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RESEARCH ARTICLE

ECONOMICAL ANALYSIS OF SOLAR WATER HEATING SYSTEM AT IIT ROORKEE CAMPUS

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ABSTRACT

In order to address the global challenges of climate change and sustainable development, there is a vital need to accelerate the development of advanced technologies for clean energy. Solar water heating system is a key technology options to realize the shift towards de-carbonize energy supply and is projected to emerge as an attractive alternate electricity source in the future. In this paper the economical analysis of solar water heating system at IIT Roorkee campus is carried out.

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INTRODUCTION

Energy is an essential input required for the social and economic development of any country. It is considered as a fundamental needs and a means to increase, productivity, enhances employment opportunities, and improves the quality of life of people (Purohit and Purohit, 2009). In 2013, the net annual electricity generation in India from all sources was 12,78,907 GWh, of which 9,51,504 GWh was generated from coal, 1,29,244 GWh from hydro, 36,102 GWh from nuclear, and 1,62,057 GWh from non-utilities (Energy Statistics, 2016). Currently, India is facing a severe scarcity of power generation capacity, even though it is the world's fourth largest energy consumer after the USA, China, and Russia (Energy Statistics, 2013). This major shortage in electricity generation capacity has a direct negative impact on the industrial and economic growth of India. The future power plants have been designed to be inevitably dependent on highly volatile fossil fuel such as coal, which could result in an inescapable increase in greenhouse gas emissions. Therefore, the use of fossil fuels is not considered as a viable long-term option for producing energy (Saidel *et al*., 2009).

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Recently China is in news due to orange and red alert in Beijing which is the capital of china. There is a problem of high concentrations of anthropogenic greenhouse gases more than its prescribed standard due to which there is so much smog and people feels difficulty to take breathe and other most popular recent example is New Delhi capital of India in which also an orange alert is declared due to which school, colleges are closed because emission level is more than its prescribed limit. So there is a need that we all puts your hand together to tackle global warming because it's not only government but individual responsibility to reduce it by taking proper measures. As we all are aware about Global warming which is a major issue of climate change. Recently in Paris COP 21 conference all 192 countries are agreed to reduce carbon footprint or GHG emissions according to Kyoto Protocol. According to this Paris summit now developed countries help to developing countries like India, china from tackle global warming in terms of money and technology. Kyoto Protocol is an agreement between Annexure I and Annexure II countries to reduce GHG emissions. The major source of GHG emissions is energy and India is mainly depends on coal energy so there is a need and now the right time comes to shift and attract in renewable energy form like wind, solar, hydro etc.

Table 1. Difference between ETC and FPC

Parameters	FPC	ETC
Cost	Cheaper due to its design	More expensive than FPC about 10-15%
Warranty/Life	Longer life about 20 years	Shorter compared to FPC about 10 years
Installation	It is heavier than ETC, take more space and become cumbersome to install on roofs	It is made of glass which are of fragile in nature
Efficiency	More efficient for warm climate	More efficient for Cool climate
Reliability	Heat water up to 170-180°F	Heat water to well over 250°F
Water	Good for domestic purpose	Heat large amounts of water very quickly above 180oF. Good for commercial purposes
Snow	Shed snow easily with just a little sunlight	Not good at shedding snow

Table 2. Technical Specification of Solar Water Heating System in IIT Roorkee campus

Name	IIT Roorkee
System Type	ETC Thermosyphon type
Capacity	339700 LPD
Total Cost	Rs. 92775733
Energy savings	Kwh per year
Make	Tata Power Solar Systems Limited
Application	Bathing and Washing

Table 3. System Specifications of Evacuated Tube Collector (ETC) solar water heating system

	Capacity (in Litres per day)					
Specifications	100LPD	200LPD	300LPD	500LPD	600LPD	750LPD
No of Tubes	15	30	46	70	92	116
Storage Tank	Stainless steel (SS 304), 1mm thick					
Life Time	20 Years					
Insulation	CFC free PUF (50 mm thickness)					
Circulation	Thermosyphon Type					
System temperature Output	60°celsius					
Water hardness handling capacity	$CaCO_3$content < 300ppm, Chloride <100ppm, fluoride content < 1ppm					
Cladding	Aluminium					

Table 4. Proposed Installation in Student Bhawans

S.No	Site (Departments / Centers)	Capacity of Bhawans (in LPD)	Electricity saved (7.5 units/year in per LPD) ```A	Electricity saved(15 units/year in per LPD) B	Monetary Saving (Rs 3.5 per unit) For A	Monetary Savings (Rs 3.5 per unit) For B
1	Ganga Bhawan	11250	84375	168750	295312.5	590625
2	Cautley Bhawan	18750	140625	281250	492187.5	984375
3	Radhakrishnan Bhawan	4000	30000	60000	105000	210000
4	Rajendra Bhawan	17700	132750	265500	464625	929250
5	Azad Bhawan	10500	78750	157500	275625	551250
6	Ravindra Bhawan	11000	82500	165000	288750	577500
7	Govind Bhawan	14000	105000	210000	367500	735000
8	Jawahar Bhawan	12600	94500	189000	330750	661500
9	Sarojini Bhawan	5500	41250	82500	144375	288750
	Total	105300	789750	1579500	2764125	5528250

Table 5. Proposed Installation in Residences

S.No	Site (Departments / Centers)	Capacity of Bhawans (in LPD)	Electricity saved (7.5 units/year in per LPD) A	Electricity saved(15 units/year in per LPD) B	Monetary Saving (Rs 3.5 per unit) For A	Monetary Savings (Rs 3.5 per unit) For B
1	Hill View Apartments	11200	84000	168000	294000	588000
2	Adarsh Nagar	4400	33000	66000	115500	231000
3	Saraswati Kunj	22800	171000	342000	598500	1197000
4	Vigyan kunj	5200	39000	78000	136500	273000
5	Govind puri	6000	45000	90000	157500	315000
6	Niti Nagar	23200	174000	348000	609000	1218000
7	Amod Kunj	9200	69000	138000	241500	483000
8	Thomson Marg	1000	7500	15000	26250	52500
9	Vikas Nagar	3800	28500	57000	99750	199500
10	Govind Puri	2400	18000	36000	63000	126000
11	Solani Kunj	90000	675000	1350000	2362500	4725000
12	Sheel Kunj	31600	237000	474000	829500	1659000
	Total	210800	1581000	3162000	5533500	11067000

Solar energy is the rich source of green energy in India. In many regions of India solar radiation is good enough. Through we are shifting to coal energy to green energy. The installation of solar system plant is costly but its maintenance is not so costly. Government is given subsidy to install solar plant which makes cheaper to people one time installation. Ministry of Renewable energy is setting some rules and regulations to provide subsidy to residential areas, hilly areas and northeastern areas.

Solar Water Heater

Solar energy is one of the main sources of renewable energy which is widely used mainly where solar radiation is good enough. Solar water heater is the application of solar energy in which water is heated to a certain level for domestic and commercial energy and save electricity made from coal and reduce carbon footprint and earn carbon credits. ETC and FPC are solar collectors.

Table 6. Proposed Installation in Married Student Hostels

S.No	Site (Departments / Centers)	Capacity of Bhawans (in LPD)	Electricity saved (7.5 units/year in per LPD) A	Electricity saved(15 units/year in per LPD) B	Monetary Saving (Rs 3.5 per unit) For A	Monetary Savings (Rs 3.5 per unit) For B
1	GP Hostel	2000	15000	30000	52500	105000
2	Khosla Bhawan	2000	15000	30000	52500	105000
3	Azad wing	6000	45000	90000	157500	315000
	Total	10000	75000	150000	262500	525000

Table 7. Proposed Installation in Guest Houses

S.No	Site (Departments / Centers)	Capacity of Bhawans (in LPD)	Electricity saved (7.5 units/year in per LPD) A	Electricity saved(15 units/year in per LPD) B	Monetary Saving (Rs 3.5 per unit) For A	Monetary Savings (Rs 3.5 per unit) For B
1	Khosla International House	12300	92250	184500	322875	645750
2	Faculty Guest House	800	6000	12000	21000	42000
	Total	13100	98250	196500	343875	687750

Table 8. Total Installation and savings in campus

Capacity of Bhawans (in LPD)	Electricity saved (7.5 units/year in per LPD) A	Electricity saved(15 units/year in per LPD) B	Monetary Saving (Rs. 3.5 per unit) For A	Monetary Savings (Rs. 3.5 per unit) For B
339200	2544000	5088000	8904000	17808000

Table 9. Cost and Area of various proposed system in campus

S No.	Proposed Installation (LPD)	Number to be installed	Area (mm2)	Total Area (m2)	Cost (in Rs.) (1 m2= Rs. 8500)
1	100	20	1280×1820	46.592	396032
2	200	1058	2270×1770	4250.938	36132975
3	300	12	2720×3200	104.448	887808
4	500	11	3870×3200	136.224	1157904
5	600	25	3200×6500	520	4420000
6	750	8	6500×3860	200.72	1706120
7	1000	19	6800×3920	506.464	4304944
8	1500	29	10170×3890	1147.278	9751860
9	2000	11	13590×3820	571.0518	4853940
10	2500	2	17000×4000	136	1156000
11	3000	2	20400×4200	171.36	1456560
Total	339200			7791.076	66224143

The main preference is given to north eastern and hill areas states about ninety percent subsidy. Solar energy can be used in various forms as solar photovoltaic system, solar heating system and solar system. In this study solar water heating system study is carried out taking a case study of Indian Institute of Technology (IIT), Roorkee campus. IIT Roorkee is situated at the foothill of the Himalayas, in Hardwar district, within the state of Uttarakhand, India. There are two types of solar collector which is used for solar water heating system are Flat Plates Collector (FPC) and Evacuated Tube Collector (ETC). Both have its pros and cons which are discussed below. In this study ETC is used in campus due to its advantages. There are total 1197 solar heater installed in all girls and boys hostels, bhawans, messes and married hostels which are shown in table 2. The total water capacity is 33000 Litre per Day (LPD).

ETC and FPC are suitable in different conditions and environment according to their structure, size, weight, cost etc. At some places FPC works well but in some other places ETC works well so which one is good is not a debate. FPC is made up of metal but ETC is fragile in nature due to its glass body which becomes lighter than FPC in terms of weight. The major difference between ETC and FPC is given in tabular form in table 1 below.

Working Principle of ETC based SWHS

SWHS is a device which supplies hot water at 60^{o}C using solar thermal energy without any other fuel. The main components used in it are: ETC, insulated hot water storage tank and cold water storage tank. Using gravity flow, water from the cold-water tank enters the solar tank and fills it up and the coldwater

from the solar tank in turn flows through the evacuated tube. The solar radiation falling on the tubes passes through the external glass tube and is absorbed by the multi layer coating and is converted into heat. This heats up the water contained in the inner glass tube. Due to thermosyphon effect, the heated water becomes less dense than the water in the storage tank starts rising through the tube. Simultaneously, cold water from tank descends to the tube, gets heated up in the absorber and rises back to the hot water tank and cycle repeats. Further when the hot water is drawn from the solar tank outlet to the utilities point, cold water enters into the solar tank, thus lowering the overall hot temperature between the water in the solar tank and the evacuated tubes, then the thermosyphon process starts once again. Technical and system specifications of SWHS installed at IIT Roorkee campus is given in table 2 and 3.

Proposed Installation in Campus and Electricity Savings

A 100 lpd system installed in a home or in commercial area can save 5 units of electricity/day depending on the place of installation & quantity of hot water use. In Delhi, assume solar hot water used 150 days and in Bangalore, assume solar hot water used 300 days; savings could be 750 and 1500 units/year/100 lpd system. The savings could be 7.5 and 15 units/year/lpd system in Delhi and Bangalore. Table 4 to 8 depicts the proposed installation of SWHS in campus and electricity saved from it according to Delhi and Bangalore criteria. It is assumed that per unit electricity cost INR 3.5.
A 100 lpd system on an average saves up to 750 or 1500 units of electricity/yr according to Delhi and Bangalore scenario. The IIT Roorkee campus is situated near Delhi so 750 units of electricity/yr is applied there. To generate that much of electricity from a coal based power plant, 0.75 tones of CO_2 /year is released in atmosphere. 339200 LPD SWHS installed in campus will therefore results in reduction of 254,400 tones of CO_2 emission in atmosphere.

Simple payback Period (SPP)

The most common and easiest method to evaluate the economic value of a project is SPP. The SPP is the minimum amount of time in years required for the positive cash flows to surpass the initial investment, with no use of time value of money (Kaplan, 1983). The payback period is the ratio of the investment required for a project (or capital cost) to the annual cost savings (or net annual cash flow).
The SPP is given as:

$$SPP = \frac{\text{Initial Investment for a project}}{\text{Net Cash Inflow per Period}}$$

If the payback period of a project computed by the above formula is shorter than or equal to the management's maximum desired payback period, the project is accepted or otherwise rejected (Baker & Powell, 2005).

1 m^2 = Rs 8500 (Acc to MNRE)
Cost of MNRE= Rs. 66224143

Total Project Investment= Rs (66224143 + 26551590(Other cost like maintenance)) = Rs 92775733
Subsidy= 60% = 60/100 × 66224143 = Rs. 39734486
Actual Cost remains = 40/100 × 66224143 = Rs. 26489657
Total cost Remains=92775733-39734486 = 53041247

Case I: Only without subsidy amount of Project:

Payback Period (Delhi Case) = 26489657/8904000 = 2.97 years
Payback Period (Bangalore Case) = 26489657/17808000= 1.48 years

Case II: Only without subsidy amount of Project cost with other expenses:

Payback Period (Delhi Case) = 53041247/8904000 = 5.95 years
Payback Period (Bangalore Case) = 53041247/17808000 = 2.97 years

Case III: Complete Project Investment:

Case	SPP if 150 days used in years	SPP if 300 days used in years
Only without subsidy amount of Project	2.97	1.48
Only without subsidy amount of Project cost with other expenses	5.95	2.97
Complete Project Investment	10.41	5.20

Payback Period (Delhi Case) = 92775733/8904000 = 10.41 years
Payback Period (Bangalore Case) = 92775733/17808000= 5.20 years

Conclusion

Globally, eighty nine percent of primary energy consumed comes from fossil fuels, and in doing so, produces one-third of global CO_2 emissions while solar energy technology generates far lower or near-zero emissions of GHGs compared with fossil fuels and by reducing carbon footprint in the environment also gaining carbon credits (ASME, 2009). This paper presents the actual hot water generated by SWHS in IITR campus, Roorkee, India. The total water capacity of SWHS plant is 33000 Litre per Day (LPD). The amount of CO2 reduction is calculated and energy and monetary savings. Additionally, the SPP has also computed.

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