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DEVELOPMENT AND INSTALLATION OF SOLAR WATER HEATING SYSTEM FOR FEDPODAM HOSTEL

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ABSTRACT

This paper presents the result of the Development, Installation and Performance evaluation of a 500 liter capacity hot water storage tank with an additional 500 liter capacity cold water storage tank that was, developed, installed and tested at Maryam Abatcha female hostel in the Federal Polytechnic Damaturu, Yobe State, Nigeria which is located at latitude 12.29^0N and Longitude 11.44^0E using available materials and thermo syphon principle at an average solar radiation of 630W/m^2 to investigate the potential of using solar either directly and indirectly for heating water and to compare its cost with electricity. This design utilized a flat plate collector which was chosen because of the simplicity in construction and ease of maintenance. Two collectors of 1m^2 each with single glazing were used as a heat exchanger. The surfaces of the collectors were painted with black paint of absorptivity 0.95 and emissivity of 0.09 to improve its absorption capacity. Readings were taken for a period of nine months starting from March, April, May, June, July, August, September, October and November with minimum ambient temperature of 32^0C. Maximum hot water temperature inside the tank as 82.3^0C with an average efficiency of 28.06% in June, with clear sunny atmosphere days and November with lower outlet likely due to cold dusty of the period. Test conducted reveal that the system could satisfy the hot /warm water requirements of the hostel. It was also observed that the water temperature is a function of solar radiation while the cloud cover and dust particles were observed to also affect the performance of solar water heating system thereby reducing its efficiency.

Keyword: Collector, Electricity, Photovoltaic, radiation, solar, water heating

INTRODUCTION

Solar water heating systems which are often times referred to as solar domestic hot water systems utilizes photovoltaic technology which is cost effective to generate alternative source of energy to provide heating of water for domestic purposes. In order to develop an efficient solar water heating system, it is important to have a good knowledge of the geographical location of the site where this system will be built and installed since the performance of any solar powered system is reliant on the insolation available at the system's site.

The insolation available at different geographical locations vary, therefore the meteorological data of the area where the system is located is necessary for the system design. Yobe State which has been considered as the best site for photovoltaic technology due to its highest annual solar radiation, clear sunny days and the highest capacity factor satisfy this requirement, (Abdulhameed et al., 2019). Over the last few decades, solar water heating systems have gained more recognition because they can provide hot water at a low long-term cost and minimal environmental damage. Solar energy reaching the Earth's surface can be harnessed directly by using photovoltaic (solar cells) and solar concentrators. Photovoltaic are used for electricity generation, while solar concentrators are used as a source of thermal energy. The utilization of solar energy collectors (concentrators) to transform radiation into heat energy is the basis of the solar water heating technology, (Lilian et al., 2018).

The Solar energy reaching the Earth's surface can be harnessed directly by using photovoltaic (solar cells) and solar concentrators. Photovoltaic are used for electricity generation, while solar concentrators are used as a source of thermal energy. The utilization of solar energy collectors (concentrators) to transform radiation into heat energy is the basis of the solar water heating technology. The design choice is often based on the number of factors such as the economic, climatic, availability of materials (Gong et al., 2016). Hernandez et al., (2014) reviewed the environmental impact of utility-scale solar energy installations (solar farms) which are typically implemented in rural areas showed that they have low environmental impacts relative to other energy systems, including other renewables. The solar energy that the Earth receives in a day is far greater than the total amount of energy that humans use up in the same time period. Eighteen days of the incident solar radiation on Earth would give an equivalent amount of energy when compared to all the planet's reserves of natural gas, coal and oil (Union of concerned scientists, 2015). Outside the earth's atmosphere, solar radiation contains about 1,300 watts per square meter. One third of this gets reflected into space once it reaches the earth's atmosphere, the rest travels toward the surface of the earth.

On average, over the earth's surface, every square meter receives about 4.2 kilowatt-hours of solar energy in a day (Union of concerned scientists, 2015). The states in the northern region of Nigeria have higher insolation values due to their proximity to the Sahara, among other factors. (Osinowo et al., 2015) carried out an analysis of the global solar irradiance data for the climatic zones in Nigeria.Based on the thermo syphon principle, the heated fluid rises by natural convection, through the pipes at the top of the collector into the storage tank, while the cool fluid from the storage tank flows into the collector by gravity. Hence, the heated water gets transported due to an increase in both temperature and volume (Ogie et al., 2013). This solar water heater consists of a collector to collect solar energy and an insulated storage tank to store hot water. The solar energy incident on the absorber collector coated with selected coating transfers the hot to the riser pipes underneath the absorber panel. The water passing through the risers get heated up and are delivered the storage tank. The re-circulation of the same water through absorber panel in the collector raises the temperature to $80^{o}C$ (Maximum) in a good sunny day. The total system with solar collector, storage tank and pipelines are called solar hot water system. Solar water heating systems are of two categories. Closed loop system and open loop system. In the first one, heat exchangers are installed to protect the system from hard water obtained from boreholes or from freezing temperatures in the cold regions. In the other type, either thermo syphon or forced circulation system, the water in the system is open to the atmosphere at one point or other.

The thermo syphon systems are simple and relatively inexpensive which makes it suitable for domestic and small institutional systems, provided the water is treated and potable in quality. The forced circulation systems employ electrical pumps to circulate the water through collectors and storage tanks. The choice of system depends on heat requirement, weather conditions, heat transfer fluid quality, space availability, annual solar radiation, etc. The states in the northern region of Nigeria have higher insolation values due to their proximity to the Sahara, among other factor. Despite this advantages, residents still depend on the national grid which is unreliable, expensive and has led to fire outbreak in some hostels in the Federal Polytechnic Damaturu and other tertiary institutions in Nigeria. This solar water heating system was developed and installed at the Maryam Abatcha Female hostel of the Federal Polytechnic Damaturu, Yobe State, which is in the northern part of the country Nigeria to curb the problem of fire outbreak in student hostels, to reduce the dependence on grid which is expensive and to also reduce the use of other fuels which contributes to greenhouse gas emission. This solar water heating system is economical, pollution free and easy for operation in warm locations like Damaturu, Yobe State in Nigeria.

ENERGY GAIN BY THE COLLECTOR

Useful Energy gain by the collector, according to Tiwari (2002), is given by:

$Q_U = MC_W (T_{out} - T_{in})$ 1

Where M is the mass flow rate

C_w - specific heat capacity of water in J/kg/k

T_{out} - collector outlet temperature ^oC

T_{in} - collector inlet temperature ^OC

The instantaneous efficiency is given by (Tiwari 2002):

$$\eta_i \quad \frac{Q_U}{A_C\, I(t)} \qquad 2$$

Where A_c - Area of the collector m^2

I (t) - The incident solar radiation in the collector surface in W/m^2

The collector efficiency, according to Danshehu and Garba (2005), was computed using equation below with Microsoft excel spreadsheet application package, thus:

$$\eta_c = \frac{MCw\ (Tout - Tin)}{G_{(t)}\ Ac,\ t} \quad . \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3$$

Where

U_c - the collector efficiency %

C_w - Specific heat capacity of water J/kg/K

A_c - The Area of the collector m^2

G(t) - The Average solar radiation W/m^2

t - The time taken s

m - The mass flow Kg/s

SIZING OF THE COLLECTOR BASED ON HOT WATER DEMAND

The sizing of the collector area is according to the hot water demand

The heat requirement is given by

$Q = MC_{pw} (T_{hot} - T_{cold})$ 4

Where Q - Quantity of heat in J

M - Mass of the water in kg

GC_{pw} - Specific heat capacity of the water J/kg/K

T_{hot} - Hot water temperature desired ^oC
T_{cold} - Cold water temperature ^oC
$\text{mass} = \text{Density} \times \text{total volume}$
$= \rho V$
Substitute for mass in the above equation
$Q = \rho VCpw\,(T_{hot} - T_{cold})$
Where ρ - density of water
V - Volume of water per day
Therefore, for 320 litres of water, the heat requirement is
$Q = \rho VC_{pw}\,(T_h - T_c)$
Density of water 1 kg/m^3 approximately
Specific heat capacity of water 4200 J/kgK
$= 1 \times 320 \times 4200\,(80 - 25)$
= 73920000 J
The water is to be heated for eight hours
$= \frac{Q}{t} = \frac{73920000}{3600 \times 8}$ = 2566.67 Watt
According to the Duffie and Beckman (1991), the efficiency of flat plate solar collector has 0.4 and 0.6. Bala and Muhammad (1995) reported an efficiency of 0.5 in their work, as reported by Rikoto (2014)
Collector area = $\frac{2566.67}{680 \times 0.5}$ = $7.5m^2$
The collector of $7.5m^2$ is required to heat water of 320 litres per day from 25^0C to 80^0C for eight hours. In this present work, it was scaled down to a collector of $2m^2$ in the construction.

MATERIAL AND METHOD

Material Selection

The selection of materials for the construction of this solar water heating system was done based on factors such as, economic consideration, availability of the materials in the market, flexibility in construction ease of maintenance, reliability of instrument for accurate data acquisition and the properties of the materials.
The material used in this research are: Absorber plate, Insulated Collector tank, Collector casing, Pipes, Cold water tank, Hot water storage tank: Collector and storage stand, Glazers, Angle iron: Black paints, Data logger, Thermometers, Hot water level sensor, Fiber glass, Foam, Collector Casing Pyrheliometer, Pyranometer, Cold water tank, Hot water storage tank, Collector and storage stand.

EXPERIMENTATION

Experimental set up

The experimentation was conducted at Maryam Abatcha Female hostel Federal Polytechnic Damaturu from March, 2023 to November, 2023. The schematic diagram of the thermo syphon solar water heating system is shown in Plates 1-4 at the appendix. The system consist of two flat plate collectors of $1m^2$ each, the cold water storage tank, hot water storage tank, and the connecting pipes. The collectors were oriented in south direction to receive maximum solar radiation. The water from the hot water storage tank was allowed to flow through the insulated pipe into the first collector at the collector inlet header, then to the second collector thereafter the heated water move up to the tank for storage. This process was repeated continuously. As the water flows the following parameters were recorded, ambient temperature, water inlet temperature, glass temperature, absorber plate temperature, water outlet temperature, tank temperature as well as the global solar radiation and wind speed .The experiment was monitored at an interval of one hour from 9am to 5pm for nine months each day of the experiment and results obtained were recorded for analysis..

DETERMINATION OF HOSTEL HOT WATER DEMAND

The hot water demand was determined based on the daily , monthly, and perhaps on the annual requirements, number of occupants of the hostel that use the hot water, the temperature of cold water, and the expected or the desire hot water temperature. This was possible based on the analysis of the Questionnaire issued, the following requirements was obtained. Daily requirements to includes: bathing, drinking, ablution and miscellaneous for twenty rooms for four students per room and four liters per student, totaling 320 liters per day.

RESULT AND DISCUSSION

The results of the experiment and test result obtained for the month of March, April, May, June, July, August September, October and November for the solar water heating system are presented in the tables below. The data were collected and tabulated in table 1-9 below. The obtain results covers period of nine months which falls within hot and cold season. The analysis of the result were presented as follows;

Table 1. Test result for solar water heating in March, 2023 at FEDPODAM, Yobe State

Time (Hours)	T_{in} (ºC)	T_{out} (ºC)	T_{tank} (ºC)	T_{glass} (ºC)	T_{plate} (ºC)	$T_{ambient}$ (ºC)	Insolation (W/m^2)	Wind speed (m/s)	Efficiency (%)
09:am	32’7	51.1	42.0	37.6	56.4	34.3	347	1.2	43.31
10:am	34.2	51.3	41.5	36.1	57.3	35.2	389	1.6	35.38
11:am	35.5	52.9	42.0	39.5	58.7	36.6	590	1.0	24.70
12:noon	37.2	58.5	48.9	44.6	65.7	38.1	896	1.5	20.13
1:pm	38.5	62.5	52.4	45.6	74.8	38.8	936	1.4	20.64
2:pm	32.8	65.9	54.9	50.1	81.2	40.0	945	2.6	28.19
3:pm	41.6	65.2	58.6	46.5	79.3	41.3	814	1.8	23.33
4:pm	43.5	58.4	57.6	48.6	68.7	38.7	621	3.0	19.31
5:pm	42.7	53.8	56.5	49.5	55.6	38.9	299	1.3	27.75
Atm. condition: Relatively clear with little cloud cover									Ave:26.92 %

Table 2.Test result for solar water heating in April, 2023 at FEDPODAM, Yobe State

Time (Hours)	T_{in} (ºC)	T_{out} (ºC)	T_{tank} (ºC)	T_{glass} (ºC)	T_{plate} (ºC)	$T_{ambient}$ (ºC)	Insolation (W/m^2)	Wind speed (m/s)	Efficiency (%)
09:am	37.1	49.7	46.5	41.5	51.7	32.7	275	1.3	43.29
10:am	41.2	59.8	51.7	42.8	64.7	43.4	938	1.6	21.35
11:am	46.4	69.7	59.1	48.7	77.9	35.5	954	2.0	21.37
12:noon	47.9	71.1	62.1	53.4	85.9	39.9	969	1.1	20.94
1:pm	49.2	73.1	64.2	52.2	86.4	38.1	955	2.5	21.88
2:pm	49.3	72.5	65.2	54.4	84.3	39.3	903	1.8	22.48
3:pm	52.1	70.5	64.9	52.8	79.5	39.7	856	2.4	18.81
4:pm	53.2	67.2	63.6	48.5	68.2	39.6	673	1.9	18.21
5:pm	51.6	64.4	63.1	46.8	62.3	38.5	518	1.5	23.23
Atm. condition: Sunny day,									Ave:26.86%

Table 3. Test result for solar water heating in May, 2023 at FEDPODAM, Yobe State

Time (Hours)	T_{in} (ºC)	T_{out} (ºC)	T_{tank} (ºC)	T_{glass} (ºC)	T_{plate} (ºC)	$T_{ambient}$ (ºC)	Insolation (W/m^2)	Wind speed (m/s)	Efficiency (%)
09:am	42.7	49.8	51.7	36.8	56.6	28.7	600	1.7	16.45
10:am	43.4	57.9	52.6	40.2	69.1	34.2	639	1.2	19.85
11:am	48.6	67.2	58.2	40.2	69.1	38.0	946	1.4	16.67
12:noon	53.5	71.7	64.4	52.8	82.4	37.4	963	3.2	16.53
1:pm	54.2	73.5	66.5	51.4	83.3	37.0	976	2.3	17.48
2:pm	53.4	72.5	67.3	52.4	88.1	38.2	964	1.3	17.33
3:pm	56.6	72.2	66.6	50.4	81.9	39.2	894	1.8	15.26
4:pm	58.1	69.5	65.9	47.2	76.8	37.2	818	2.5	14.19
5:pm	57.9	65.8	64.7	45.5	72.4	37.6	681	2.2	13.47
Atm. condition: clear sunny day									Ave:26.94%

Table 4. Test result for solar water heating system in June, 2023 at FEDPODAM, Yobe State

Time (Hours)	T_{in} (ºC)	T_{out} (ºC)	T_{tank} (ºC)	T_{glass} (ºC)	T_{plate} (ºC)	$T_{ambient}$ (ºC)	Insolation (W/m^2)	Wind speed (m/s)	Efficiency (%)
09:am	43.1	65.5	52.2	45.4	54.7	35.7	588	1.9	32.39
10:am	46.4	79.3	62.8	49.5	84.9	35.4	945	1.5	30.64
11:am	50.7	76.6	63.5	50.1	82.8	37.9	914	2.4	25.08
12:noon	51.8	75.4	65.0	49.5	83.3	38.2	936	1.0	22.06
1:pm	52.4	82.3	66.5	50.3	84.2	40.2	928	1.3	24.34
2:pm	53.6	77.9	68.5	52.1	88.1	40.3	936	1.1	22.71
3:pm	55.4	79.6.	69.4	54.9	89.4	42.3	948	1.6	23.17
4:pm	51.4	76.8	65.3	52.1	77.4	39.1	712	1.2	31.38
5:pm	51.0	75.8	65.1	50.6	76.5	38.2	658	1.8	31.86
Atm. condition: clear sunny weather,									Ave:28.06%

Table 5. Test result for solar water heating system in July, 2023 at FEDPODAM, Yobe State

Time (Hours)	T_{in} (ºC)	T_{out} (ºC)	T_{tank} (ºC)	T_{glass} (ºC)	T_{plate} (ºC)	$T_{ambient}$ (ºC)	Insolation (W/m^2)	Wind speed (m/s)	Efficiency (%)
09:am	37.8	48.1	48.0	37.1	51.4	34.0	425	1.8	23.56
10:am	40.5	58.0	52.4	48.9	61.6	34.7	482	2.1	31.76
11:am	44.9	60.5	54.3	49.8	70.7	38.1	623	2.3	21.91
12:noon	46.3	61.5	55.1	49.5	71.0	35.1	509	2.8	26.12
1:pm	46.4	60.1	52.2	50.1	70.4	35.6	647	1,4	18.52
2:pm	46.5	58.4	56.2	49.5	61.2	41.8	340	1.2	30.62
3:pm	47.6	58.5	54.8	44.7	59.8	40.6	391	2,5	24.39
4:pm	47.2	56.1	54.6	43.8	56.7	38.1	299	2.0	26.04
5:pm	46.6	51,8	55.7	42.7	53.8	32.9	198	2.6	20.00
Atm. condition: Hazy and Cloudy									Ave:25.57%

Table 6. Test result for solar water heating system in August, 2023 at FEDPODAM, Yobe State

Time (Hours)	T_{in} (°C)	T_{out} (°C)	T_{tank} (°C)	T_{glass} (°C)	T_{plate} (°C)	$T_{ambient}$ (°C)	Insolation (W/m^2)	Wind speed (m/s)	Efficiency (%)
09:am	43.6	56.7	52.5	34.1	66.4	32.6	587	2.4	20.82
10:am	43.9	64.2	55.1	39.9	68.3	34.8	698	1.9	25.69
11:am	46.9	64.6	56.7	45.2	70.5	34.5	670	2.0	23.11
12:noon	50.7	67.5	58.4	47.2	75.2	36.5	697	2.9	21.09
1:pm	51.5	68.9	60.6	52.1	76.4	36.4	743	1.7	20.49
2:pm	52.2	66.0	62.9	50.3	72.5	39.4	553	2.8	21.83
3:pm	53.2	66.1	63.0	49.7	72.1	39.4	539	2.5	20.94
4:pm	53.4	65.2	62.8	45.3	70.1	39.3	492	1.6	20.98
5:pm	52.8	63.4	62.5	44.8	69.5	38.7	389	2.1	22.94
Atm. condition: Cloudy day									Ave:22.98%

Table 7. Test result for solar water heating system September, 2023 at FEDPODAM, Yobe State

Time (Hours)	T_{in} (°C)	T_{out} (°C)	T_{tank} (°C)	T_{glass} (°C)	T_{plate} (°C)	$T_{ambient}$ (°C)	Insolation (W/m^2)	Wind speed (m/s)	Efficiency (%)
09:am	45.8	58.8	51.2	46.1	64.5	35.9	597	1.3	21.37
10:am	48.6	61.9	53.5	49.3	68.3	36.6	872	1.0	13.34
11:am	49.9	69.4	60.4	50.6	86.4	36.4	931	1.5	18.32
12:noon	49.7	70.7	61.2	52.2	89.0	39.8	938	1.2	19.58
1:pm	50.1	70.1	63.6	52.8	82.6	40.9	908	2.2	19.27
2:pm	51.8	69.6	65.5	51.2	80.9	40.3	899	1.4	17.32
3:pm	52.3	69.8	65.8	52.3	78.7	40.5	884	1.8	17.32
4:pm	54.9	66.6	66.0	50.3	75.2	39.8	551	2.0	19.05
5:pm	54.6	62.1	65.2	48.2	73.8	41.0	447	1.7	15.07
Atm: Dusty and Sunny Day									Ave:18.62

Table 8. Test result for solar water heating system October, 2023 at FEDPODAM, Yobe State

Time (Hours)	T_{in} (°C)	T_{out} (°C)	T_{tank} (°C)	T_{glass} (°C)	T_{plate} (°C)	$T_{ambient}$ (°C)	Insolation (W/m^2)	Wind speed (m/s)	Efficiency (%)
09:am	41.8	57.2	50.1	42.9	62.8	33.0	455	2.2	31.43
10:am	43.5	59.1	53.1	44.3	66.9	34.1	655	1.8	20.73
11:am	44.8	62.7	55.4	46.3	69.0	34.6	547	1.5	28.63
12:noon	48.4	67.7	59.1	50.1	74.4	36.4	943	1.3	17.90
1:pm	50.0	69.6	61.6	52.4	76.5	36.4	924	1.6	18.56
2:pm	51.4	70.1	62.3	52.1	79.2	37.3	867	2.3	18.87
3:pm	50.9	62.5	62.7	50.3	71.4	38.1	236	1.8	43.00
4:pm	46.4	58.1	60.7	49.2	68.4	37.8	329	1.4	31.13
5:pm	45.9	52.9	60.7	48.3	65.3	36.5	256	1.0	25.36
Atm. condition Sunny and cloudy									Ave:29.08%

Table 9. Test result for solar water heating system in November, 2023 at FEDPODAM, Yobe State

Time (Hours)	T_{in} (ºC)	T_{out} (ºC)	T_{tank} (ºC)	T_{glass} (ºC)	T_{plate} (ºC)	$T_{ambient}$ (ºC)	Insolation (W/m^2)	Wind speed (m/s)	Efficiency (%)
09:am	38.0	59.5	40.4	43.8	69.9	32.7	722	1.5	27.04
10:am	39.1	60.3	42.5	45.2	75.8	32.9	820	1.2	27.03
11:am	39.4	60.1	47.9	45.2	79.5	34.8	885	2.3	20.17
12:noon	39.4	59.5	51.6	47.5	74.7	37.5	909	1.8	19.36
1:pm	40.1	63.8	54.1	44.4	70.9	38.2	933	2.5	31.60
2:pm	42.3	63.2	55.6	44.9	77.1	37.9	930	1.4	30.95
3:pm	42.1	64.1	58.7	45.6	78.5	38.0	850	2.0	28.41
4:pm	43.3	57.5	72.5	44.8	72.5	37.5	801	1.6	14.34
5:pm	42.9	55.2	65.4	43.1	69.3	36.6	637	1.3	15.37
Atm. condition: Sunny day with dusty cloud									Ave:25.84%

Key: Ave = Average, Atm=Atmospheric

DISCUSSION OF RESULTS

The results obtained from the experiment which was conducted for the period of mine months i.e. March – April as tabulated in table 1-9 above. This involves the hourly variation of the ambient temperature, collector temperature, and storage tank temperature, plate temperature for both the clear sunny and cloudy days of the months. The useful energy faun and efficient of the collectors were determined using equation 1 and 2. From the results it can be seen that the maximum temperature of the plate and the efficiency for the nine months are 81.2^{0}C,86.4^{0}C,88.1^{0}C,88.4^{0}C,71.0^{0}C,76.4^{0}C,89.0^{0}C,79.2^{0}C, 79.5^{0}C and 26.92%, 26.86%, 26.94%,28.06%,25.57%,22.98%,18.62%,29.08%,25.84% respectively. The highest insolation for the period of this research was recorded as 976W/m^2 in the month of May at 1.00 pm. The storage tank temperature could be improved by lagging the hot water delivery pipe from the collector outlet to the storage tank as reported by Rikoto (2014). It was observed that the collector efficiency decreases as the water temperature increases.

CONCLUSION

The design and construction of the 500 liters capacity passive solar water heating system was successfully done at the Federal Polytechnic Damaturu workshop. The solar water heater which has total collector area of 2m$^{2.}$ was installed and tested at the Maryam Abatcha female hostel of the Polytechnic. The results obtained an presented above confirmed that the system is efficient and can be used for providing hot water for cooking and other domestic activities in the hostel.

RECOMMENDATIONS

From this research work, the following recommendations have been made for better performance of the solar water heating system:

- Data loggers should be used in the acquisition of data for higher degree of accuracy.
- A pump should be introduced into the system with a solar panel in order to provide the electricity to drive the pump.
- An auxiliary heater should also be incorporated to be used when there is no sunshine or when there is rainfall.

- The glass should be cleaned regularly to remove the dust particles that may have settled on the glass cover which will block the rays and reduce output of the system.
- Ensure that there is always cold water supply to the tank and flush out the entire system to remove any floating.

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APPENDIX

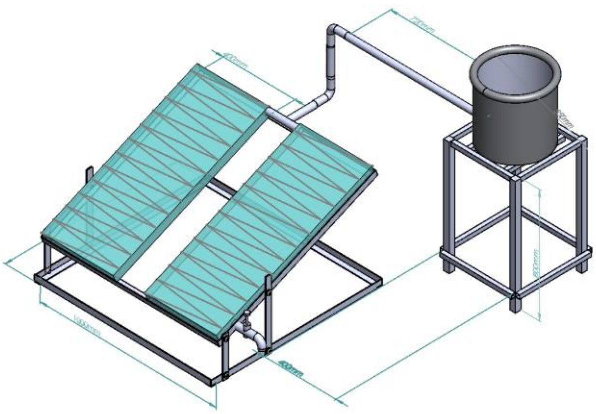

PLATE 1: Complete Assemble of Solar Water Heater

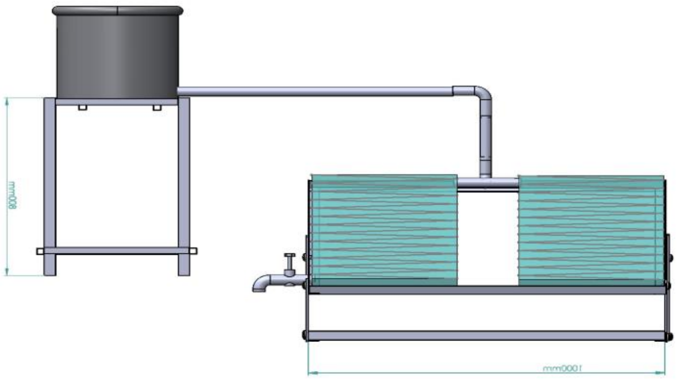

PLATE 2: Collector Back View

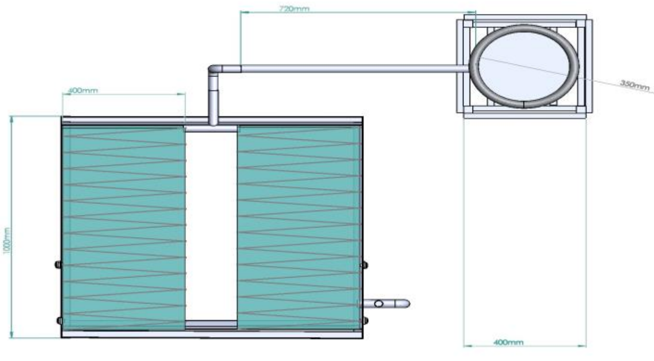

PLATE 3:Collector Plan

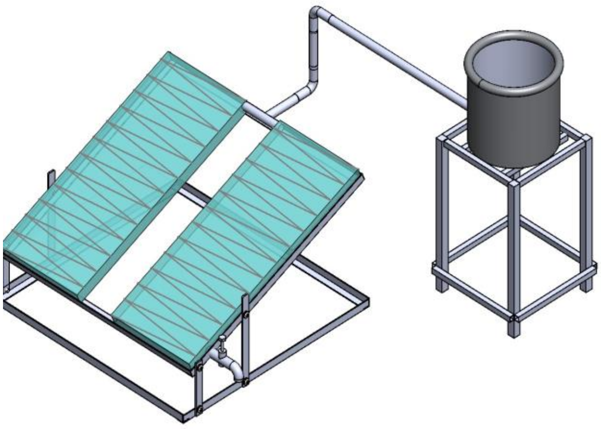

PLATE 4: Collector Isometric View

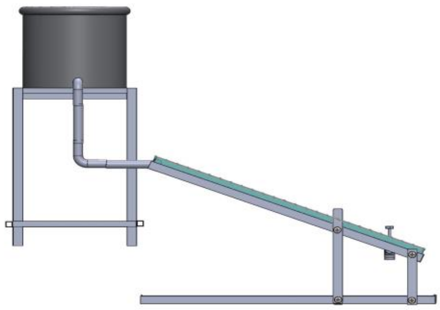

PLATE 5: Collector Left Plan

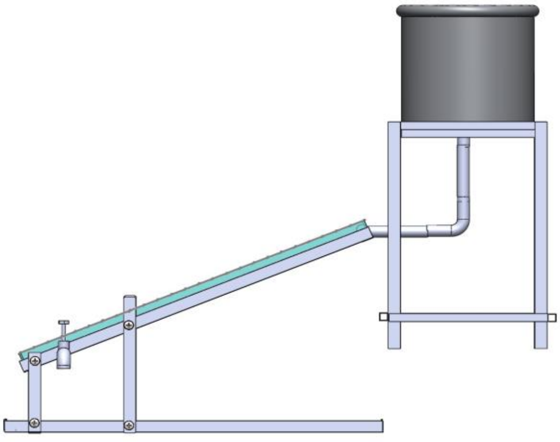

PLATE 6:Collector Right Plan