An Energy Saving Opportunity by Replacing Hot Water Geyser with Solar Water Heater

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Abstract **- Today's world is full of various forms of energy. Living being uses different forms of energy in one or more ways and so it is important to conserve energy. Energy audit is a key to systematic approach for conserving energy. Renewable sources of energy are anticipated to play a significant role in energy generation in India in the future. The word itself- solar, describes that we are dealing with some renewable energy source for a hot water system. This report consist of audit of a Jabalpur hospital & Research Center, in which various electrical and thermal utilities are considered such as transformer, lighting, HVAC system, hot water geyser, pumps etc. Audit was conducted and various measurements and calculation was done on the basis of the data collected and performance assessment was done of the equipments installed in the hospital. The total load of this hospital is 473.421 kW. In this paper the main focus is on hot water geyser system, the total load of hot water geyser is 20 kW. In case we replace the hot water geyser by solar water heater then we gets annual energy savings of 36,500 kWh which accounts to Rs. 1,86,150/- as annually savings.**

Keywords **- Energy conservation, energy saving, hot water system, loads, renewable sources**

I. INTRODUCTION

We are blessed with Solar Energy in abundance at no cost. The solar radiation incident on the surface of the earth can be conveniently utilized for the benefit of human society. One of the popular devices that harness the solar energy is solar hot water system (SHWS) [5]. A solar water heater is the most competitive alternative to conventional water heating methods such as electric geysers and fuel-fed boilers. It makes an attractive and sustainable option, with its global distribution, pollution free nature, virtually inexhaustible supply and near-zero operational cost. Solar water heaters run on a free fuel (i.e. sunshine), thus saving on energy costs that help recover its initial cost in just 2-5 years. In India, the Ministry has assessed a techno-economic potential of 40 million sq. meters. of collector area. Out of this, 20 million sq. meters is targeted to be achieved by 2022 [6]. To accelerate the installation of solar water heating systems, a UNDP–GEF (United Nations Development Program-Global Environmental Funds) supported project is in operation by the Ministry of New and Renewable Energy since 2009.

For hospitals, commercial water heaters play a vital role because they provide a source for clean and hot water that is used in just about every room of the hospital, but more importantly they are used for and by the patients. It is crucial that the patients and nurses are being provided hot water when needed for emergency and daily uses. Hospitals use water in countless ways, which provides them several opportunities to have multiple kinds of commercial water heaters. The most obvious places where hot water is needed include the patient care areas such as treatment rooms, the emergency department, operating rooms , patient rooms, shower and bathing functions, process functions (such as dishwashing equipment), or hand washing.

II. SOLAR WATER HEATING POTENTIAL

We are blessed with solar energy in abundance, which is absolutely free of cost. India, receives solar energy more than 5,000 trillion kWh per year, which is far more than its total annual consumption. The global radiation is around 5 kWh per sq. m. per day with the sunshine ranging between 2300 and 3200 hours per year. Though the energy density is low and the availability is not continuous, by providing appropriate storage, it is possible to harness this abundantly available energy in a reliable manner for many purposes. This can be achieved by converting it to usable heat or through direct generation of electricity. The conversion systems are modular in nature and can be appropriately used for decentralized applications. India has high demands for energy consumption, amidst the world energy crisis, to fuel its growing economy. In order to address these growing demands, the Ministry of New and Renewable Energy (MNRE), Government of India, is working hard to shift the dependence on exhaustive and expensive fossil-fuels towards low-cost, non-conventional energies such as the solar energy [7].

The Government of India has, in effect, approved a policy to extensively promote the development of solar energy in the country by launching the Jawaharlal Nehru National Solar Mission (JNNSM) [8]. This National Solar Mission is a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing one of the country's biggest challenges i.e. saving energy.

The National Action Plan on Climate Change (launched on June 30, 2008) also points out that India, being a tropical country, avails sunshine for longer hours per day and in greater intensity. Solar energy, therefore, has great potential as a future energy source. It also has the advantage of permitting the decentralized distribution of energy, thereby, empowering people at the individual level to harvest their own share of solar energy.

III. TYPES OF SOLAR HOT WATER HEATER

1. Evacuated Tube Collectors (ETC) based Solar Water Heaters

Evacuated Tube Collector is made of double layer borosilicate glass tubes evacuated for providing insulation. The outer wall of the inner tube is coated with selective absorbing material. This helps absorption of solar radiation and transfers the heat to the water which flows through the inner tube.

Figure-1

2. Flat Plate Collectors (FPC) based Solar Water Heaters

The solar radiation is absorbed by Flat Plate Collectors which consist of an insulated outer metallic box covered on the top with glass sheet. Inside there are blackened metallic absorber (selectively coated) sheets with built in channels or riser tubes to carry water. The absorber absorbs the solar radiation and transfers the heat to the flowing water.

Figure-2

The various advantages by using Evacuated Tube Collector (ETC) System in place of Flat Plate Collector (FPC) System can be summarized as follows :-

1. Sunrays remains always perpendicular to cylindrical absorber surface of evacuated tubes, So it can absorbs more energy compared to flat plat absorber. This results in higher efficiency of ETC than FPS.
2. Even in smaller capacity range, many models are designed just by varying numbers of evacuated tubes. Hence wide ranges are available to select the exact system to match the individual requirement. Due to this feature, the system has become more economical & cost effective.
3. The Flat plate collector uses costly metals like copper & Aluminum. On the contrary the ETC collector requires only glass tubes. This is made possible due to technological advancement, which has resulted in substantial cost saving.
4. Due to the non-mixing design of system & plumbing the hot water temperature from first to last bucket remains almost same. On the other hand, as we draw hot water from FPC system, the temperature goes on reducing due to mixing hot & cold water inside the tank.
5. Area required for installation in ETC system will be very less as compare to the FPC system. FPC system required more area for installation.
6. Installation of the ETC system is very easy as compare to the FPC system.
7. Incase of damage to the collector tubes in ETC system, individual tube can be replaced. But FPC system entire flat plate has to be replaced and it involves high cost

for replacement.

8. In ETC system gives 10^0C higher temperature of hot water in winter & Cloudy days. In FPC system the heating efficiency falls significantly on cloudy and winter days.
9. Salt or scale formation when using hard water will be reduced in ETC System. In FPC System the Scale formation will be more and may choke the narrow pipes within the collector.
10. In ETC System the Heating continues till late evening, but FPC System falls down after 2 p.m.

From the above discussion there are various advantages by using Evacuated Tube Collector (ETC) System in place of Flat Plate Collector (FPC) System, so we proposed Evacuated Tube Collector System are used in place of electric hot water geyser.

IV. WORKING PRINCIPLE OF EVACUATED TUBE COLLECTOR (ETC) SYSTEM

ETC System works on a simple principle 'Black body heat absorption principle'. The principle says, 'black color absorbs maximum heat, more than any other color'. Solar water heating systems using vacuum tubes made of borosilicate glass with special coating to absorb the solar energy are called as Evacuated Tube Collector system or (ETC Systems).Vacuum tube is the main component, which absorbs solar energy.

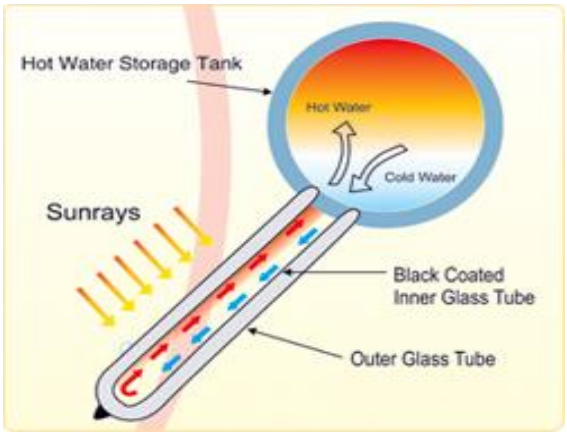

Figure-3

The vacuum tube is an assembly of two concentric, borosilicate glass tubes. Air between the gaps of two glass tubes is evacuated. It results in high level of vacuum, which acts as the best insulation to minimize the heat loss from inner tube. The black coating on the inner tube absorbs the solar energy and transfers, it to the water. The inner tube absorbs the solar energy and transfers it to the water. The water on upper side of Vacuum Tube becomes hot and thus lighter, so it starts moving upwards in the tank. At the same time cold water, which is heavy, comes downward from the tank and is stored at the bottom. With today SWHS, water can be heated up to temperatures of 60^0C to 80^0C [1]. Heated water is collected in a tank insulated to prevent heat loss. Circulation of water from the tank through the collectors and back to the tank continues automatically due to the thermo- siphon principle [4].

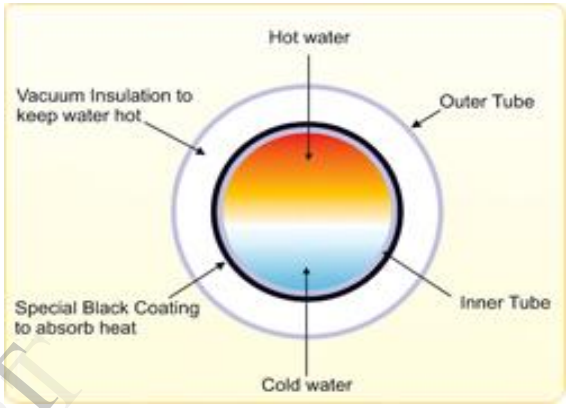

Figure-4

V. ENERGY CONSERVATION MEASURE & METHODOLOGY

The energy management includes planning and operation of energy related production and consumption units. Table 1 show that the different load condition in Jabalpur Hospital.

Table 1: Type of loads

TYPE OF LOAD	kW
Lighting	31.67
AC load	184.03
Fan	20.135
Pumps	15.666
Sterilizer & autoclaves	18
Medical equipments	116.49
Computing equipments	10.375
UPS & Inverter	18
Miscellaneous load	7.255
Geyser (Hot Water)	20
Lifts	31.8

Hospitals are one of the many institutions that rely on commercial water heaters on a daily basis. According to a study of Jabalpur hospital and research center use an average of 2500 to 3000 liters of hot water per day. In the hospital having 10 numbers of electric geysers are used, whose capacity in liters is 25 (each) and rated capacity in kW is 2 kW (each). Table 2 shows that the hospital is having total load of hot water geyser is 20 kW.

Table 2: An inventory of the hot water geyser load

Specifications of Hot Water Geyser	
Model	025GLV-T
Kilowatt	2 kW (each)
Capacity in liters	25 liters
Time to rise temp.	33 min.
Output temp. of hot water	65 ^{0}C
Dimension (in mm)	520x366x380
Rated pressure	8 bars (8kg/cm^2 ; max 80 m water head)
Cost of geyser	9780/-
Total no. of quantity	10
Total kW	20 kW
Total cost of geyser	97,800/-

The solar hot water system has been a popular throughout the world as it is cost effective and easy to maintain. The system is always successful when its efficiency level increases. Solar water heating systems are gaining popularity in India with increasing number of affluent population in society and environmental concerns from seemingly unchanged reliance on fossil based fuels. The penetration of these systems and technologies into Indian markets is a welcome development; however there is a need for the method of an assessment of their thermal performances. A solar water heater consists of a collector to collect solar energy and an insulated storage tank to store hot water. The solar energy incident on the absorber panel coated with selected coating transfers the hat to the riser pipes underneath the absorber panel. The water passing through the risers get heated up and are delivered the storage tank. The re-circulation of the same water through absorber panel in the collector raises the temperature to 80 ^{0}C (Maximum) in a good sunny day. The total system with solar collector, storage tank and pipelines is called solar hot water system [5].

Evacuated tube collector system is one of the effective methods of solar water heating systems. The usage of evacuated tube collectors is increasing day by day. Morrison et al has mentioned that evacuated tube solar collectors perform better than flat plate collectors during high temperature operations [2]. So, we used Evacuated Tube Collector (ETC) System in place of Flat Plate Collector (FPC) System, and proposed Evacuated Tube Collector System in place of electric hot water geyser. In Jabalpur hospital use an average of 2500 to 3000 liters of hot water per day, so we proposed 4500 liters of solar hot water system for future extension. Table 3 shows that the specification of solar water, evacuated tube heating system [10].

Table 3: Specification of Solar Water Heater System

Evacuated Tube Solar Collector (ETC)	
Sr. No. (outer structure)	1641
Model	ETC manifold
No. of Tubes	792
Type of Tube/ ETC	1800 x 58 mm

Glass Tubes Specification	
Model	1800/58-3T
Size	1800x280x250mm
quantity	1080
Tube Specifications	Length -1800 mm, 58 mm OD
Vacuum Tube Material	Borosilicate Glass
Absorber Coating	Coating of Aluminum Nitride by worlds latest innovative technology 'Magnetron Sputtering Technique'

Absorptivity	> 92%
Thermal Expansion	3.3 x 10^{-6} deg C
Stagnation Temperature	> 200 ^{0}C
Weight of Single Tube	2.2 Kg
Tube Resting Caps	UV Stabilized ABS Plastic
Water Circulation	Natural Thermo-siphon

Tank Specification	
Tank capacity (LPD)	1500 liters
No. of tanks	3
Tank Material	SS-304L
Tank Material Type	Food Grade
Insulation material	PUF
Insulation thickness	50mm
Type of tank	Horizontal
Size of tank	60x48x48 inch
Tank cladding material	Pure Polyester Powder Coated Cover
Support Structure	GI-Powder coating
Stand Angel	24°
Chloride Hardness Should be less than	< 50 ppm
Input water pipe (GI)	720 x 1.25 inch
Output water pipe (GI)	720 x 1.00 inch

VI. EQUIVALENT MONEY SAVING AND ANNUAL ENERGY SAVINGS

Solar energy, being abundant and wide spread in its availability, makes it one of the most attractive sources of energies. Tapping this energy will not only help in bridging the gap between demand and supply of electricity but shall also save money in the long run. A solar water heating system is a device that makes available the thermal energy of the incident solar radiation for use in various applications by heating the water [3].

A study has been done separately for hot water geyser and solar water heater. Table 4 shows that he total load of hot water geyser is 20kW. In case we replace the hot water geyser by solar water heater then we gets annual saving in electricity is 36,500kWh and their respective cost 1,86,150/-Rs. are annually savings. The payback period of solar water heater is 34 months.

Table 4: Annual savings in Electricity

Model (lit/day)		4500
Total cost of a solar water heater		5,14,575/-
Cost of electric geyser		97,800/-
Annual saving in electricity	**kWh**	36,500
	Rs.	1,86,150/-
Pay back period		34 months

WITH SUBSIDY- Under "Jawaharlal Nehru National Solar Mission"

The Government of India has, in effect, approved a policy to extensively promote the development of solar energy in the country by launching the Jawaharlal Nehru National Solar Mission (JNNSM) [8]. This National Solar Mission is a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing one of the country's biggest challenges i.e. saving energy.

Under 'Jawaharlal Nehru National Solar Mission' (JNNSM), central government is providing financial assistance in the form of capital subsidy. A customer

can avail 30% capital subsidy; the details of subsidy scheme for Madhya Pradesh Region are as follow:

Commercial Establishments:

Subsidy 30% of total system cost or Rs. 3000 per square capacity of the system, whichever is minimum, for ETC system In addition to subsidy, commercial customers can also claim for Income Tax benefit from accelerated depreciation of the system (@ 80% depreciation per year) [9].

Figure-5

A study has been done separately for solar water heater Under 'Jawaharlal Nehru National Solar Mission' (JNNSM). Table 5 shows that, In case we replace the hot water geyser by solar water heater under JNNSM subsidy, then we gets annual saving in electricity is 36,500kWh and their respective cost 1,86,150/-Rs. are annually savings. The payback period of solar water heater under JNNSM subsidy is reduced in 24 months.

Table 5: Annual savings in Electricity under JNNSM Subsidy

Model (LPD)		4500
Total cost of a solar water heater		5,14,575/-
Total cost of a SWH with 30% Subsidy		3,60,203/-
Cost of electric water heater		97,800/-
Annual saving in electricity	**kWh**	36500
	Rs.	1,86,150/-
Pay back period		24 Months

VII. CALCULATION

Replace Hot water Geyser by Solar Water Heater System

- One 4500 LPD Solar water heater replace 10 No. of 25 liter electric water heater.
- Assuming usage of solar water heater for 365 days/ year.
- Energy consumed for 5 hours –
  = 20 x 5 = 100 kWh
- Energy consumed for 5 hours daily-
  = 100 x 365
  = 36500 kWh/ year
- Calculate at tariff rate of Rs. 5.10/kWh. Then Energy cost –
  = 36500 x 5.10
  = Rs. 1,86,150/-
- Pay back period = (Investment) / (Money saving)
- Pay back period = (5,14,575) / (1,86,150)
  = 2.76 years
  = 34 months

Replace Hot water Geyser by Solar Water Heater System (Under JNNSM Subsidy)

- One 4500 LPD Solar water heater replace 10 No. of 25 liter electric water heater.
- Assuming usage of solar water heater for 365 days/ year
- Energy consumed for 5 hours -
  = 20 x 5 = 100 kWh
- Energy consumed for 5 hours daily-
  = 100 x 365
  = 36500 kWh/ year
- Calculate at tariff rate of Rs. 5.10/kWh. Then Energy cost –
  =36500x5.10
  = Rs. 1,86,150/-
- Pay back period = (Investment) / (Money saving)
- Pay back period = 3,60,203 / 1,86,150
  = 1.93 years
  = 24 months

Requirement of stand by energy to maintain temperature of water at 65°C

- If a 25 L geyser filled with cold water (30°C, say) is switched on, how long will it take a 2kW element to heat the water to 65°C.
- The basic equation is -
  Q = mc (T2-T1)/3600

Where:

Q = energy in KWh needed to raise water temperature from T1 to T

m = mass of water (Kg); = 25 in this case

c = specific heat of water (4.19 KJ/Kg/°C)

- Therefore Q can be calculated as 1.018 kWh, and a 2 kW element will take 1.018/2 = 0.509 h or 30.55 min to bring the geyser's water up to 65°C.

VIII. CONCLUSIONS

The solar hot water system has been a popular through out the world as it is cost effective and easy to maintain. The system is always successful when its efficiency level increases. Solar water heating system are gaining popularity in India with increasing number of affluent population in society and environmental concerns from seemingly unchanged reliance on fossil based fuels. A solar water heating system is a device that makes available the thermal energy of the incident solar radiation for use in various applications by heating the water [3]. By using solar water heater in place of hot water geyser then we gets annual saving in electricity is 36,500 kWh and their respective cost 1,86,150/-Rs. are annually savings. The payback period of solar water heater is 34 months without considering subsidy. Under 'Jawaharlal Nehru National Solar Mission' (JNNSM) Subsidy the payback period of solar water heater is reduced in 24 months.

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