Macrothink Institute™

International Journal of Global Sustainability
ISSN 1937-7924
2024, Vol. 8, No. 1

Design and Manufacturing of Thermosyphon Solar Water Heater Using Locally Available Materials in Nsanke Village

Paulin Marvel Djimeli (Corresponding author)

Department of Renewable Energy, Higher Institute of Agriculture, Forestry, Water and Environment, University of Ebolowa, Ebolowa, Cameroon

Division of Scientific Research and Innovations, African Scientific Association for Innovative and Entrepreneurship (ASAIE), Dschang, Cameroon

E-mail: djimarpau@hotmail.com

Marie Danielle Fendji

Department of Electrical and Electronics Engineering, Faculty of Engineering and Technology (FET), University of Buea, Buea, Cameroon.

Division of Scientific Research and Innovations, African Scientific Association for Innovative and Entrepreneurship (ASAIE), Dschang, Cameroon

E-mail: fendji.marie@ubuea.cm

Clautaire Mwebi Ekengoue (Corresponding author)

Division of Scientific Research and Innovations, African Scientific Association for Innovative and Entrepreneurship (ASAIE), Yaounde, Cameroon

Department of Civil and Architectural Engineering, Faculty of Engineering and Technology (FET), University of Buea, Buea, Cameroon.

E-mail: clautaire.mwebiekengoue@yahoo.fr

Denis Djiyo

Department of Environment, Division of Environmental Management, Senghor University of Alexandria, Alexandria, Egypt

Division of Scientific Research and Innovations, African Scientific Association for Innovative and Entrepreneurship (ASAIE), Dschang, Cameroon

E-mail: djiyodenis@rocketmail.com

Macrothink Institute™

International Journal of Global Sustainability
ISSN 1937-7924
2024, Vol. 8, No. 1

Richard Vivien Youagam

Division of Scientific Research and Innovations, African Scientific Association for Innovative and Entrepreneurship (ASAIE), Dschang, Cameroon

Ministry of Finances, Yaounde, Cameroon

E-mail: richardyouagam@gmail.com

Received: June 22, 2024 Accepted: August 2, 2024 Published: September 19, 2024

doi:10.5296/ijgs.v8i1.22264 URL: https://doi.org/10.5296/ijgs.v8i1.22264

Abstract

The weather conditions of Nsanke village starting from April to October emphasis the need for judicious utilization of warm water. We designed, constructed and tested a Solar Water Heater based on Thermosyphon principle in Nsanke village using locally available materials. Solar energy is received by two flat-plate collectors of 1.68 m^2 each, consisting of absorber plate carrying copper tubes and placed in an insulated casing with a transparent glass cover of thickness 4 *mm*. The collectors are connected in series and are assumed to operate on the same efficiency. The resultant collector is connected to a storage tank, which is an association of two barrel nested overall and separated with an insulator. The radiation emitted by the absorber plates cannot escape through the glass, thus increasing its temperature. The system's performance evaluation has shown that it can heat water from 23°C to at least 51°C on sunny days. The water heated flows into a storage tank through Thermosyphon principle. The Solar Water Heating System uses the Thermosyphon principle and can therefore be called Thermosyphon Solar Water Heater (TSWH) for simplicity. This system finds useful application in serving as a renewable energy resource in Nsanke village and neighboring villages.

Keywords: Weather conditions, Warm water, Thermosyphon principle, Solar Water Heater, Nsanke village.

1. Introduction

Nowadays, air pollution management (Asangwe, 2006; Kenfack, 2017; Puiu et al., 2022) and energy supply (Fotsing et al., 2014; Tamba, 2017; Muhammad et al., 2022) have become major issues. A number of policies and campaigns aim not only at reducing the volume of harmful emission release into the atmosphere, but also to provide strategies mitigating the high demand for energy have been initiated (Fotsing et al., 2014; Manjia et al., 2014; Timme, 2016; Sofia et al., 2020; Ou et al., 2020). Globally, those programs which were launched by many countries were focused particularly on strategies for energy consumption, fuel diversification, and the use of renewable energy, paying attention to renewable energy technologies such as and not limited to solar photovoltaic (Maka and Alabid, 2022), wind turbines (Darwish and Al-Dabbagh, 2020), geothermal, biomass, water reservoir, energy supply, wave generators solar thermal (Minerva, 1999; Blaabjerg and Ionel, 2015; Ruiz et al., 2014; Day et al., 2015; Weller et al., 2013). Nevertheless, the strategies implemented for using these renewable energy technologies and devices, differ between industrialized nations and developing countries. Therefore, while the former achieved significant energy savings through demand management, developing countries still focus their strategies on increasing the domestic energy supply (Falcone, 2023).

In Cameroon, like in many other African countries, the production and use of renewable energy have been found as the main solution to be adopted in order to improve the current energy crisis (Kidmo et al., 2021) characterized by power cuts with direct impacts as it makes the functioning of government and the state basic services difficult (Flora et al., 2019). Among various solutions which have been proposed (Rauf et al., 2024), Manjia et al. (2014) focused on four primary mitigation strategy components including (i) carbon efficiency, (2i) energy efficiency of technology, (3i) systemic and infrastructure efficiency and (4i) service demand reduction. While Abanda et al.(2014) designed and implemented an improved mud-brick cook stove, Tidze et al.(2016), in their research study based on the dynamics of household energy and cooking stoves in Maroua, Far North Region of Cameroon, suggested the usage of energy efficient stoves as a sustainable cooking energy alternative source. Similar research works, concerning the development of renewable energy technologies in Cameroon in order to address energy demand have been carried out by several authors including Munongo (2012), Ayompe and Duffy (2013), Ho-Yan et al. (2014), Mungwe et al. (2016), Kwaye et al. (2016) and Koholé et al. (2022).

In the same line, we designed and manufactured a TSWH which uses locally available materials in Nsanke village. Our motivation for designing such a solar system comes to the fact that, in Nsanke village as well as in many villages in Cameroon (in particular, villages in the Mbo'o community including and not limited to Nsanke, Mama, Ebang-Mama, Etabang, Mbokambo, Ekah, Ebakong and Nlolak), essential commodities are very expensive. The aim of the present research study is to look for the possible alternatives including the development of renewable energy technologies and devices more reliable and less expensive to sustain inhabitant's daily activities. We recall to readers that the present research work is the continuity of the Central African Sustainable Cities Initiative (CASCI) launched in Nsanke village by a research group of the African Scientific Association for Innovative and Entrepreneurship (ASAIE) in partnership with *Laboratoire Energetique Carnot (LEC)*, Promotion Centre of Research for Technological Advancement and Sustainable Development (PCR-TASD) and *PROSOFOR AFRIQUE* aiming to fight against poverty and rural exodus and stimulate the local economy in the Central Africa Region.

The rest of the paper is organized as follows: in section 2 we present the materials used and methodology choose in order to attempt the objectives. In section 3, results are presented. The above results are discussed in section 4. The paper ends in section 5 with a summarized conclusion.

2. Materials and methods

2.1 Materials

Various materials have been used in order to achieve the aim followed in this study. These materials have been selected depending on some keys factors. These include the economic considerations, availability of the materials in the local market, the extensibility of the material in construction, ease in maintenance and also their physical properties such as thermal conductivity and resistivity to cite only these few. The materials are depicted in Table 1, which presents each material and its use in the present research work.

Other important materials used in this study constitute of global positioning system (GPS) for surveying in order to map the location of the study area and a camera. For instance, we do not find it necessary to insert the designed localization map of the study area in the present study since it’s included in another research paper carried out by the same research group of ASAIE organization and partners. In addition, for a perfect design of the model TSWH, interviews were carried to collect basic data in the Chieftaincy consider as our sample. The target groups selected for interview consist of occupants of the Chieftaincy. The phase consisted of the interview has been essentially based on a systemic gait. Our questions, either oral or mentioned in the questionnaires, allowed us to get information concerning essentially the volume of hot water used by every occupant in a day and the average number of occupants of the Chieftaincy.

Table 1. Various materials used for design and construction of the model TSWH.

Materials	**Usage**
Nails Hammer	To join the various part of our model TSWH
Gate Faucet Compression pipes	These materials were used for connecting pipe from storage tank to the collector header and riser
Solarimeter	Type of measuring component used to measure combined direct and diffuse solar radiation
Thermal probe Multimeter	Devices, designed to measure temperature within and out of the storage tank and collectors
Hot water tank or storage tank	A hot water tank or storage tank was constructed from two barrels of 100l and 250l respectively. The first one, that is the one with the volume of 100l is shifted in the largest one; the interval between them been filling with chip.
Chip	Chip is used as a heat insulator to prevent heat loss.

2.2 Methods

In order to assess data, we follow a qualitative approach consistent with literature review, field investigation and data analysis. In the former, some data were downloaded online from Google page (https://www.google.com/). The informations provided basic knowledge concerning TSWH such as various assembly elements and their characteristics. In particular, the collected information allowed us to understand previous research studies focused on TSWH. On the field, both detailed field surveys and interviews were carried out using GPS and questionnaires in order to map the location of the Chieftaincy on one hand, gather information regarding the volume of hot water used by each occupant in a day and the average number of occupants present in the Chieftaincy at any time on the other hand. The step-by-step method employed for constructing the TSWH is well presented in Table 2.

Table 2. Step-by-step method employed for constructing the TSWH.

Step Nº	Designation	Activities involved
1	Choice of the technology	- Choosing a type of collector - Choosing a type of boiler
2	Measure of irradiation in Nsanke village	- Choice of the appropriate software : RETScreen - Measurement of irradiation in Nsanke village
3	Evaluation of warm water needs in the Chieftaincy	- Evaluation of number of occupants and their need of warm water (in liters)
4	Choice of materials for TSWH manufacturing	- Glazing, - Heat exchanger, - Absorber and its cover, - Insulations, - Frame, - Constituent elements of the storage tank.
	Sizing of collector's elements	- Absorber's area, - Insulator 's thickness, - Sizing of the frame,
	Sizing of storage tank	- Storage volume, - Insulator 's thickness.
	TSWH system assembly	- Storage tank - Collector
5	TSWH device installation	- Choice of the site - Installation of the system
6	Performance evaluation of the TSWH manufactured	- Measurement of the temperature at the entrance and at the exit point of the collector as well as those at the exit point of the storage tank by means of thermocouple.

Choice of the technology. In order to respond to the current energy problem in Nsanke village, we have chosen to design a TSWH by means of a sensor glazed plan because of its advantages over other types. Due to its glazing, the sensor glazed plan allows better heat insulation and creates the greenhouse effect. Consequently, it considerably increases the internal temperature of the system and, by rebound, that of the outflowing water. Furthermore, the necessary materials for the realization of the sensor glazed plan are easily accessible in the market. After choosing the type of sensor that will be used, we then turn ourselves to the appropriate type of boiler. With regards to the expected results and model characteristics, we decided to use thermosyphon boiler. This choice was based on the fact that such a boiler is cheap and simple.

Measure of irradiation in Nsanke village. The realization of the TSWH requires beforehand evaluation of individual warm water needs in the Chieftaincy. Nevertheless, various parameters influence the daily consumption of warm water by each occupant. These include mainly: (i) the living standard cost per occupant, (ii) reasons for using warm water and (iii) seasons. Globally, the need of warm water in a particular locality can be evaluated either by means of occupants, or by means of equipment (Alioune, 2007). Theoretically, Eq.1 gives the mathematical expression for the value of warm water needed in the Chieftaincy of Nsanke village. In Eq.1, C represents the value of warm water needed in the Chieftaincy of Nsanke village in KWh/day, V the warm water volume needed by each occupant in liter/day, T_f and T_c the temperature of cool and hot water respectively.

$$C = 0.0011611\left(T_c - T_f\right)V \qquad (1).$$

Sizing of the sensor and its elements. The choice of materials is of primordial importance. Such a choice depends on some requirements including the design (dimensioning), the price and the market accessibility. Each material mentioned earlier in the previous section has been needed in certain dimensions. Therefore, the dimensions of the absorber are identical to that of its surface and glazing which is given by Eq.2 where η is the desired performance of the system, f is the fraction of warm water needed covered during the most disadvantaged period, C the value of warm water needed in KWh/day given in Eq.1 above and G the sunniness in KWh/day.

$$S = \frac{1}{\eta}\frac{fC}{G} \qquad (2).$$

For precise manufacturing, we chose copper tubes of diameters $10/12mm$ and $14/16mm$. In order to reduce the thermal slowness while making optimal heat exchange between water and sensor, we choose a value of $100mm$ interval between tubes. Since the system interacts with the surrounding environment, we then investigated various losses at the level of the sensor which are of two types. The first one is loss by conduction through the side faces and behind the sensor given by Eq.3 and the second is loss by convection on both faces of the window pane expressed in Eq.4. In those expressions, $\lambda_{air}, \lambda_c, \lambda_{ab}, \lambda_i$ are respectively air thermal conductivity, frame thermal conductivity, absorber's thermal conductivity and insulator's thermal conductivity. T_{ab}, T_i, T_{vi} are internal temperature of the absorber, temperature of the lower face of the absorber and that of the top of glaze respectively; while e_i, e_{ab}, e_c are insulation thickness, absorber's thickness and frame's thickness respectively. In the same equation, S_b, S_l are respectively the basic surface of the sensor and the sum of the side surfaces.

$$q_{cond} = \frac{\lambda_{air}}{e}\left(T_{ab} - T_{vi}\right) \qquad (3),$$

$$q_{conv} = \frac{T_{ab} - T_i}{\frac{e_i}{\lambda_i} + \frac{e_{ab}}{\lambda_{ab}} + \frac{e_c}{\lambda_c}} S_b + \frac{T_{ab} - T_i}{\frac{e_i}{\lambda_i} + \frac{e_c}{\lambda_c}} S_l \qquad (4).$$

Other losses found in the system are loss by reemission given in Eq.5 and loss by reflection given in Eq.6. Lastly are losses observed at the level of transparent lid and absorber. The first term in the right hand side of Eq.6 represents losses at the level of the transparent lid while the second term represents the losses at the level of absorber. In those expressions, both G and S are well known parameters depicted in Eq.2. Other parameters such as $\sigma_0, \varepsilon_{ab}, \varepsilon_{vi}$ are respectively the Stefan-Boltzmann constant evaluated at $5.6 \times 10^{-8} W / m^2.K^4$, absorber permittivity and glaze permittivity. From Eqs.2-6, the total energy loss of the sensor is given by Eq.7.

$$q_{ray} = \frac{\sigma_0 S\left(T_{ab}^4 - T_{vi}^4\right)}{\frac{1}{\varepsilon_{ab}} + \frac{1}{\varepsilon_{vi}} - 1} \qquad (5),$$

$$q_{ref} = \left(\rho + 0.61\alpha\right) GS + 0.006GS \qquad (6),$$

$$q_{tot} = q_{cond} + q_{conv} + q_{ray} + q_{ref} \qquad (7).$$

For the frame, we decided to use firewood, the most accessible material in Nsanke village. Its size depends essentially on that of the absorber, the thickness of the insulating material and its personal thickness which we have chosen to be the value of $3cm$. Concerning the glazing, its dimensions also depend on the frame and on the absorber's size. Nevertheless, its thickness must be chosen in such a way that the performance of the sensor increases. These dimensions have to be also chosen in such a way that the frame stands as the support of the window pane. Figure 1 show the sensor designed and its elements.

Figure 1. Longitudinal section of the sensor glazed plan.

Sizing of the storage tank. To allow its continues usage, some hot water must be store in an adiabatic system. For our system's storage tank (Figure 2), we opted to use two metallic barrels nested overall and separated with shaving. The internal barrel is that prepared to contain hot water. Its sizes are length $L = 0.68m$ and radius $R = 0.18m$. Here, the main part of heat loss is summarized to nocturnal losses, given in Eq.8. In addition, the quantity of heat through the insulation is given by Eq.9.

$$q = mC\Delta T \qquad (8),$$

$$\begin{cases} \varphi = \dfrac{2\pi\lambda_i L\left(T_b - T_a\right)}{\log\left(\dfrac{R_0}{R}\right)} \\ R_0 = R + e \end{cases} \qquad (9).$$

In the above expressions, m is the mass of the stored water, T_a, T_b the average temperature of the ambient air at night and that of the storage tank respectively. λ_i is identical parameter well illustrated in Eq.4. From Eq.8 and Eq.9, the thickness between the two barrels is given in Eq.10. Based on the assumption that, the temperature in the tank at 8 AM is 55°C and that at 7 PM is 60°C and noticed that the storage mass of water in the tank is 100 kg, given that 1 liter correspond to 1 Kg, we obtained appropriate values in Eq.11. However, in order to reduce energy losses in the system's tank, we reset the insulator's thickness and chose $e = 11cm$. From these results, the storage tank is then carefully designed as illustrated in Figure 2.

$$e = R\left\{ \exp\left(\frac{2\pi\lambda L\left(T_b - T_a\right)}{\varphi} \right) - 1 \right\} \qquad (10),$$

$$\begin{cases} q = 2090000J = 580.55Wh \\ \varphi = 38.703W \\ e = 0.0566m = 5.66cm \end{cases} \qquad (11).$$

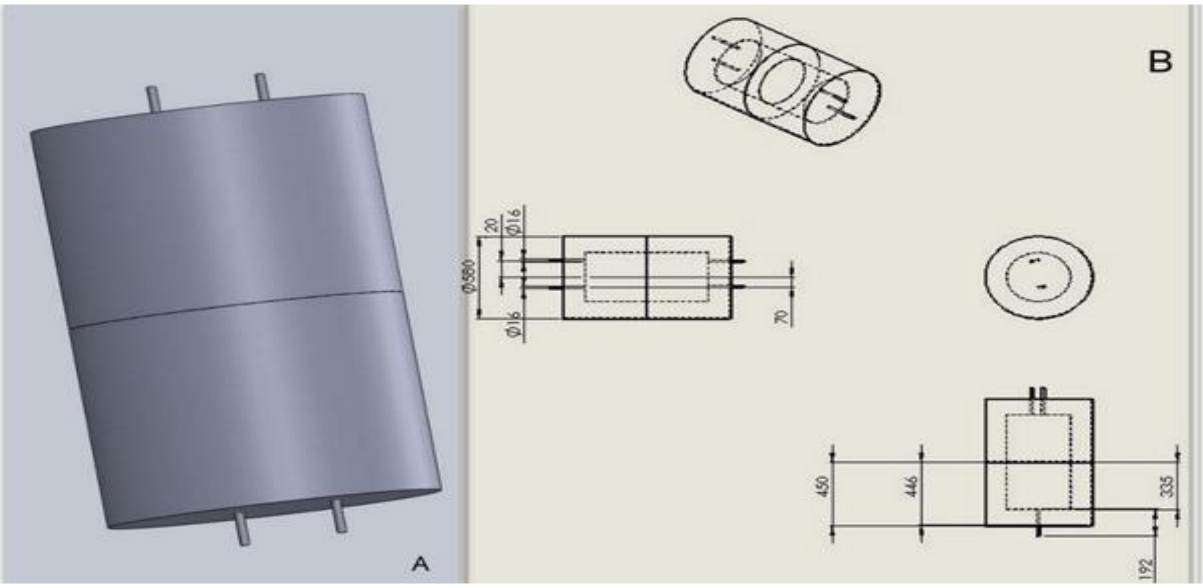

Figure 2. Storage tank design.

TSWH system assembly. The manufacturing of the system has consisted of three different stages: (i) the realization of the sensor, (ii) the realization of the absorber and (iii) the realization of storage tank. In the first stage, the main element to be manufactured is the wooden frame. Its realization consisted of cutting boards in desired dimensions and then fixing the pieces by means of nails (Figure 3a). The absorber is established by a serpentine fixed to sheet steel painted in black. The realization of the absorber is in two stages: the manufacturing of heat exchanger (Figure 3b) and its fixation on the absorber already placed on the frame [Figure 3 (c and d)]. The preparatory stages of the serpentine are tubes cutting, fixation of both tubes on the frame and assembly of various elements by welding with the tin. The principle of the realization of storage tank consists of operations of drilling, of assembly and the connecting to the sensors by means of compression pipes of $16mm$ diameter [Figure 3 (e and f)].

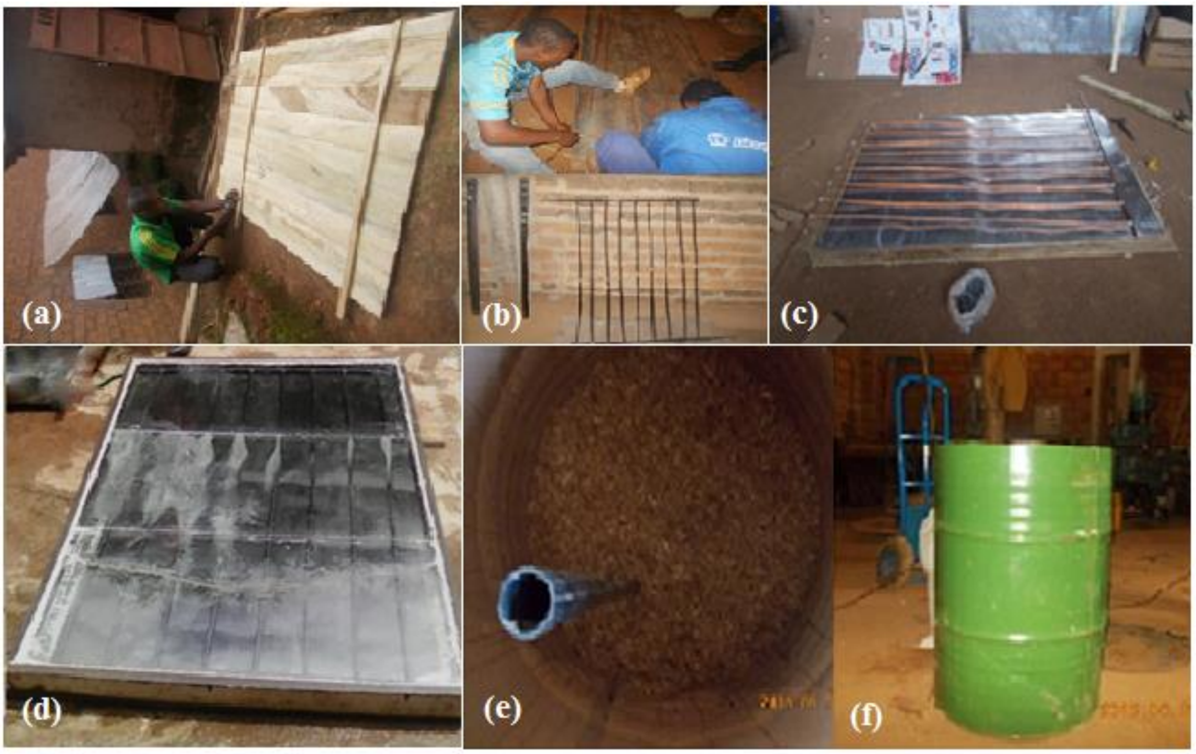

Figure 3. Final TSWH system assembly. (a) manufacturing of the collector, (b) manufacturing of the exchanger, (c and d) manufacturing of the absorber, (e and f) manufacturing of the storage tank.

Performance evaluation. Performance evaluation of the final manufactured TSWH system is subjective to at least two dimensions. First, determining what constitutes performance and how that is measured. Second, determining for each measurement of performance what constitutes an acceptable minimum level. In the present study, we concentrated on investigating the temperature of the sensor (Figure 4a), the temperature at the exit point of the sensor (Figure 4b) and the one at the exit point of the storage tank (Figure 4c) by means of a thermometer. In addition, Alioune (2007) has mentioned in Table 3 the average value of warm water consumption for each individual in a particular house.

Table 3. Average value of warm water consumption for each occupant in various comfort type of local

House/Local	Maximal comfort	Normal comfort	Minimal comfort
Average value hot water consumption (50°C) for each occupant (liter/day)	75	50	30

Figure 4. Performance evaluation of the final manufactured TSWH system. Temperature evaluation of the sensor (a), temperature evaluation of the TSWH system at the exit point of the sensor (b) and temperature evaluation of the TSWH system at the exit point of the storage tank (c).

3. Results

3.1 Occupation of the Chieftaincy and need of hot water

Data investigation and analysis based on the number of occupants and their need for warm water has leads to the results in Figure 5 and Figure 6 respectively. Our results clearly indicate that both the number of occupants (Figure 5) and the need for warm water (Figure 6) in the Chieftaincy of Nsanke village are consistent within June and August.

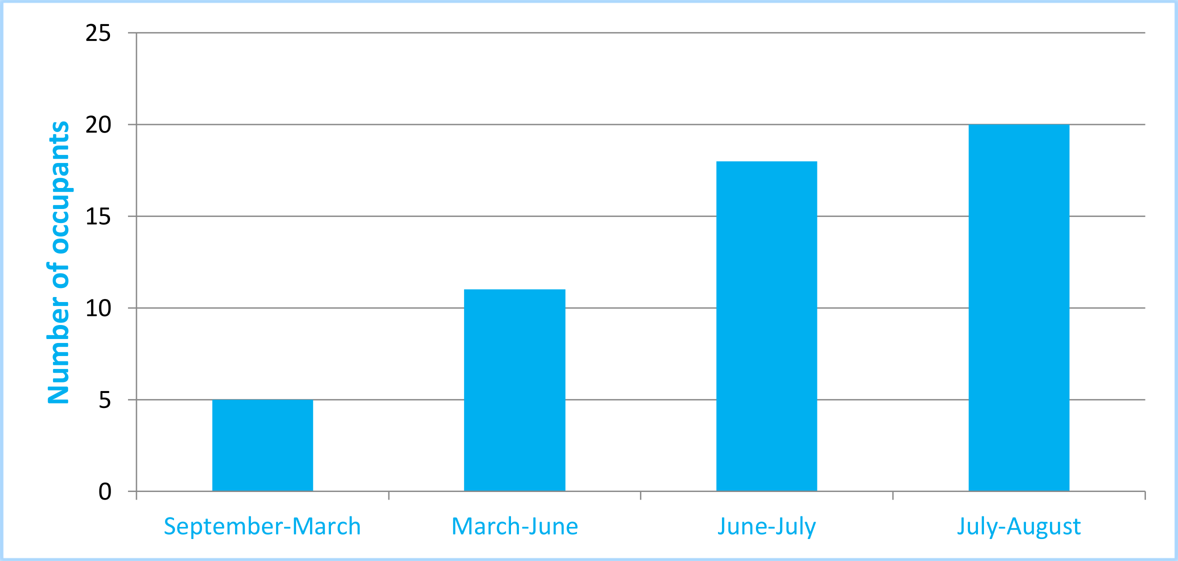

Figure 5. Graphical representation of number of occupants versus period in the year.

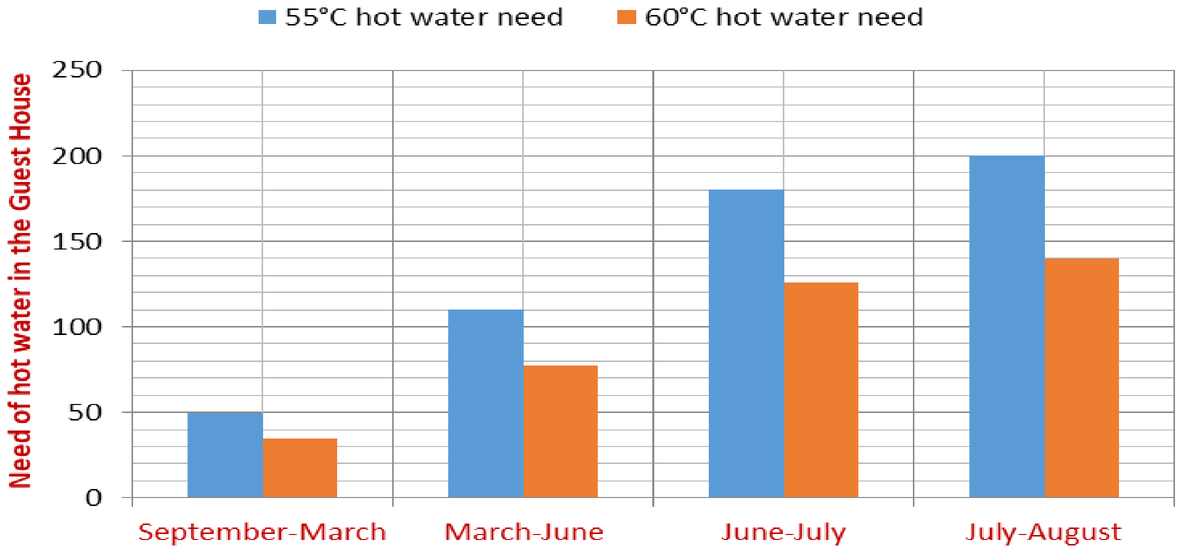

Figure 6. Graphical representation of the needs of water for occupants of the Chieftaincy versus period in the Year.

3.2 Description of the Thermosyphon Solar Water Heater system manufactured

Following each step of design and manufacturing well illustrated in section 2, we obtained the final TSWH system given in Figure 7 below. The system is made up of a 100l metallic tank nested in that of 250l. The system has the following components: solar thermal collectors, water storage tanks, connecting pipelines, and the water to be heated and circulated within the solar water heating system. The heat source is solar energy. The sunrays fall directly over the collectors, which result to the heating of tubes, which constitute the collector. The water then flows through the heated tubes which results in its rise in temperature.

Figure 7. Final TSWH system designed, manufactured and installed.

3.3. Physical characteristics of the TSWH manufactured

Physical characteristics of the TSWH manufactured are given in Table 4.

Table 4. Design results for TSWH manufacturing.

Items		**Results or assumptions**
Guest House	Individual hot water need (l/day)	7
	Irradiance (KWh/day)	2.25972 KWh/day
Sensor	N° of glass covers	1
	Thickness of glass cover	$4mm$
	Absorber’s material	Aluminium
	Material of the serpentine	Copper
	Serpentine’s dimensions	$10mm/12mm$ 10
	Material of the sensing insulator	Cardboard $\left(\lambda = 0.048Wm^{-1}{}^\circ C^{-1}\right)$
	Thickness of the sensor’s insulator	$e = 2.64cm$
	Cock material	Firewood
	Thickness of cock material	$e = 30mm$
	Absorber’s area	$S = 2.85m^2$
	Fame’s dimensions	Length: $L = 160cm$; Width: $l = 105cm$; Thickness or elevation: $h = 9cm$
	Tubes spacing	$100mm$
Storage tank	Material of the storage tank	Barrels
	N° of tanks used	$2(100l, 250l)$. The first one $(100l)$ is nested in the other $(250l)$
	Material of the storage tank insulator	Shaving
	Thickness of the storage tank insulator (the interval between 100l barrel and 250l barrel nested all in all)	$e = 11cm$
	Water inlet temperature	$23^\circ C$
	Water outlet temperature	$55^\circ C - 65^\circ C$

3.4 Performance evaluation of the TSWH manufactured

After having designed and manufactured the TSWH, several tests were carried out in order to evaluate the performance of the system. During these tests, we measured the temperature at the entrance and at the exit points of the sensor as well as that at the exit points of the storage tank by means of thermocouple. These measurements were investigated on four different days, starting on Wednesday 9th August 2023 to Saturday 12th August 2023, in order to appreciate the results, since sunniness is a function of day irradiation. Measurements were taken for different days, at different times. The results obtained are shown in Table 5. The result shows that sensor output temperatures increase with sunshine, sky clarity and sunshine time.

Table 5. TSWH performance evaluation results.

Day	**Time (h)**	**Irradiance (W/m^2)**	**Sensor**		**Storage tank**	**Efficiency (%)**
			Inlet Temp (^oC)	**Outlet Temp (^oC)**	**Outlet Temp (^oC)**	
Wednesday	10:00	240	18	27	25	36.2
	11:00	260	18.5	30	28	42.7
	12:00	283	18.7	34	32	52.3
	13:00	300	19	37	35	58.0
	14:00	333	20	40	37.5	58.1
Thursday	13:00	390	18	37	35	47.1
	14:00	384	19	40	38	52.9
	15:00	440	20	45	41	54.9
	16:00	241	22	38	39	64.2
	17:00	230	22	34	35	50.4
Friday	10:00	206	18	33	33	50.7
	11:00	220	19	35	36	50.6
	12:00	306	19	41	38	51.0
Saturday	11:30	300	18	39	38	62.7
	12:30	500	19	48	39	63.8
	13:30	600	19	51	40	65.3
	14:30	374	19	43	40	63.5
	15:30	380	20	43	40	59.9
	16:30	400	21	49	42	69.3
	17:00	375	21	43	42	58.1

4. Discussions

Numerical results have shown that both the number of occupants and the need of warm water in the Chieftaincy of Nsanke village is consistent within June and August. The augmentation of number of occupants in Nsanke village is because June-August is considered as the holiday period for all students under the Ministry of basic education and the Ministry of secondary education according to the academic calendar in Cameroon. During this period, almost all children who left the village for school come back to assist their families in other activities especially farming which is the major activity of the population in Nsanke village.

This therefore results in a high rate use of warm water in various families as the amount of warm water used is related to current occupancy (Parker et al., 2015).

The overall results presented in Table 5 clearly indicates that the irradiance levels and the output temperature (both for the sensor and the storage tank) are closely related. This result is in agreement with the observation of Ubani and Adejare in Nigeria (2022). During the testing days, an outlet temperature of 51°C was the highest temperature observed at the exit point of the sensor and 42°C at the exit point of the storage tank. The outlet temperature obtained through our system for both the senor and the storage tank were higher than that obtained by Ubani and Adejare (2022) in Nigeria. The result is not surprising since the authors (Ubani and Adejare, 2022) performed experimentations within the same period. In fact, the authors mentioned the fact that the Solar Water Heater performs well in dry season than in raining season. During the testing day of the dry season, the maximum outlet temperature observed by Ubani and Adejare (2022) was 75°C.

In general, as likely as the results of Ogie et al. (2013), maximum fluid (water) output temperatures at both the exit point of the sensor and the storage tank were obtained between noon and afternoon. The insolation increased from a low value at 10:00 AM got to a peak between noon and 3:00 PM and then fell back to a low value. No matter the output temperature of the water at the exit point of the storage tank is lower than the one obtained by Ubani and Adejare (2022) (44.30°C), we cannot explain such a result in regards to the collector's area given that using a larger collector area would not necessarily improve the system's performance based on the results comparison of Ubani and Adejare (2022) and Rikoto and Garba (2015). For instance, the difference can be due to the total volume of water heated up and the time taken by the fluid to move from the entrance of the sensor to its exit point.

5. Conclusion

Due to the weather conditions in Nsanke village, we carried out the design and construction of a TSWH. The materials for the system's design were selected considering design calculations, market availability and cost of the materials. Based on Thermosyphon principle, we designed and sized the major components of the system. The system is made up of two flat-plate collectors of 1.68m^2 each, consisting of absorber plate carrying copper tubes and placed in an insulated casing with a transparent glass cover of 4*mm* thickness. The collectors are connected in series and are assume to operate on the same efficiency. The resultant collector is connected to a storage tank, which is an association of two barrel nested overall and separated with an insulator. The radiation emitted by the absorber plate cannot escape through the glass, thus increasing its temperature. Performance evaluation results of the TSWH has shown that the water heater system can heat up water from 23℃ to at least 51℃ during the dry and sunny days when the irradiance levels are higher. This Solar Water Heating system finds useful application and acts as a renewable energy resource in Nsanke village and neighboring villages. However, the authors highlight the problem of sealing at the level of the connections between the boiler and the storage tank, which deserves to be taken into account in future research works.

Acknowledgments

Not applicable.

Authors contributions

All authors made significant contributions to the conceptualization, design, data collection, data analysis, manuscript writing and editing, manuscript translation and proofread. Paulin Marvel Djimeli and Clautaire Mwebi Ekengoue conceptualized and designed the study. Paulin Marvel Djimeli, Marie Danielle Fendji and Denis Djiyo designed the data collection tools and conducted the study. Clautaire Mwebi Ekengoue and Richard Vivien Youagam conducted manuscript writing and editing, and manuscript translation and proofread. Clautaire Mwebi Ekengoue and Marie Danielle Fendji gave overall guidance for the study. All the authors gave final approval to the manuscript for journal submission and are responsible for the content of the manuscript.

Funding

Not applicable.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Macrothink Institute.

The journal’s policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

Open access

Copyrights

References

Abanda, F. H., Manjia, M. B., Cole, E., & Mempouo, B. (2014). The potential of efficient improved Mud-Brick Cookstove in Cameroon: An exploratory study. *Environmental management and sustainable development, 4*(1), 106. https://doi.org/10.5296/emsd.v4i1.6715

Diallo Sy Alioune, D. S. Y. (2007). *Conception et réalisation d'un chauffe-eau solaire*. Final Year Project submitted in the Department of Mechanical Engineering for the award of Master of Engineering, Option Mechanical Engineering at the Cheikh Anta Diop University, Dakar, Senegal.

Asangwe, C. K. (2006). *The Douala Coastal Lagoon Complex, Cameroon: Environmental Issues*. In *Administering Marine Spaces: International Issues*. FIG publication 36.

Ayompe, L. M., & Duffy, A. (2013). An assessment of the energy generation of photovoltaic systems in Cameroon using satellite-derived solar radiation datasets. *Sustainable Energy Technologies and Assessments,* 1. https://doi.org/10.1016/j.seta.2013.10.002

Blaabjerg, F., & Ionel, D. M. (2015). Renewable energy devices and systems—State-of-the-art technology, research and development, challenges and future trends. *Electronic power components and systems, 43*(12), 1319. https://doi.org/10.1080/15325008.2015.1062819

Darwish, A. S., & Al-Dabbagh, R. (2020). Wind energy state of the art: Present and future technology advancements. *Renew. Energy Environ. Sustain.,* 5(7), 1. https://doi.org/10.1051/rees/2020003

Day, A. H., Babarit, A., Fontaine, A., He, Y.-P., Kraskowski, M., Murai, M., Penesis, I., Salvator, F., & Shin, H.-K. (2015). Hydrodynamic modeling of marine renewable energy devices: A state of the art review. *Ocean Engineering, 108,* 46. https://doi.org/10.1016/j.oceaneng.2015.05.036

Falcone, P. M. (2023). Sustainable energy policies in developing countries: A review of challenges and opportunities. *Energies, 16*(18), 6682. https://doi.org/10.3390/en16186682

Flora, F., Donatien, N., Donatien, N., Tchinda, R., & Hamandjoda, O. (2019). Impact of sustainable Electricity for Cameroonian Population through Energy Efficiency and Renewable energies. *Journal of Power and Energy Engineering, 7,* 11. https://doi.org/10.4236/jpee.2019.79002

Fotsing, F. I. M., Njomo, D., & Tchinda, R. (2014). Analysis of demand and supply of electrical energy in Cameroon: Influence of meteorological parameters on the monthly power peak of South and North interconnected electricity networks. *International Journal of Energy and Power Engineering, 3*(4), 168. https://doi.org/10.11648/j.ijepe.20140304.12

Gamba, J. R., et al. (1986). *Inchtrial hergy RatiOIYI/izattzattmon Dewloping Counmes*. Baltimore: The John Hopkins University Press.

Ho-Yan, B., Lubitz, W. D., Ehlers, C., & Hertlein, J. (2014). Field investigations in Cameroon towards a more appropriate design of a renewable energy pico hydro system for rural electrification. In J. C. Bolay, S. Hostettler, & E. Hazboun (Eds.), *Technologies for Sustainable Development* (pp. 43). https://doi.org/10.1007/978-3-319-00639-0_5

Kenfack, P. U. E. (2017). Urban and peri-urban agriculture in Cameroon: Status and perspectives for development. *Int. J. agron. Agri.*, 11(3), 116.

Kidmo, D. K., Deli, K., & Bogno, B. (2021). Status of renewable energy in Cameroon. *Renew. Energy Environ. Sustain.*, 6(2), 1. https://doi.org/10.1051/rees/2021001

Koholé, Y. W., Fohagui, F. C. V., & Tchuen, G. (2022). A holistic overview of Cameroon renewable energy sources: Potentials, achievements, challenges and perspectives. *International Journal of Ambient Energy, 43*(1), 7308. https://doi.org/10.1080/01430750.2022.2068065

Kwaye, M. P., Bendfeld, J., & Anglani, N. (2015). Assessment of renewable energy resources and the use of hydropower for fluctuation compensation in Cameroon. In *5th International Youth Conference on Energy*.

Maka, A. O. M., & Alabid, J. M. (2022). Solar energy technology and its roles in sustainable development. *Clean Energy, 6*(3), 476. https://doi.org/10.1093/ce/zkac023

Manjia, M. B., Abanda, F. H., & Pettang, C. (2014). Household Energy appliances in Cameroon. *Environmental management and sustainable development, 4*(1), 73. https://doi.org/10.5296/emsd.v4i1.6716

Minerva, F.-M. (1999). *The use of solar water heaters in Mexico city*. School of architecture, McGill University, Montreal, Quebec. A thesis submitted to the faculty of graduate studies and research in partial fulfillment of the requirements of the degree of Master of Architecture.

Muhammad, S. M., Hafiz, M. M., Shenxian, Z., Mannan, H., Muhammad, U., Ahmad, A., & Basem, A. (2022). A comprehensive analysis of the power demand-supply situation, electricity usage patterns and the recent development of renewable energy in China. *Sustainability, 14*(6), 3391. https://doi.org/10.3390/su14063391

Mungwe, J., Mandelli, S., & Colombo, E. (2016). Community pico and micro hydropower for rural electrification: Experiences from the mountain regions of Cameroon. *Aims Energy, 4*(1), 190. https://doi.org/10.3934/energy.2016.1.190

Munongo, V. G. N. (2012). *La mise en œuvre du mécanisme pour un développement propre au Cameroun : le cas du projet Hysacam*. Mémoire online, Université Catholique d'Afrique Centrale. Retrieved from https://www.memoireonline.com/03/12/5601/La-mise-en-oeuvre-du-mecanisme-pour-un-developpement-propre-au-Cameroun--le-cas-du-projet-HYSACAM.html

Ogie, N. A., Oghogho, I., & Jerumirewhe, J. (2013). Design and construction of Solar Water Heater based on the Thermosyphon principle. *Journal of Fundamentals of Renewable Energy and Applications, 3,* 1. https://doi.org/10.4303/jfrea/235592

Ou, Y., West, J. J., Smith, S. J., Nolte, C. G., & Loughlin, D. H. (2020). Air pollution control strategies directly limiting national health damages in the US. *Nat Commun, 11*(957), 1. https://doi.org/10.1038/s41467-020-14783-2

Parker, D. S., Fairey, P. F., & Lutz, J. D. (2015). Estimating daily domestic hot-water use in North American houses. *ASHRAE Transactions, 121*(Part 2), 1. AT-15-021.

Puiu, S., Udristioiu, M. T., & Velea, L. (2022). Air pollution management: A multivariate analysis of citizens' perspectives and their willingness to use greener forms of transportation. *Int. J. Environ. Res. Public Health, 19*(21), 14613. https://doi.org/10.3390/ijerph192114613

Rauf, Q., Li, Y., & Ashraf, A. (2024). Exploring sustainable energy futures: Assessing the viability of CanmetENERG's hydropower initiatives in Cameroon. *Journal of Power and Energy Engineering, 12*(7), 1. https://doi.org/10.4236/jpee.2024.127001

Rikoto, I. I., & Garba, M. M. (2015). Design, Construction and Installation of 250-Liter Capacity Solar Water Heating System at Danjawa. *Renewable Energy Model Village, 4*, 39.

Ruiz, A., Morillon, D., & Munoz, F. (2014). Renewable energy devices in ecological park. *Energy Procedia, 57*, 957-964. https://doi.org/10.1016/j.egypro.2014.10.078

Sofia, D., Gioiella, F., Lotrecchiano, N., & Giuliano, A. (2020). Mitigation strategies for reducing air pollution. *Environ Sci Pollut res, 27*, 19226. https://doi.org/10.1007/s11356-020-08647-x

Tamba, J. G. (2017). An analysis of Cameroon's energetic system, 2001-2010. *Energy Sources, Part B: Economics, Planning, and Policy, 12*(3), 216. https://doi.org/10.1080/15567249.2015.1060547

Tidze, V. C., Ibrahim, M., & Issac, T. (2016). Dynamics of household energy and cooking stoves in Maroua, Far North Region of Cameroon. *Journal of Scientific Research and Reports, 9*(4), 1. https://doi.org/10.9734/JSRR/2016/21548

Timme, M. J. E. (2016). *Enhancing urban energy security through renewable energy solutions*. Case study, Douala Cameroon. Master's Thesis in Environmental Technology, Lahty University of Applied Sciences Faculty of Technology.

Ubani, A. C., & Adejare, O. G. (2022). Design and Construction of a domestic portable Solar Water Heater. *International Journal of Advances in Engineering and Management, 2*(7), 98. ISSN: 2395-5252

Weller, S., Johanning, L., & Davies, P. (2013). *Best practices report—mooring of floating marine renewable energy devices*. A report prepared as part of the Merific project "Marine energy in far peripheral and island communities". Retrieved from http://www.merific.eu/files/2012/06/D3.5.3_Best-practice-report-mooring-of-floating-marine-renewable-energy-devicesv21.pdf