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An Analytical Study of the Potential of Domestic Solar Hot Water usage in Egypt

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Abstract

The renewable energy resources (specifically the solar power) is one of the main concerned applications to achieve energy efficiency in the whole world. Since Egypt has an excellent solar energy availability with the annual global solar radiation between 900-2600 kwh/m2, [1] therefore, solar thermal technologies are identified as one of the thrust areas for development. Solar Hot Water System (SHWS) is one of the main solar thermal technologies promoted by the government [1]. This paper is concerned with using the solar power efficiently to generate clean energy in Egypt. It aims to investigate the potentiality of using SHWS in Egypt. The research shed the light in on the specs, the process of designing and the cost benefit of using SHWS in Egypt.

Keywords: Renewables; Solar power; SHWS; Clean Energy; Solar heating; Designing SHWS

Introduction

At present, the main source of fuels in Egypt are the petroleum fuels (oil & natural gas) in addition , the hydro power contributes significantly to the electric generation 22.5% of the total electricity generated in 1998-99. Those non-renewable energy resources (oil & natural gas) would be inadequate to meet the future needs . The government of Egypt recognized the importance of using the renewable energy sources to generate energy in early eighties of the last decade & formulated a national strategy adapting the Renewable Energy Technologies (RETs) as an integral element of the national energy planning. Effective market penetration of RETs has been below expectations. Some barriers amended from using RETs efficiently. The barriers are:

a. Economic & financial barriers (high costs).

b. Awareness & information barriers.

c. Technical barriers.

d. Market barriers.

e. Social barriers.

f. Institutional & policy barriers.

(NREA, 2001) Although Egypt has an excellent solar energy availability, The total energy savings by RETs is about 0.4 Million Ton Oil Equivalent(MTOE) annually, and over 39% of it is from the implementations of the SHWS, industrial process heating and electricity generation (solar & wind), which justify the need for this research.

Hypothesis

Could the use of SHWS in Egypt conserve the need for consuming the non-renewable resources ? The BAC chart compares different major technologies for Energy Efficiency (EE) & Renewable Energy sources (RE). It shows horizontal (x axis) their potential for electricity savings in the country per year & vertical (y axis) their economic attractiveness compared to the avoided cost of electricity generated by fossil fuel. The electricity saving potential of the technologies below the O-line can be achieved with combined cost savings , those above the line need additional funding to compensate for the balance of electricity cost saved and cost of the technologies. The data research and calculations for the BAC have been conducted with the Natural Renewable Energy Authority (NREA) of Egypt, (Figure 1). The objective of this paper is to use the solar power efficiently to generate energy in Egypt. Therefore, the paper aims to investigate the potentiality of using solar power SHWS in Egypt. To achieve this, aim the following Methodology is adapted:

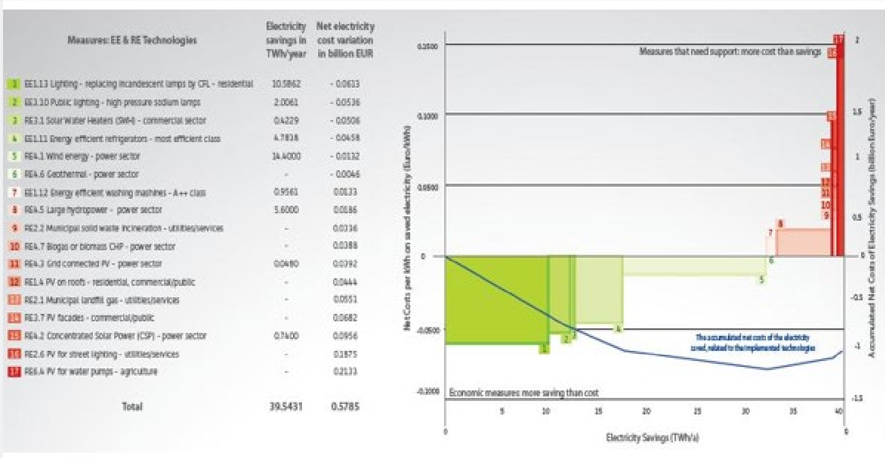

Figure 1: Budget Allocation Chart (BAC) :Egypt until 2020.

i. Define the solar hot water system.

ii. Review the types of SHWS that can be used in domestic house buildings.

iii. Present the guidelines of designing an optimum SHWS .

✓ Case study: A chalet in Ain- Sukhna , Egypt, that implemented SHWS in generating energy.

Definition of Solar Hot Water System

Solar thermal power has two main parts :Solar heating SHWS and Solar Thermal Electricity. The SHWS is the system that gathers energy from solar radiation and turn it into heat that is then distributed in the form of hot air or water to where it is to be used or stored until needed [2-4].

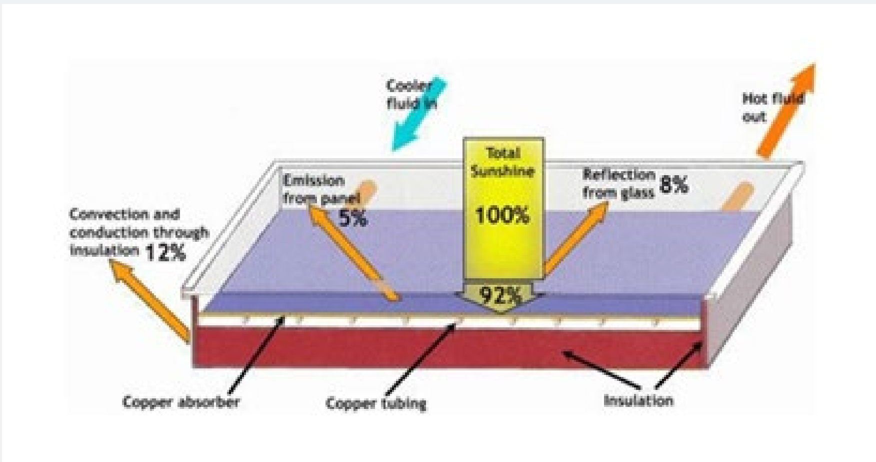

Figure 2: Flat plate collector.

- Flat plate collector: consist of metal plates coated matt black behind glass or plastic. They are tilted to maximize uptake for solar radiation. Behind the plates are pipes carrying out the heat absorbing medium, either water or air. Water for indirect systems contains anti-freeze. The underside of the plates is insulated. Flatbed collectors realize temperature around 35 C and are best employed to supply pre-heated water for gas boiler or immersion heater as shown in (Figure 2) [3]. The angle of inclination of the sun to the surface of the array is closest to 90 degrees which will minimize reflectance [2].

- Evacuated tube collector: The vacuum tube collector uses a series of glass tubes that act like thermos bottles. The glass allows the light through, which heats up the fluid inside the inner tube. The vacuum between the layers of glass prevents that heat from escaping back to the atmosphere on cold days. Because the losses are so small, evacuated tube collectors can deliver heat even by very low irradiance levels occurring in winter and during overcast periods .The individual tubes can be rotated to an optimal absorber tilt angle. The pipes should have an adequate separation avoiding one shadowing the next. Heat pipe collectors need to be mounted with a slight tilt to allow for the gravity flow as shown in (Figure 3) [2,5].

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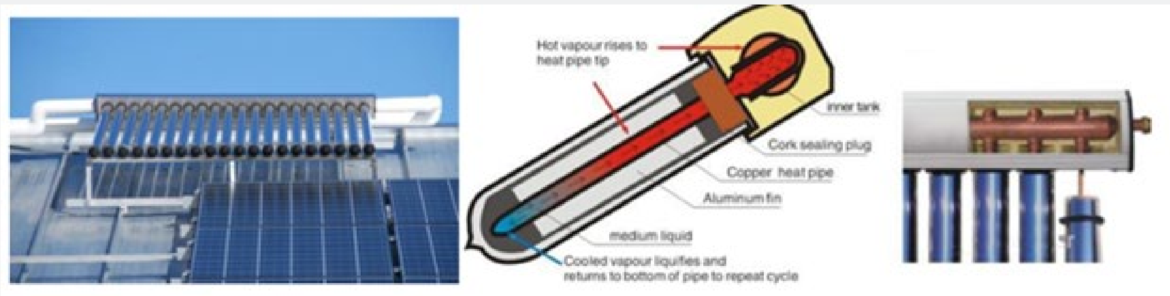

Figure 3: Evacuated Tube Collector Mechanism.

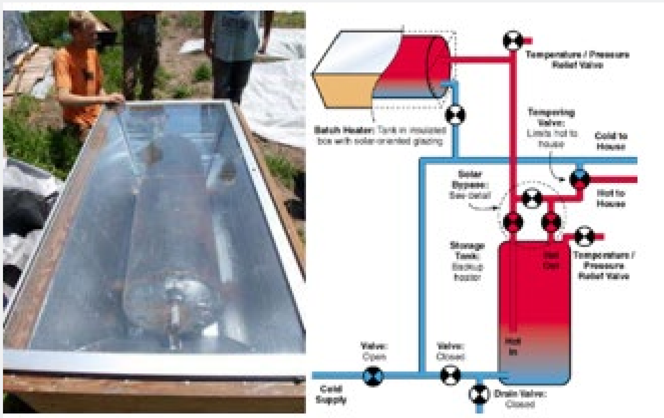

Figure 4: Batch solar heater diagram.

- Solar batch water heater collector: Cold water, which normally goes to the bottom of your conventional water heater, is detoured to the batch heater first. There it bakes in the sun all day long and is preheated to whatever temperature the sun is able to provide. Water only flows when used. House water pressure causes the supply of new cold water to flow to the inlet of the batch heater, the lower of the two ports. At the same time, the hottest water exits from the higher port. It flows to the input of the existing water heater, which now serves as a backup to finish the heating job as required. Solar preheated water has become the cold-water input to the existing water heater as shown in (Figure 4) [6].

The main solar collector specifications:

a. Copper water tubes and headers in the collector are necessary if any water solution is to be used as the heat transfer liquid.

b. The absorber plate is made of copper, aluminum or steel and bonded to the water ways.

c. The sides and the back of the solar collector that don't face the sun should be insulated to prevent heat loss and covered in a weather-tight enclosure as shown in Figure 5 [4].

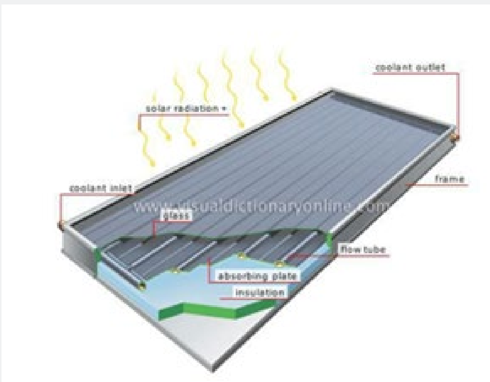

Figure 5: Solar collector.

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d. An emergency pressure relief valve at the highest point on the top collector is required to avoid pressure extremes beyond the rating of the thermal collectors [7].

The Heat Distribution System

These are the pipes that circulate hot water from the collector to its storage tank or point of use. It is by circulating water through the solar collectors that the absorbed energy is brought to the point where it will be used. Water can be moved round the system in one of two ways: gravity circulation (thermosyphon) and forced circulation. The decision to use or not to use a pump is one of the first steps in planning a solar system [4].

Direct system

Direct system is one where the tap water is circulated directly through the solar collector:

- These systems have less storage transfer loss.
- Long-term scaling and corrosion of components can occur with aggressive water types, possibly increasing transfer loss.
- Non-chemical methods of preventing damage by freezing water are required in many climates.
- In hot and sunny areas, the direct system allows for a cheap, simple method via a black painted metal tank on the roof, absorbing solar radiation to heat the water during the day for domestic use in the evening.

Indirect system

Indirect system is one that employs a separate fluid circuit to transfer heat from the solar collector to the store:

- Permits use of anti-corrosion inhibitors and anti-freeze (food-grade polypropylene glycol) that permits a wide range of materials to be employed in the absorber and the pipe work.
- These systems usually have higher initial purchase costs but less risk of corrosion or bursting.
- Allows higher temperature collection
- Reduces disposition of solids within collector during stagnation [4].

Circulation Systems for Hot Water

A Natural Thermosyphon System

The solar energy heats the water that rises above the cold water creating a thermosyphon pressure which can drive a fluid movement through an inclined pipe. The store should be located at least 0.5m above the collector, even for short pipe runs. Requires careful planning and installing for the pipe routs and the collector types. Is a simple low cost system. No standby electrical losses. Inactive performance interim weather conditions. Poor control of overheating as shown in Figure 6 [3,4].

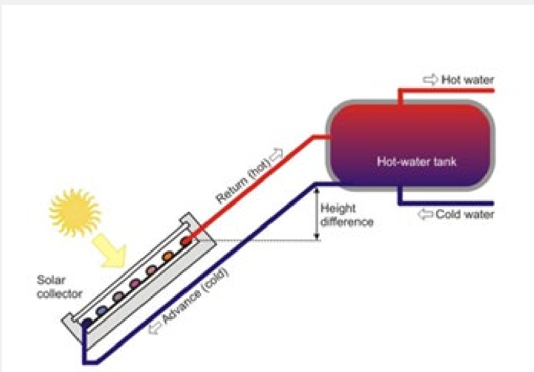

Figure 6: Thermosyphon system mechanism.

Pump system

The power to move heat between collector and store is derived from an electrically driven pump (as shown in Figure 7) which:

i. Allows greater choice of collector and pipe layout. Removes the heat from the collector at the optimum rate. Reduces heat loss through pipes.

ii. Permits overheat control and integral frost-protection. Makes it possible to accurately calculate heat flow.

iii. Costs more than thermosyphon system as there are more parts to moving to wear out. Requires pump control when used with AC mains entailing standby losses.

iv. Has option of direct PV pumps [4].

Active systems

Can be open loop or closed loop in which the circulating fluid passes through a coil heat exchanger within the storage tank [3].

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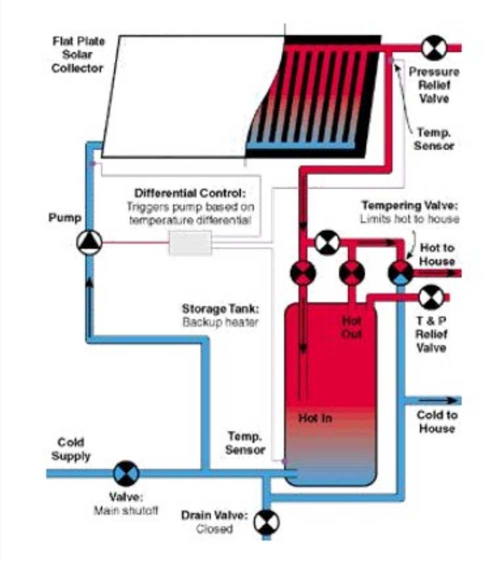

Figure 7: Pump circulation system.

The hot water store (Tank)

Heat storage is a key feature of the solar hot water system. Without it the hot water would be available only when the sun is actually shining. A storage tank allows the solar system to operate whenever energy is available and to supply the energy when it is needed. The heat absorbed in the collector passes into the water in the tank and heats it up.

- The tank can be sized to hold enough heat for 24 hours, so that the water heated during the day can be used in the evening.
- A larger store can be gradually heated up over hot days and retain that heat through the following cloudier ones.
- A heat exchanger will be needed with the tank if an indirect system is chosen. This serves to separate the fluid flowing though the collectors from the water flowing to the tap inside the house.
- The tank should have a minimum of 50mm of mineral fibre quilt or equivalent should be sought.
- Proper sizing of the tank is essential for defining the strategy for collector, heat distribution and circulation design and maybe likened to the safety of the whole system as shown in Figure 8 [4,7].

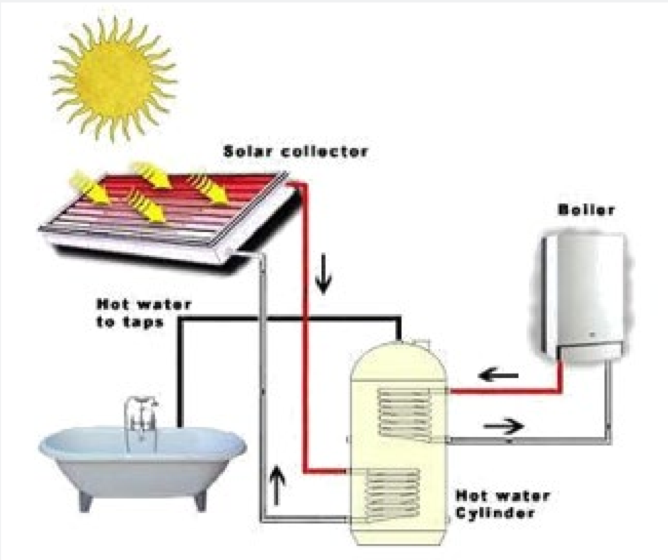

Figure 8: SHWS Tank (http://solarcoloradoinfo.com/7.html).

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Tank location

- ➢ It could be in or next to the bathroom.

- ➢ Preferred the most in the basements or on the top of the roofs, cause the insulated building interior is a very expensive volume to sacrifice for a tank.

- ➢ Pipe runs from the tank should be within the heated house envelope as much as possible to keep circulation heat loss small [5].

The process of designing SHWS

There are many different types of SHWS available with different features, capabilities and costs. It gets to an efficient result to follow the steps described to get the optimum SHWS.

Identifying the Variables

Hot Water Usage: Hot water usage per person varies by countries for example in 40-60 litre UK, 55-110 litre US, 50 litre Australia, 50 litre Egypt [1,4,7].

Collector and Storage (Tank) Capacity: In UK for a single-family house (approx: 150 m2, 4 persons) Collector area = 1.3-2.5 m2/person, 5-10 m2/house Tank volume = 100-150 L/person, 400-600 L/house (Wall, 2009)

Hot Water Type: Can limit some choices of tank and collector. Therefore, choosing the system depends on: Most commercially available collectors operate within 20% of each other's energy conversion rate.

- ➢ Often higher costs reflect the higher efficiencies and durability of products. Take care that packaged systems have not reduced quality of system components simply for the gain of initial cost or reduced installation time.

- ➢ Appearance of the collector.

- ➢ Local conditions may restrict choice.

- ➢ Some collector's types cannot simply be switched off when the store becomes hot enough. Choosing a collector that is designed to repeatedly allow this upon demand is more optimum [4].

- ➢ Tanks with temperature sensors would be very helpful by examining the transition between the hot upper layer and the cold lower layer, getting an idea of how much hot water is in the tank that could be drawn off [7].

Climate /isolation: Minimum and maximum ambient temperatures and isolation affects collector and tank choices.

I. A high differential, above 7C between collector and tank, is appropriate where system losses in pipe work are high.

II. Sensors must be used to monitor the temperatures and control pumps.

III. The high sensor should be located so as to best represent the temperature of the collected solar energy, i.e. immersed in the collector waterways.

IV. The low sensor should represent the temperature of the stored water, i.e. immersed inside the lower part of the store [4].

V. Using good isolation materials in the system (collectors, tank and pipes) reduces the heat loss.

Position

a. In installing the solar collector

b. At ground level.

c. As canopies on the outside walls of buildings, above sunspaces or as sunshades above flat roofs.

d. On a sloping reef.

e. On an angled collector supports on flat roofs or walls.

f. Flat horizontally or vertically where the collector design permits rotation of tubes.

g. Do not put the collector in a position shaded from the sun by the building or adjacent trees.

h. Best inclined 45degrees towards the south specially when using a thermosyphon system because the water tank still needs to be above the collectors.

i. Sometimes it can operate well even when laid flat, due to the abundant sunshine.

SHWS (Domestic use) Financial Cost Analysis in Egypt (NREA, 2001)

i. Based on the data collected in the companies' investments in this field:

ii. A typical unit (150litres & 2m2) currently costs between 1800 to 2200 LE, where a similar conventional domestic electrical water heater currently costs about 400 LE.

iii. The estimated annual electrical energy savings for a typical Domestic SHWS ranged from 1400-1800 kWh. Using midpoint 1600 kWh can be saved annually.

iv. The present residential electrical prices for kWh are 0.083 LE/kWh.

v. The reduction of the annual purchase of electricity by using Domestic SHWS can be estimated to be: 1600 kWh/year * 0.083 LE/kWh= 132.8 LE/year

vi. The estimated lifetime of the system is about 20 years, hence the Domestic SHW typical system can save: 132.8 LE/ year * 20 = 2656 LE.

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vii. Assuming the price of the Domestic SHWS is: 1800 LE. The incremental cost of Domestic SHWS compared to conventional Domestic water heater is :

viii. 1800 LE- 400 LE= 1400 LE

ix. The payback period for Domestic SHWS will be : 1400 LE / 132.8 LE/year=10.5 years.

NREA noticed that this analysis indicates that the present initial cost is very high (which is recognized as one of the main barriers). The payback period associated with the initial cost is too long. It recommends If the optimum production rate was achieved (3000-5000 system annually), and then the prices will range from 1000-1300 LE. This will yield to a payback period from 4.5 to 6.7 years, which is relatively accepted if the system performance was guaranteed.

(NREA, 2001)

Case Study: A Chalet in Ain – Sukhna, Egypt

The existing situation: The chalet is located in Ain- Sukhna on the Gulf of Suez. The total area of the chalet is 64 m2 plus 60 m2 for the terrace and garden shown in (Figure 9).

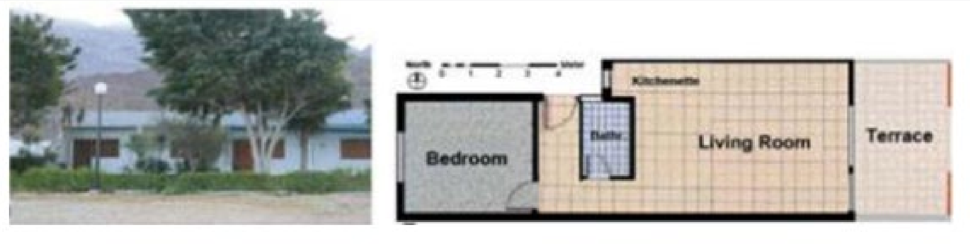

Figure 9: The chalet outside view and detailed plan.

Household annual energy consumption is: 3486 kWh.

Hot water proportion of the annual energy consumption is: 427 kWh.

Domestic SHWS used specifications

- 2m^2 collector area, NGO-150 Solar Thermosyphon (150 litre's)
- Collector installed on the roof, inclined to the south with a tilt angle of 42 degree.
- Cost :935$
- The expected energy produced is 1224 kWh
- Mentioning that the system will be turned off during the summer, assumption was taken that 60% of the total energy production of the system will not be achieved = 734 kWh.
- The energy production used from the system:1224-734= 490 kWh
- Assuming that the system will work efficiently in the other seasons in an average of 66%.
- Given that the SHWS used saved 317 kWh
- So instead of paying for(427 kWh = 115 LE), it's going to be (110= 19 LE)

Results

1. Oversized Thermosyphon system SHWS comparing with the demand of the chalet.
2. High cost for purchasing the system (935$ = 5610 LE).
3. Using 2m2 collector area, high amount of production comparing with the usage of hot water.

Conclusion

The use of SHWS in Egypt conserves a considerable amount of the need for consuming the non-renewable resources effectively.

a. There are many factors that affect the choices of types for SHWSs such as the size of the hot water usage, the place for installation and the budget for purchasing the system.

b. Average family persons in Egypt = 3-5 persons.

c. Average hot water usage = 50litre's per person.

d. Most common SHWS used is Flat Plate Collectors.

e. Common SHWS size = 150-300litre's for the tank, 2-4 m2 for the collector.

f. Total price of SHWS =1800-2200 LE estimated by NREA, other sources estimated the price with 4000 LE for a Thermosyphon Galvanized steel Tank 180litres.

g. Total energy cost per month= 15-80 LE, according to living standards.

h. Savings due to SHWS usage = 5-20 LE / month.

Discussion

Noticing that NREA mentioned the average cost of a typical unit of SHWS is between 1800-2200 LE. Also, It was mentioned in the paper for" Egyptian-German Private Sector Development

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Programme (PSDP)" the price with 4000 LE for a Thermosyphon Galvanized steel Tank 180litres. On the other hand, in the Case Study: A Chalet in Ain- Sukhna, the cost of the SHWS used his 953 $ equivalents to 5610 LE. There is a big variation between the three costs, so is NREA underestimating the prices?? Or the user of the Chalet picked the wrong type of SHWS? In the book "Sustainability Solar Housing: Volume 1" it was mentioned that for a single-family house (approx: 150 m2, 4 persons), Collector area = 5-10 m2/house, Tank volume = 400-600 L/house. On the other hand, NREA mentioned concerning the same issue that a family with 3-5 persons, collector area 2-4 m2, tank volume= 150-300 L. There is too a big variation between the two results, is it due to the difference in the climate and the living standard between Egypt and UK?

Recommendations

a. Financial support from the government and private sectors to the SHWSs needs to be put in place. Availability of credit facilities with low interest rates and reduction in SHWS prices to make it competitive with other alternatives is equally important.

b. Encouraging local manufacture of SHWS by reducing taxes and customs duties on solar water heating system components.

c. Current manufacturing standards and specifications should be revised to include quality control and assurance components and installation requirements.

d. Simplicity: because little energy is needed and the required heating power is low, the system investment cost should reflect this. Simple systems are also more likely to be reliable and less prone to being falsely set during installation or by the occupants.

e. Development of effective public awareness and promotion programmes that are prepared based on market surveys and studies.

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