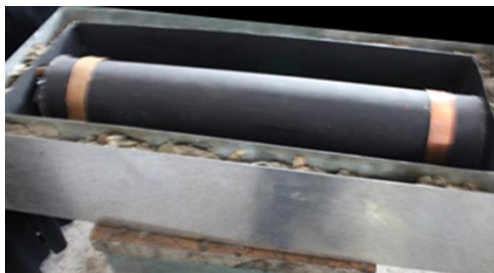


Figure 2. The copper cylinder is placed inside the box



Figure 3. The addition of the mirrors

4. RESULTS

Cold water is allowed to pass through SEHT while the sun is focused by the mirror into the cylinder turning the cold water into hot water leaving the cylinder through the outlet. The water coming out from the cylinder in a normal sunny day (23-25°C) is in the boiling condition.

5. CONCLUSION

In this work, we propose a unit that can use solar energy to heat water. This unit is designed in Gaza using Junk materials. It can be easily installed and maintained. The unit can serve people in the rural area and who live in tents and mobile houses. The average degree obtained from the system is 100°C in a normal sunny day. It also can provide hot water to almost three people per day including showering, washing and cooking. SEHT is proved to be more efficient and cost effective than other available local systems in local market.

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APPENDIX

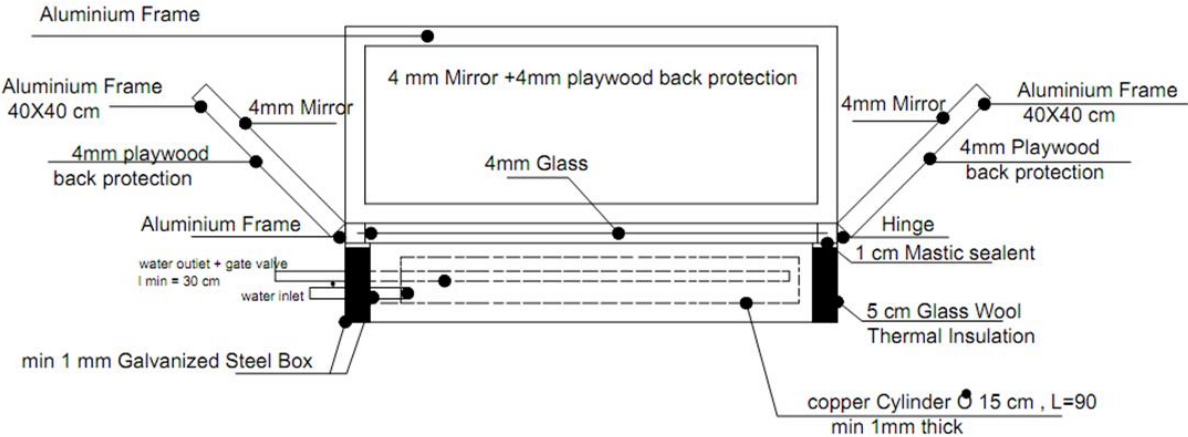


Figure A1.SHET as built at home from component found in junk yard