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# Optimal Design & Analysis of Solar Water Heating System using Solar Factors for Energy Efficiency & Thermal Performance

**P. Veeraboina[a], G.Yesuratnam[b]**
[a] Electrical Engineering Section, Engineering Department, CDFD, Dept., of Biotechnology, MoS&T, India
v_m2004@hotmail.com
[b] University College of Engineering, Campus, Osmania University, Hyderabad, India
ratnamgy2003@yahoo.co.in

## Abstract
Solar water heating systems usually cost more to purchase and install than conventional water heating systems. However, a solar water heater can usually save money in the long run. Many factors are involved for a detailed analysis of a solar flat plate collector (FPC). The important subsystems are: solar collectors, fluid transport and distribution systems, hot-water storage container, and its control systems. Solar Water Heating (SWH) System has the potential to reduce household energy consumption by more than 50%. SWH make use of freely available solar energy to preheat water before it enters in to a conventional water heaters (electric or gas); there by substantially reducing energy usage and expenditure. By the current research, many efforts have been made to combine a number of the most important factors (Solar Energy Factor, Solar Fraction and Energy Factor) into a single equation for estimating the energy (thermal) efficiency and also analyzed the cost for various systems as compared with conventional systems. The process used is to rate solar water heating performance by the use of energy factors, the same efficiency rating used for electric and gas heaters.

**Key Word and Phrases**
Solar Fraction, Energy Efficiency, Solar Energy Factor, Thermal Analysis, Energy Factor, Solar Rating & Certification Corporation (SRCC), Solar Energy Factor (SEF), Conditioned Floor Area (CFA).

## 1. Introduction
Solar thermal technology has existed since at least the time of the ancient Greeks, who designed their homes to capture the winter sun. SWH is one of the simplest and oldest ways to harness renewable energy and can contribute both to climate protection and sustainable development efforts. Today, the global SWH market is growing rapidly. Over one-third of homes in Metropolitan cities are equipped with SWH systems. SWH is considered among the country's most commercialized renewable energy technologies. Increasingly, hot water is seen as a fundamental aspect of a healthy and hygienic life, and demand for it is growing steadily.

Solar Water Heating is now a mature technology. Wide spread utilization of solar water heating systems can reduce a significant portion of the conventional energy being used for heating water in homes, factories and other commercial & institutional establishments. There has always been a gap between supply and demand of electricity in India especially during peak summer and winter seasons. The situation further worsens during early hours of the peak winter season when enormous heating load is switched 'ON'. This has been a consistent problem. If the heating load is switched over to non-conventional sources of energy from conventional energy sources; the gap can be bridged considerably. Therefore, 'Solar Energy' is an unlimited source of renewable energy. Solar Energy, if utilized, shall not only bridge the gap between demand and supply of electricity, it will also help in reducing pollution and maintenance of eco balance.

## 2. Literature survey

In the SWH system the solar radiation is absorbed by flat plate collectors (FPC) which consist of an insulated outer metallic box covered on the top with glass sheet. Inside it are blackened metallic absorber sheets with built in channels or riser tubes to carry water. The absorber sheets absorb the solar radiation and transfer the heat to the flowing water. The flowing hot water is then collected in the storage tank.

These systems have long life (15- 20 years) and work efficiently especially in non-hilly regions and regions, where water quality is good. For other regions Heat-exchangers are required. Such systems are available in multiple of 100 LPD (Liters per day) i.e. 100,200,300 LPD etc.

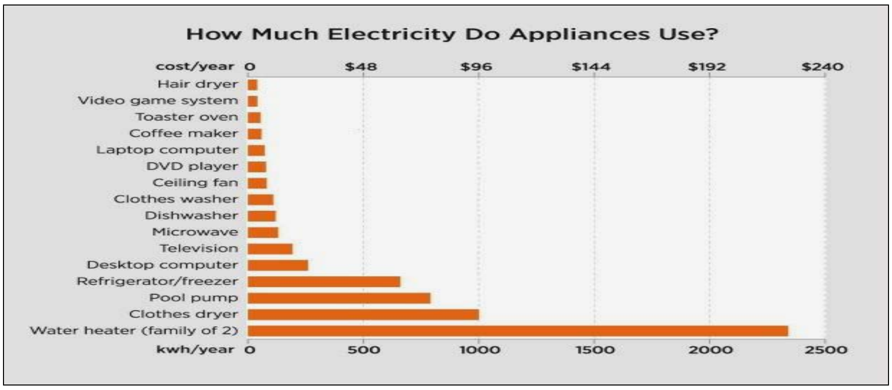


**Fig.1** Typical appliance uses per year.

The heighest contribution of consuming power is a water heaters. Fig 1, shows how much energy a typical appliance uses per year and its corresponding cost based on national averages.

**Electricity/ Diesel Savings:**

i. A 100 LPD system installed in a home can save 4-6 units of electricity/day depending on the place of installation & hot water use. On an average it could be taken as 5 units per day. Maximum average saving with 300 clear days, therefore, could be taken as 1500 units/year.

ii. Assuming 300 days of solar hot water use in Bangalore and 150 days in Delhi in India, the savings could be 1500 & 750 units per year respectively i.e. replacement of a 2 kW electric geyser working for 2.5 hours in a day. Considering all parts of the country and maximum installations in areas where hot water requirement is more during the year, average savings could be taken as 1200 units/year/100 LPD system.

iii. One million such systems installed will be able to save 1200 million units of electricity/year.

iv. A 100 LPD system installed in an industry can save around 140 liters of diesel in a year.

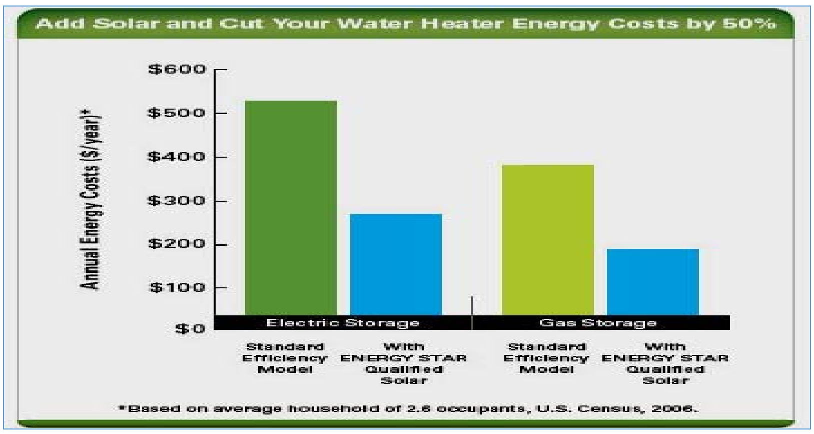


**Fig.2** Stadard efficiecy model.

On average, the water heating bills can be reduced to 50%-80%. Also, because the sun is free, the future fuel shortages and price hikes can be protected.

The following factors are influenced in money savings:

- Systems performance.
- Amount of hot water utilization.
- Available financing and incentives.
- Geographic location and solar resource.
- The cost of the fuel use for the backup water heating system, if have one.
- The cost of conventional fuels (electricity, natural gas and oil).

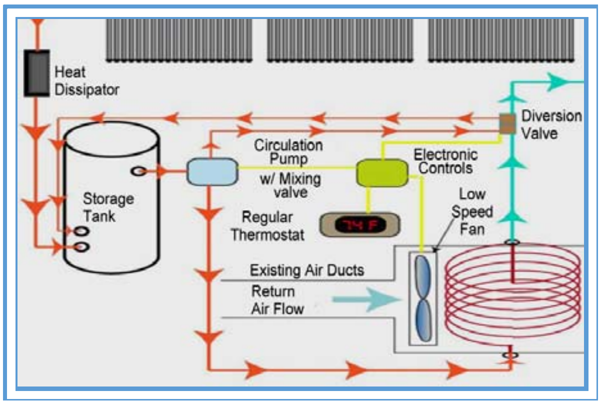


**Fig.3** Schematic diagram of the SWH system.

Fig.3 shows the controls of the system like temperature, flow and storage by using thermostates, valves and level gauges respectively.

The technology of SWHs is not very complex, but it has certainly advanced from simple design to more efficient systems. Resource assessment, technological appropriateness and economic feasibility are the basic requirement of project evaluaion. Innovations have been made brodly in areas such as type of collector; loaction of collector and loaction of the storage tank in relation to the collector, as well as in the method of heat transfer (that is, open-loop or closed-loop with heat exchanger) [1]. When selecting a heat-transfer fluid, the one should be consider the coefficient of expansion, viscosity, thermal capacity, freezing point, boiling point and flash point.

In cold climate, SWHS require fluids with low freezing points. Fluids exposed to high temperatures, as in a desert climage, should have a high boiling point. Viscosity and thermal capacity detemine the amount of pumping energy required. A fluid with low viscosity and high specific heat is easier to pump, because it is less resistant to flow and transfers more heat. Other properties that help to detemine thte effectiveness of a fluid are its corrosiveness and stability. Greater use would increase the use of electrical back-up and so reduce the enrgy savings. However, it should be noted that the usage paterns for piped hot water in low-income areas is not well understood [2].

**OG 300 Protocol**

The process for rating and certifying SWHS under the OG 300 protocol includes five steps each system being rated. Fig 4 explains the process [7].

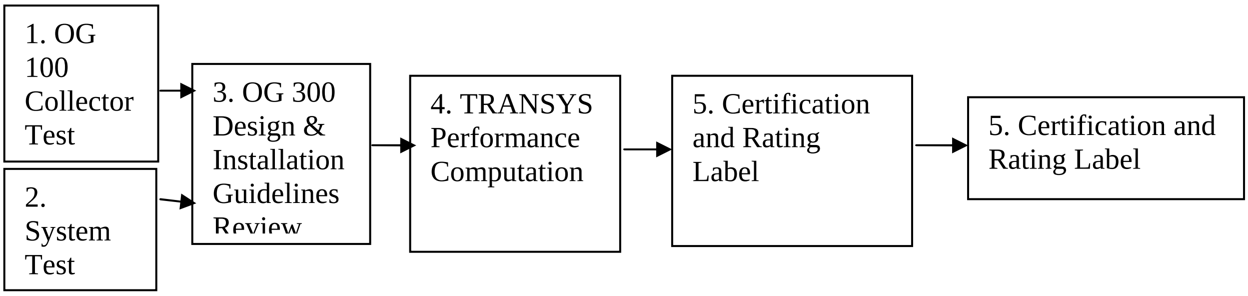


**Fig.4** SRCC OG-300 Test and Certification Process.

- The collectors which are part of the system must be tested and rated under the OG 100 protocol.
- Passive systems in which the collector can not be tested separately must be rated and certified under a system test protocol.
- The complete specified system of collectors, tanks, pumps, motors, valves, piping, etc., is evaluated for essential elements related to system design, projected durability and reliability, safety, operation and service procedures, installation guidelines and operation and maintenance manuals.
- Data from the OG 100 collector test, the system test, and review of design and installation guidelines are input to a computer program (TRNSYS).
- Numerical results of the design and insallation review (step 3) and TRNSYS evaluation are intergrated and entered on a certification to the supplier.

### 2.1 Thermal Performance Rating

The thermal performance rating is based on the system design and performance projections derived from testing of the collector components used in the system, or from testing and evolution of the system as a whole. The type of auxiliary system (electric or gas) utilized will have a large impact on the overall performance of the system. These differences arise because different types of auxiliary systems have varying standby losses and fuel conversion efficiencies. The gas backup systems have lower efficiencies and higher standby losses than do electric systems, it should be expected that the entire system's (including backup) performance will be lower, even if the solar output from both system types are equal.

SRCC uses the Solar Energy Factor as its performance rating for SWH Systems. The SEF is defined as the energy delivered by the system divided by the electrical or gas energy put into the system. The SEF is presented as a number similar to the Energy Factor given to conventional water heaters. Most rating programs require the equipment to be tested in accordance to a standard test with specified test conditions. This provides a repeatable performance within an accepted uncertainty band. There are, however, some rating programs which combine a standard test and a calculation procedure to produce a performance rating. Such is the case for the energy guide label for electric and gas residential hot water heaters. SRCC has used a similar method to develop a consumer friendly, practical rating system. The intent is to present to consumers and easily understood comparison between SWHS and conventional hot water systems. Note that the performance any individual consumer will experience may differ due to location and hot water usage. Additional location specific information on the performance of SRCC certified SWHS is provided in the SRCC directory of Annual Performance Ratings:

$$SEF = \frac{Q_{DEL}}{[Q_{DEL} + Q_{PAR}]} \quad (2.1)$$

where:
$Q_{DEL}$: Energy delivered to the hot water load: 43,302 kJ/day or 41,045 Btu/day (using the SRCC rating conditions).
$Q_{AUX}$: Daily amount of energy used by the auxiliary water heater or backup element with a solar system operating, kJ/day or Btu/day.
$Q_{PAR}$: Parasitic energy: Daily amounts of AC Electrical energy used to power pumps, controllers, shutters, trackers, or any other item needed to operate SWH System, kJ/day or Btu/day.

The Solar Energy Factor can be further converted to an equivalent Solar Fraction (SF) [3].
To convert to kWh, divide this value by 3,600 (3,412) and to convert therm, divide this value by 105,000 (1, 00,000).

$$SEF = 1 - \frac{EF}{SEF} \tag{2.2}$$

The EF for the SRCC standard electric auxiliary tank is 0.9 and for the gas tank is 0.6. in this context, the SF is the portion of the total conventional hot water heating load provided by solar energy. Note that an alternate definition of SF is often used.

In this alternate definition, SF is the portion of the total water heating load (losses are not included) provided by solar energy. The alternate method of calculating SF will yield higher SF. Therefore, use caution when comparing the SF for specific systems, inputs into energy codes to ensure that the same calculation procedure for solar fraction has been used.
The SF can be converted to an equivalent Solar Savings ($Q_{SOLAR}$) as follows:

$$Q_{SOLAR} = Q_{DEL}[\frac{1}{EF} - \frac{1}{SEF}] = SF * Q_{CONV} \tag{2.3}$$

where: $Q_{CONV}$: Daily amount of energy used by the auxiliary water heater or backup element without a solar system. The SRCC standard electric auxiliary tank has an energy usage of 47,865 kJ per day or 45,369 Btu/day.
The SRCC standard gas auxiliary tank has an energy usage of 72,203 kJ per day or 68,439 Btu/day.
EF: The EF is the ratio of delivered energy to input energy for the reference electric auxiliary tank without a solar contribution. The balance of the energy is lost to the surroundings due to standby losses and conversion efficiency.
$Q_{SOLAR}$: The Solar savings is the amount of the total conventional water heating load provided by solar energy minus any parasitic energy use.
In this context, the solar savings is the amount of the total conventional hot water heating load provided by solar energy minus any parasitic energy use.

### 2.2 Determining Energy Efficiency of a Solar Water Heater

The SEF and SF are used to detmine a SWH's energy efficiency. Solar Energy facors range from 1.0 to 11. The value of SEF is higher, then the system is more energy efficient. Systems with SEF of 2 to 3 are the most common.

Energy Factor is the ratio of useful energy output from the water heater to the total amount of energy deliverd to the water heater. Solar Fraction is the portion of the total conventional hot water heating load (delivered energy and standby losses) provided by solar energy. The highest the SF, the greater the solar contribution to water heating, which reduces the energy required by the backup water heater. The SF varies from 0 to 1.0. Typical SF are 0.5 -0.75. The selection of the SWHS not solely on the basis of its energy efficiency, but also consider the size and overall cost of the system.

## 2.3 Solar Fraction (SF) Calculator for Rated Systems

Total Conditioned Floor Area (CFA) $ft^2$: 2500, Climate Zone (1-16):3
Inputs for systems SRCC OG-300 [4]:

**Table 1** Solar fraction calculator for rated systems.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Enter Solar Energy Factor of OG-300 solar water heating system as listed in SRCC directory | **1.2** | **2** | **2.4** | **2.8** | **3.2** |
| 2 | Enter Energy Factor of Water Heater (enter 0.6 for gas0.9 for electric) | **0.90** | **0.90** | **0.90** | **0.90** | **0.90** |
| 3 | Constant - 41045 (amount of energy used in SRCC test ) | **41045.00** | **41045.00** | **41045.00** | **41045.00** | **41045.00** |
| 4 | Constant - 3500 average parasitic loss value in SRCC test | **3500.00** | **3500.00** | **3500.00** | **3500.00** | **3500.00** |
| 5 | Gallons per day use value calculated as: ( 21.5+0.014*CFA (from top of page) | **56.50** | **56.50** | **56.50** | **56.50** | **56.50** |
| 6 | Constant - 64.3 gallons used in SRCC test method | **64.30** | **64.30** | **64.30** | **64.30** | **64.30** |
| 7 | Constant - Hot water supply temperature 135 | **135.00** | **135.00** | **135.00** | **135.00** | **135.00** |
| 8 | Enter inlet water temperature (Inlet water temperature values are listed on Table 3 by climate zone ) | **57.52** | **57.52** | **57.52** | **57.52** | **57.52** |
| 9 | Difference in supply and inlet water temperature (subtract line 7 by line 8) | **77.48** | **77.48** | **77.48** | **77.48** | **77.48** |
| 10 | Constant - 1500 Solar radiation value used in SRCC test | **1500.00** | **1500.00** | **1500.00** | **1500.00** | **1500.00** |
| 11 | Solar radiation level from Table 3 | **1220** | **1220** | **1220** | **1220** | **1220** |

**Calculation for System:**

**Table. 2** Calculation of SF for a given rated system

| | | | | | | |
|---|---|---|---|---|---|---|
| 12 | Multiply line 2 by line 3 | **36940.50** | **36940.50** | **36940.50** | **36940.50** | **36940.50** |
| 13 | Divide line 12 by line 1 | **30783.75** | **18470.25** | **15391.88** | **13193.04** | **11543.91** |
| 14 | Divide line 5 by line 6 | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** |
| 15 | Divide the result in line 9 by 77 | **1.01** | **1.01** | **1.01** | **1.01** | **1.01** |
| 16 | Subtract 1 by line 2 | **0.10** | **0.10** | **0.10** | **0.10** | **0.10** |
| 17 | Multiply lines 13, 14 and 15 | **27219.28** | **16331.57** | **13609.64** | **11665.40** | **10207.23** |
| 18 | Multiply line 4 by line 16 | **350.00** | **350.00** | **350.00** | **350.00** | **350.00** |
| 19 | Add line 17 to line 18 | **27569.28** | **16681.57** | **13959.64** | **12015.40** | **10557.23** |
| 20 | Divide line 19 by line 3 | **0.67** | **0.41** | **0.34** | **0.29** | **0.26** |
| 21 | Divide line 10 by line 11 | **1.23** | **1.23** | **1.23** | **1.23** | **1.23** |
| 22 | Multiply line 20 by line 21 | **0.83** | **0.50** | **0.42** | **0.36** | **0.32** |
| 23 | Subtract 1 by line 22 | **0.17** | **0.50** | **0.58** | **0.64** | **0.68** |
| **Solar Fraction (SF)** | | **0.17** | **0.50** | **0.58** | **0.64** | **0.68** |

**Table.3** Climatic Zones with water Temperature and Solar Radiation

| Climate Zone | Water Temperature $^oC$ | Solar Radiation $w/m^2$ |
|---|---|---|
| 1 | 53.90 | 1220 |
| 2 | 57.52 | 1220 |
| 3 | 57.69 | 1533 |
| 4 | 59.12 | 1601 |
| 5 | 57.93 | 1602 |
| 6 | 61.55 | 1599 |
| 7 | 62.63 | 1586 |
| 8 | 62.97 | 1682 |
| 9 | 63.76 | 1685 |
| 10 | 63.76 | 1612 |
| 11 | 61.00 | 1580 |
| 12 | 59.65 | 1670 |
| 13 | 63.99 | 1726 |
| 14 | 61.48 | 1827 |
| 15 | 73.55 | 1884 |
| 16 | 50.54 | 1513 |

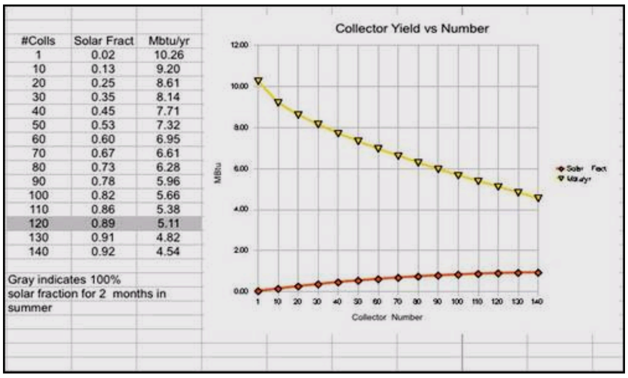


**Fig.5** Declining Per Unit Output for Solar Hot Water Systems.

The graph shows that as the number of collectors goes up, the yield per collector steadily decreases. Each additional collector makes all the others a little bit lazier. The cost is increases by addition additional collectors, spending more money and have the performance per collector going down. In any diminishing return situation, the question is where to stop.

Note that the monthly SF doesn't reach 100% (in June and July) until there are 120 collectors, and the annual SF is 89%. Each collector produces 5.11 MBtu/yr which is 37% less energy than a system with a SF of 35% [5].

## 2.4 Calculating Annual Operating Cost

Before purchasing a SWHS, estimate the annual operating costs and compare several systems. This will help to determine the energy savings and payback period of investing in a more energy-efficient system, which will probably have a higher purchase price. There is a need to choose and compare the costs of various systems.

The estimation of the annual operating cost of a SWHS is depends on the system's SEF, the auxiliary tank fuel type (gas or electric) and costs (your local utility can provide current rates).

**With a gas auxiliary tank system**
Estimated annual cost of operation:
365 x (41,045/SEF) x Fuel Cost (Btu) (or) 365 x (0.4105/ SEF) x Fuel Cost (therm)
If SEF is 1.1 and the gas costs is Rs 63.80/ therm.
365 x (0.4105/ 1.1) x Rs 63.80 = Rs 8,690.

The energy usage per day in the above equation is based on the DoE test procedure for hot water heaters, which assumes an incoming water temperature of 14.5$^{o}$C, hot water temperature of 57$^{o}$C, and total hot water production of 243.4 liters/day, which is the average usage for a household of three people.

**With an electric auxiliary tank system**
Estimated annual cost of operating cost:
365 x (12.03 kWh per day/SEF) x Electricity cost (kWh)
Assuming the SEF is 2.0 and the electricity costs is Rs 4.64/kWh.
365 x (12.03/1.1) x Rs 4.64 = Rs 10,187.

Comparision of SEF, SF with Gas and Electric auxiliary systems:

**Table.4** Comparision of SEF and SF

| SEF | SF | Cost for gas auxiliary tank system (Rs) | Cost for electric auxiliary tank system (Rs) |
|---|---|---|---|
| 1.2 | 0.17 | 7966 | 16978 |
| 2 | 0.5 | 4780 | 10187 |
| 2.4 | 0.58 | 3983 | 8490 |
| 2.8 | 0.64 | 3414 | 7276 |
| 3.2 | 0.68 | 2990 | 6367 |

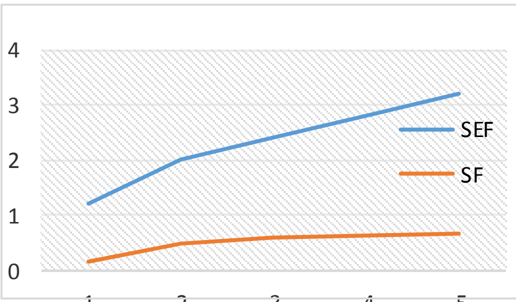


**Fig.6** Graph between SEFand SF

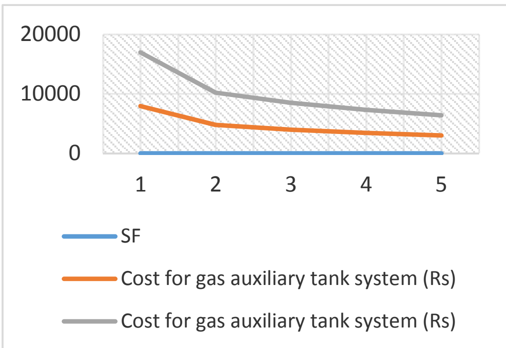


**Fig.7** Graph between Cost of gas and electric auxiliary tank systems with SF

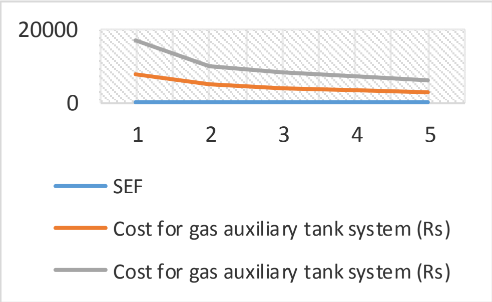


**Fig.8** Graph between Cost of gas and electric auxiliary tank systems with SEF

Comparision of EF with Gas and Electric auxiliary systems:

**Table.5** Comparision of EF with Gas and Electric auxiliary systems

| EF | Cost for gas auxiliary tank system (Rs) | Cost for electric auxiliary tank system (Rs) |
|---|---|---|
| 0.5 | 10757 | 42887 |
| 0.75 | 7171 | 28591 |
| 1.0 | 5378 | 21443 |
| 1.25 | 4303 | 17185 |
| 1.5 | 3586 | 14295 |
| 2.0 | 2690 | 10720 |

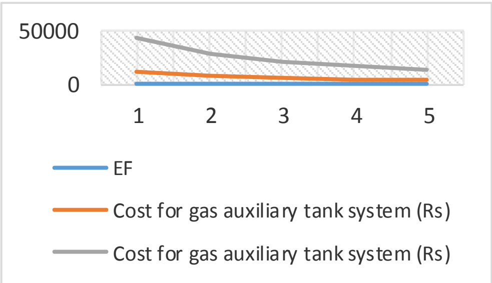


**Fig.9** Graph between Cost of gas and electric auxiliary tank systems with EF

### 2.5 Comparing Costs and Determining Payback

Comparisons made between solar water heating system and conventional water heating system after knowing the purchase and annual operating cost of the system.

Table 2, explains and compare the two solar water hetaing systems and determine the cost savings and payback of the more energy-efficient system model.

Comparison of two SWHS models with electric backup systems, and electricity costs of Rs 4.64 per kWh.

**Table 6** Comparison of two models with example of solar water heating system (SWHS) with SEF.

| System Models | System Price .Rs | SEF | Estimated Annual Operating Cost |
|---|---|---|---|
| **System Model A** | **61,480** | **2.0** | **Rs 10,208.00** |
| **System Model B (higher SEF)** | **66,410** | **2.9** | **Rs 7,018.00** |
| **Additional cost of more efficient model (Model B)** | | | **(Rs 66,410-Rs 61,480)= Rs4,930 [Price of System Model B - Price of System Model A = Rs Additional Cost of Model B]** |
| **Estimated annual operating cost savings (System Model B)** | | | **Rs 10,208-Rs 6,960=Rs 3,248.00 per year [System Model B Annual Operating Cost - System Model A Annual Operating Cost = Model B's Cost Savings Per Year]** |
| **Payback period for Model B** | | | **Rs 4,930/Rs 3,248= 1.5 years [Rs Additional Cost of Model B/Rs. Model B's Cost Savings Per Year = Payback period/years]** |

### 2.6 Comparing System Costs (Electric Auxiliary)

The Energy Factor (EF) and the Solar Energy Factor (SEF) can be used to compare different water heating systems with one another and to estimate typical yearly operating costs for the specified rating conditions. The EF and SEF can be used to compare solar and electric system's energy use on a one-to-one basis. A higher SEF or EF indicates less conventional energy use and consequently, lower operating cost.

For electric systems: Yearly cost (Rs) = 365 x (12.03 kWh per day/EF) x Electricity cost (kWh)

If the electricity costs Rs 6.96/kWh

1. Typical Electrical water heater (EF = 0.86), then Yearly cost = 365 x (12.03/0.86) x 6.96 = Rs 35,536.
2. Typical Solar System (SEF = 2.0), then Yearly Cost = 365 x (12.03/2.0) x 6.96 = Rs 15, 280.

From the above calculations the solar system saves Rs 20,256/year.

This figure can be used as the assumptions for the standard DoE (EF) and SRCC-OG300 rating conditions (SEF). Other factors such as initial cost, maintenance, inflation, interest rate, and replacement costs also need to be considered when making an economic analysis.

OG-300 is a certification by the SRCC. The designation and seal is given to each model of a solar hot water kit. The OG-300 SRCC seal essentially verifies that a pre-engineered residential solar thermal system has been tested and has been proven safe, effective and will deliver a certain amount of solar energy on a typical sunny day [8].

### 2.7 Estimating Costs and Efficiency of Storage, Demand and Heat Pump Water Heaters

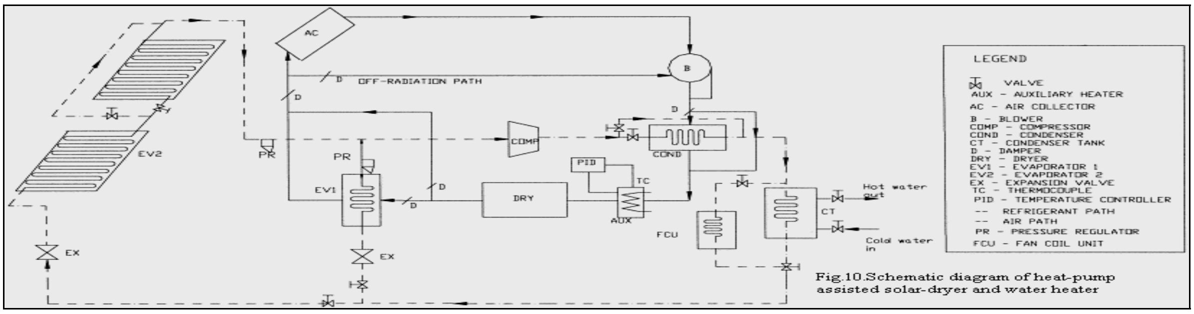


**Fig.10** Schematic diagram of Heat pump assisted Solar dryer and water heater

A water heater's Energy Efficiency is determined by the Energy Factor (EF), which is based on the amount of hot water produced per unit of fuel consumed over a typical day. The Energy Factor is directly proportional to the efficiency of the water heater.

When considering a water heater model for a home, estimate its energy efficiency and annual operating cost. Then, compare costs with other more and/or less energy-efficient models. This will help determine the energy savings and payback period of inverting in a more energy-efficient model, which will probably have a higher purchase price.

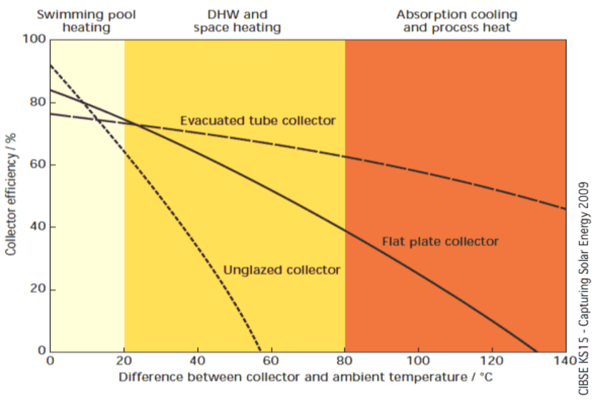


**Fig .11** Approximate solar panel operating bands

In Fig 11, the Flat Plat Collectors (FPC) is used for low temperature water applications, where the loss of heat will not be as significant as with higher temperature panels [8]. The collector efficiency is more for FPC as compared with ETC with reference to the temperature (difference between collector and ambient temperature).

## 2.8 Determining Efficiency of Storage, Demand and Heat Pump Water Heaters

Use the EF to determine the energy efficiency of a storage, tankless or demand-type water heater or heat pump water heater. The EF indicates a water heater's overall energy efficiency based on Recovery efficiency, Standby losses and Cycling losses. The Energy Factor is higher, more efficient of water heater. However, higher EF values don't always mean lower annual operating costs, especially when you compare fuel sources.

**Calculating annual Operating Cost**

Before choosing and comparing the costs of various models, there is a need to determine the correct size water heater for your home. If haven't done this already, see sizing a new water heater. The estimation of the annual operating costs of storage, demand (tankless or instant) or heat pump (not geothermal heat pump) water heater is depends upon the Energy Factor (EF), Fuel type and cost (your local utility can provide current rates). Then, use the blow calculations:

**For Gas and Oil water heaters**
Estimated annual cost of operation:
365 x (41,045/EF) x Fuel Cost (Btu) (or) 365 x (0.4105/ EF) x Fuel Cost (therm) = estimated annual cost of operation.

If EF is 0.57 and a fuel costs of Rs 0.00035902/Btu.
365 x (41,045/ 0.57) x Rs 0.00035902 = Rs 9,436.

**For electric water heater, including heat pumps units**
Annual cost of operation:
365 x (12.03 kWh per day/EF) x Electricity cost (kWh)
A heat pump water heater with an EF is 2.0 and the electricity cost is Rs 4.8836/kWh.
365 x (12.03/ 2.0) x Rs 4.8836 = Rs 10,720.
The energy usage per day in the above equations is based on the DoE test procedure for hot water heaters, which assumes an incoming water temperature of 14.5$^{o}$C, hot water temperature of 57$^{o}$C and total hot water production of 243.4 liters/day, which is the average usage for a household size of three people.

## 2.9 Comparing Costs and Determining Payback

Table 7 explains and compare the need.

**Table.7** Comparison of two models with example of Solar Water Heating System with Energy Factor

| Models | Price of Water Heater | EF | Estimated Annual Operating Cost |
|---|---|---|---|
| **Model A** | **Rs 9,570.00** | **0.54** | **Rs 9,628.00** |
| **Model B (higher EF)** | **Rs 12,180.00** | **0.58** | **Rs 8,990.00** |
| **Additional cost of more efficient model (Model B)** | | | **Rs 12,180-Rs 9,570= Rs 2,610.00**<br>**[Price of Model B - Price of Model A = Rs Additional Cost of Model B]** |
| **Estimated annual operating cost savings (Model B)** | | | **Rs 9,628-Rs 8,990=Rs 638.00 per year**<br>**[Model B Annual Operating Cost - Model A Annual Operating Cost = Rs Model B's Cost Savings Per Year]** |
| **Payback period for Model B** | | | **Rs 2,610/Rs 638 per year= 4.1 years**<br>**[Rs Additional Cost of Model B/Rs Model B's Cost Savings Per Year = Payback period/years]** |

### 2.10 Improving Energy Efficiency

After your demand water heater is properly installed and maintained, try some additional energy saving strategies to help lower the water heater bills. Some energy-saving devices and systems are more cost-effective to install with the water heater.

Comparison of Solar water heaters [6]

**Table.8** Comparison of different types of solar water heating systems.

| | Storage | Tankless | Heat pump | Solar | Tankless coil & indirect |
|---|---|---|---|---|---|
| **Cost** | **Rs R** | **Rs RR** | **Rs RR** | **Rs RRR** | **Rs RR** |
| **Life Expectancy** | **10-15 years** | **20+ years** | **10-15 years** | **Above 20 years** | **10-11 years** |
| **Solution** | **Look for an insulated tank to reduce heat losses and lower operating costs** | **Install two or more tankless water heaters connected in parallel or separate ones for appliances that use a lot of hot water.** | **Switching the heat pump water heater to regular resistance mode will stop cold air exhaust but also reduce the appliance's efficiency.** | **Make sure you buy a solar water heating system that includes a storage water heater as part of the system package.** | |

### 3. Conclusions

Solar Energy Factor, Solar Fraction and the Energy Factors are used to compare different water heating systems with one another and to estimate typical yearly operating costs for the specified rating conditions. The SEF and/or EF increases, then the system estimated annual operating cost decreases. The energy factor is used for rating solar systems and for comparing solar with other system types. The EF and SEF are used in comparison of solar and electric system's energy use on a one-to-one basis. A higher SEF or EF indicates less conventional energy use and consequently, lower operating cost. The energy factor lies in the premise that solar performance is different at each location. The rating procedure is to be used as a design tool. Design and sizing are functions to be carried out by the solar manufactures. Product literature from a manufacturer usually provides a water heater model's Energy Factor. Don't choose a water heater model based solely on its Energy Factor. The EF is not only the factor to decide the water heater model, it is also equal important to consider the size and first hour rating, fuel type and overall cost of the system. The cost estimates are varied depends upon the fuel rates and electricity tariffs.

## References


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