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Economical analysis of a solar water heating system refurbishment in student hostel

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Abstract— solar water heating system (SWHS) is one of the common application of solar thermal systems, but it is still not a common asset for a common man due to its high initial cost. In this paper, the economic feasibility of a solar water heating system is carried out of proposed systems one of which is SWHS having flat plate collector and the other one is SWHS having evacuated tube collector for a student hostel in DIT University, Dehradun. The effect of discount rate, useful lifetime and capital cost on the variation of NPV and benefit to cost ratio is discussed in this paper. These variation is also compared for both types of systems, i.e sytems having FPC and system having ETC. this economic feasibility is checked by using the current cost of the equipments and the benefits in terms of subsidy provided by the Government of India.

Index Terms— Solar water heating system, *Net present value, Payback Period, Discount rate, Useful lifetime, benefit to cost ratio, capital cost.*

1 Introduction

Solar water heating system (SWHS) is one of the common application of solar thermal systems, but it is still not a common asset for a common man due to its high initial cost. The economic assessment of SWHS is equally important as its technical assessment. In 2001 a cost benefit analysis for SWHS in comparison with competitive conventional technologies in Greece is evaluated in which it is concluded that the use of solar collectors results in considerable net social benefits if substituted for electricity and Diesel but not for replacing natural gas [1]. Similarly, the economic feasibility of a SWHS that has a built-in electric coil to provide for hot water needs during cold days is compared with the economic feasibility of a GGS in 2002 in Jordan, whose result said that Proper and supervised manufacturing, installation, and maintenance of SWH Systems in Jordan will lead to prolonging the operation life of the system and to maximizing its efficiency which in turn leads to increased demand on SWHS [2]. In 2004, the techno-economic evaluation of domestic solar water heating systems in India, and it is found that The potential numbers of Indian households who can invest in DSWHS have been estimated based on the income distribution in the country, the capital cost of solar water heating systems, the interest rate charged on the loan provided for the purchase of DSWHS etc. [3]. In 2005, in Greece the market situation of sources of energy consumption for domestic uses and compared the conventional energy sources and solar energy sources are studied and found that DSWHSs are definitely more financially attractive than electric heaters, even with zero subsidization, under the precondition of 10 years' service period and a 25% annual utilization factor, at least [4]. In determining the effective capital cost of solar energy technologies to the user with the provision of financial and/or fiscal incentives in India in 2005, it is found that the provision of income tax benefit of the amount of investment made by the user on the purchase and installation of renewable energy system is likely to be more attractive than the provision of low interest loan [5]. An optimization model for water heating system design parameters, using a numerical simulation routine, in a long term transient regime is developed in Brazil, 2006 and the results show that system depends on the investor's concerns and on the electric energy tariff. The traditional sizing based on the specifications recommended by the Brazilian manufacturer is simplistic and more expensive in all the life cycle for consumers [6]. A methodology for potential estimation (technical, economic and market potential) of solar water heating in a target area is proposed in India in 2007 and it is found that methodology is useful for estimation of the potential of SWHS in an area based on the meteorological data, hot water usage patterns and secondary data regarding the area. This framework can be used by energy planners and policy makers for tracking and promoting the diffusion of solar water heating systems [7]. Whereas in 2008, SWHS using meteorological and geographical data from 129 sites over Turkey for three different types of collector compared in terms of absorber material (copper, galvanized sheet and selective absorber is investigated which gives that based on their economic, environmental, and product quality advantages, implementing the galvanized solar water heater was favored due to its shorter payback period and higher NPV [8]. The techno-economic feasibility of some models of SWH Systems from Malaysian's market is again compared with the Electric Water Heaters (EWH) by study the annual cost of operation for both systems in 2009, whose results is that The annual cost of the electric water heater becomes greater than the annual cost of the SWH Systems for all models in long-term run so it is advantageous for the family to use the solar water heater, at least after 4 years [9]. The effect of water replenishment on the system sizing and a novel strategy for water replenishment is proposed to improve the design and performance of SWHS in 2009, which found that. The annualized system cost can be reduced by 13.7%. For the cost-optimal system configuration, a reduction of 12.7% in the collector area and 10.2% reduction in the storage volume are observed. The proposed methodology is particularly important and advantageous for large commercial and industrial SWHS [10]. The thermal performance, economics and environmental protection offered by thermosiphon SWHS are studied in 2009 and found that the system investigated give positive and very promising financial characteristics with a payback time of 2.7 years and life cycle savings of 2240 € with electricity backup and payback time of 4.5 years and life cycle savings of 1056 € with diesel backup [11]. The techno-economic feasibility of CSP technologies in Indian conditions two projects, namely PS-10 (based on power tower technology) and ANDASOL-1 (based on parabolic trough collector technology) is studied and found that the use of CSP technologies in India makes financial sense for the northwestern part of the country (particularly in Rajasthan and Gujarat states). Internalization of the secondary benefits of carbon trading under the clean development mechanism of the Kyoto Protocol further improves the financial feasibility of CSP systems [12]. In 2011, the impacts of solar water heating in low-income households on the distribution utility active, reactive and apparent power demands are analyzed and found that in comparison with identical residential units using electrical shower heads, with the adoption of solar water heating the reductions in the active, reactive and apparent power demands on the distribution utility were 49%, 29% and 49% respectively [13]. N ew angles on analyzing SWHS deployment in China by addressing both the economic potential and the institutional dimensions at the local level are presented and found that Dezhou's SWHS deployment is driven by an urge to develop businesses and the local economy, and its success results from at least five unique factors, including the development of SWHS industrial clusters in Dezhou, big manufacturers' market leadership in SWHS innovations, a tight private enterprise-local government relation, geographic location within the SWH industrial belt, and the adaptive attitude of Dezhou's households towards natural resource scarcity [14]. The optical analysis, experimental study and cost analysis of the stationary V-trough solar water heater system are studied and found that the prototype has achieved the optical efficiency of 70.54% or 1.41 suns and the temperature of 85.9 °C, easily constructed with a total cost of RM 1489.40 and total payback period of 12.2 year for discounted form or 8.9 years for undiscounted form [15]. The solar water heating systems for the U.S. typical residential buildings, from the energetic, economic and environmental perspectives are evaluated and the performance of solar water heating systems are compared with conventional systems that use either natural gas or electricity which results in that flat-plate solar water heating systems using natural gas auxiliary heater has the best performance among all the types and at all locations. The energy and environmental payback periods for solar water heating systems are less than half of a year, and the life cycle cost payback for solar water heating systems vary from 4 to 13 years in different cities and different configurations [16]. The level of the subsidy is suggested which Serbian government should offer in order to reach the level of SWH deployment comparable to that of more developed countries whose conclusion said that 20% subsidy is justified already by CO_2 mitigation potential of SWH systems, while 50% subsidy, which lowers equity payback period to 5.5–6 years, generates more interest among household owners [17]. Long-term performances of an evacuated tube solar water heating system used for single-family households under typical Nord-African climate (Tunisia) is predicted in a study and found that ETC generated about 9% more energy than the FPC. An economic appraisal was performed to select the most cost savings between the two DSWHS [18]. The energies and the economic potential of the deployment of Domestic SWHSs instead of using electric/gas/town gas water heaters are studied and give that the use of the domestic SWHSs instead of installing gas/town gas water heaters save about $1518 (FPC) and $2035 (ETC). From an environmental point of view the annual GHG emission per house is reduced [19]. In another study, the effect of working fluid design, on technical and economic performance of a typical solar water heater having concentric evacuated tube solar water heater in a household located in Sydney, Australia is investigated and give results that The performance of the solar water heater can be significantly enhanced up to 28% and 50% from economical and technical points of view, respectively [20]. The effect of different parameters on the thermal performance of SWHS is investigated with the aim of reducing both the initial and the running costs and found that An increase in thermal efficiency and a significant reduction in the initial and running costs of the system have been achieved due to the increase in outlet temperature, the reduction in the length of the service water tube and the circulating pump elimination [21]. In 2014, the technical and economic evaluation of a typical solar space and water heating system are studied designed according to the latest Greek Regulation on the Energy Performance of Buildings as a means toward Nearly Zero Energy Buildings and found that the typical solar space and water heating system can provide a viable solution toward Nearly Zero Energy Buildings with solar coverage and Discounted Payback Period being strongly influenced by the climatic zone of the building and the type of fossil fuel substituted. In all cases the solar system covers at least 45% of the total heating loads while the payback period is as low as 4.5 years with an annual abatement of more than 50 t of CO_2 in the worst case scenario [22]. The impact on energy consumption and Green House Gases emissions as well as the techno-economic feasibility of retrofitting solar domestic hot water heating systems to all houses in the Canadian housing stock are studied and then evaluated and found that the energy and Green House Gases emissions impact of retrofitting SWH systems into the Canadian housing stock is substantial. If all eligible existing Domestic Water Heating systems were to be retrofitted with SWH systems, the energy consumption and Green House Gases emissions of the Canadian residential sector would be reduced by about 2% [23]. A water heating system using ETC, its TRNSYS simulation and techno economic evaluation is redesigned and found that the water temperatures at the solar collector outlet and in the tanks are much higher in summer than in winter, on comparing with the original GGS, the SWHS is cost-effective and its payback period is 7.4 years [24].

In this paper, a economic feasibility is checked of a solar water heating system for a student hostel. Initially the importance of assessment of economic feasibility is described which is followed by the methodology used in this paper. Later the conditions on which the SWHS is to be refurbish are described and then its economic feasibility is discyssed in the section results and discussions.

2 Need for Economic Analysis

Solar processes are generally known for high initial cost and low operating cost. Thus the major economic problem is one of comparing an initial known investment with estimated future operating costs. Maximum Solar thermal equipments are made in combination with any conventional source (auxiliary) to meet the desired demand load. In essence, solar energy equipment is bought today to reduce tomorrow's fuel bill. The unit cost of producing energy in SWHSs has to consider the hardware cost, labor cost and all the expenses which include in installing the system. Factors which may need to be taken into account include interest on money borrowed, property and income taxes, resale of equipment, maintenance, insurance, fuel and other operating expenses. For solar energy processes the problem is to determine the size of solar energy system that gives the lowest cost combination of solar and auxiliary energy. In India, the area of solar collectors installed is increasing by a rapid rate.Fig. 1 shows the area of installed solar collectors in different years.

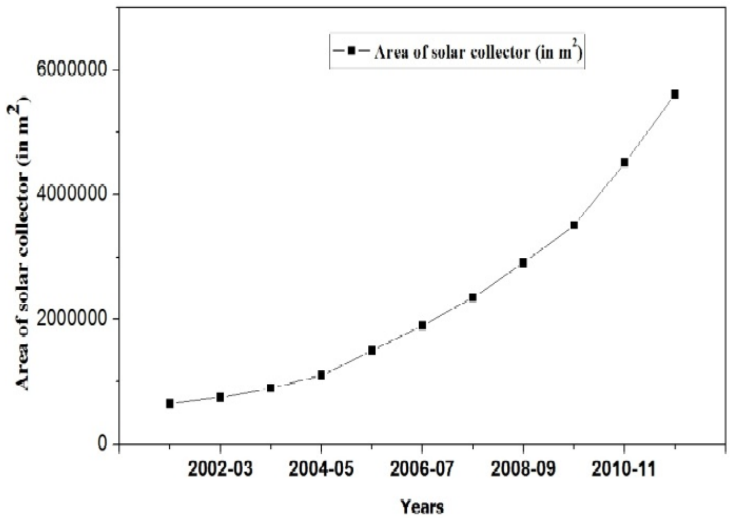

Fig.1 – Increment in total installed are of solar collectors India [25]

A SWHS cannot to be proposed for implementation just on its technical feasibility, until economic feasibility is not checked. The economic feasibility can only be justified for a SWHS when it gives a considerable return on investment as compared to the conventional market. It is important to know the payback period for a known life. The payback period and the optimum life time for replacement should be computed for a domestic SWHS in a dynamic economic environment. The techno-economic analysis should be done in terms of different economic parameters. The optimum life and payback period are a function of interest rate, energy inflation, initial maintenance cost, and rate of increase in maintenance cost.

3 Methodology for Economic Analysis

For analyzing any system economically, first of all the cost of the system should be known. In this study the cost of the system is obtained on the basis of the approximated cost data provided by the MNRE, IREDA, BIS, SOLAR Ratings etc. the cost of both types of systems SWHS having FPC and SWHS having an ETC are as per the following costs in India –

Table 1 – Average cost for FPC based SWHS as per the capacity

System capacity in liters per day (LPD)	Collector Area (in m²)	Upper cost limit (in Rs.)
50	-	-
75	-	-
100	2	18000
200	4	35000
250	-	-
300	6	50000
400	8	65000
500	10	80000
600 to 2000	2 m² per 100 LPD	14500 per collector

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2100 and above	2 m² per 100 LPD	12000 per collector

Table 2 – Average cost for ETC based SWHS as per the capacity

System capacity in liters per day (LPD)	Number of tubes	Upper cost limit (in RS.)
50	7	9500
75	11	14500
100	14	18000
200	28	35000
250	34	42500
300	40	50000
400	52	65000
500	64	80000
600 to 2000	12 tubes per 100 LPD	1207 per tube
2100 and above	12 tubes per 100 LPD	1000 per tube

So, as per these tables the cost of the SWHS is obtained, and then the Subsidy (30% of the benchmark cost) or loan at very low rate of interest (5 % per annum) is applied to the cost of the system. After reducing the financial benefits which are provided by the IREDA, the annual and monthly costs of the instruments are obtained of FPC based SWHS as well as ETC based SWHS using the given expression –

$$\text{EMI} = P * r * \frac{(1+r)^n}{(1+r)^n - 1} \quad (1)$$

Where p = principle amount, r = rate of interest per annum, n = number of years (5)

The economic analysis of these systems is done as per the following formulas:

The net annual cost of the solar system = Cost of fuel/electricity consumed by the auxiliary + Repayment of loan + Maintenance charges

Annual cost equivalent to conventional energy system = Cost of fuel/electricity consumed

[Neglecting the cost of the Conventional heating system]

Annual savings = savings on fuel/electricity – repayment of loan – maintenance charges

Cumulative savings = annual savings – Initial down payment of the system

These annual costs are added to the cost of auxiliary and the total annual cost of the system is compared with the annual cost of the conventional water heating system (Electric geyser in this study). The benefits of SWHS over conventional heating system are shown, as well as the comparison between the annual costs of FPC based SWHS and ETC based SWHS are shown. The effects on NPV and B/C of discount rate, useful lifetime, capital cost and maintenance cost are also shown in the economic analysis in this study using the given expressions [5] –

Present worth (B_{pv}) of Net annual monetary benefit (B_{na}), $B_{pv} = B_{na} PWF(d,T)$ (2)

Simple payback period,

$$SPP = \frac{C_o}{B_{na}} \quad (3)$$

Net present value,

$$NPV_1 = B_{na} PWF(d,T) - C_o \quad (4)$$

Benefit to cost ratio,

$$(B/C)_1 = \frac{B_{na} PWF(d,T)}{C_o} \quad (5)$$

4 "RAMAN" STUDENT HOSTEL

Dehradun is located 240 kilometers northeast of Delhi the capital of India. The DIT University is exactly located at 30.3992° N and 78.0753° E, which is 12 km away from the railway station of Dehradun. The area of the campus of DIT University is 25 acres out of which 23 acres are developed, the prominent buildings are Vedanta and Chanakya. DIT University has four hostels for boys and one for girls. Out of these four boys hostels, one is RAMAN of which the case study is done in this study [26]. From the site survey it is found that the RAMAN hostel has the capacity 205 men at a time. In the northeast side of the RAMAN, there is a basketball court, and beyond that in this direction, there is a field of which students generally takes advantage to play. While in the southeast direction, after the piece of square shaped area having marvel flooring the building of another hostel exist, but the heights of these two buildings are such that, there is no effect of the proposal of SWHS. The site plan of DIT university extracted from google earth is shownin Fig. 2.

By using the method given in the handbook of United nations development program, the area of collector required to fulfill this requirement was 136 m², and for the safer side, this area is taken 140 m². The amount of hot water required is maximum in the month of Dec (as per the information gathered by site survey) which is 6100 litres per day. The economic analysis of is done for SWHS of this size. The SWHS designed for the economic analysis having the electric coil as an auxiliary in it.

Fig. 2 – Site plan of DIT University and location of RAMAN hostel

5 Results and Discussions

The economic analysis of any solar thermal application is necessary because the economic feasibility should be checked before recommendation of any system. In this study the table 3 gives the values which are assumed in different equations during economic analysis. As the IREDA gives the facility to take advantage of any one from the two of the options which are either subsidy of 30 % of the benchmark cost or loan on the 80 % of the benchmark cost with the 5 % per annum rate of interest, in this study the second option (i.e., loan on the 80 % of the benchmark cost with the 5 % per annum rate of interest) is chosen.

Table 3 – Assume values taken for different parameters in this study for economic analysis

PARAMETERS	FPC	ETC
Capital cost	Rs. 8,40,000	Rs. 7,32,000
Capacity	6100 liters	6100 liters
Analysis Period	10 years	10 years
Rate of interest	5 %	5 %
Loan period	5 Years	5 Years
Discount rate	10 %	10 %
Annual maintenance cost	2 %	2 %
Unit cost of electricity	Rs. 3.5/kWh	Rs. 3.5/kWh

The table 4 gives the values for the 10 years which have to be paid with or without SWHS for both types of collectors. As explained in earlier section, that the SWHS having FPC collector as well SWHS having ETC collectors are analyzed in this study. These two types of SWHSs are compared with each other and they are even further compared with conventional water heating system i.e. electric water heater. In table 4, it can be easily understood that the There is a lot of difference in the annual expense of SWHS and conventional water heating system. In this table the annual cost of EWH is calculated by the cost of electricity per kWh and the annual energy required to heat water for RAMAN hostel. The costs of SWHSs are calculated by the sum of annual installment of loan for the capital cost and the cost of electricity which is using as an auxiliary.

Table 4 – Annual cost and annual monetary benefits for various kind of water heating systems (in Rs.)

Year	Annual Cost of EWH	Annual cost of SWHS having FPC	Annual cost of SWHS having ETC	Annual Mo fit of SW F
1st Year	322396.9	309948.21	251475.95	12448.684
2nd Year	322396.9	311689.30	253602.24	10707.595
3rd Year	322396.9	313412.90	255707.11	8983.999
4th Year	322396.9	315119.71	257791.28	7277.182
5th Year	322396.9	316809.04	259854.38	5587.858
6th Year	322396.9	163260.02	126632.89	159136.87
7th Year	322396.9	164915.79	128654.94	157481.10
8th Year	322396.9	166555.13	130656.64	155841.76
9th Year	322396.9	168178.05	132638.70	154218.84
10th Year	322396.9	169784.91	134600.78	152611.98
Total	**3223969**	**2399673**	**1931615**	**824296**

The net annual monetary benefit is the difference between the costs of EWH and SWHSs. It can be clearly seen that the SWHSs of both kind i.e. having FPC and ETC, are economical than the EWH, but if the comparison is taken between the SWHS having FPC and the SWHS having ETC, the later one is more economical because it was even sounds good from technical point of view as it saves more energy, so the energy needed to heat water from the auxiliary is required less, so that cost results in the net monetary annual benefit. The first 5 years for both types of SWHS are having quite higher annual cost and so less annual monetary benefit, because of the installments of the loan of capital cost. From the sixth year, the annual cost is just the cost of auxiliary and the maintenance cost, that's why the monetary benefit from this years increases at a large slope.

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After getting these results, there is a need to evaluate these figures in terms of long run. It is necessary to evaluate the monetary benefits in terms of discount rate, useful lifetime, capital cost etc. because the time value of money will always changes. So fig. 3 and fig.4 shows the effect of discount rate on the net present value of the annual monetary benefit and benefit to cost ratio for SWHS having FPC and SWHS having ETC respectively.

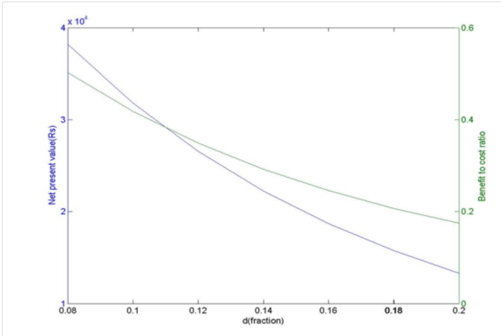


Fig. 3 – Effect of discount rate on NPV and B/C for SWHS having FPC

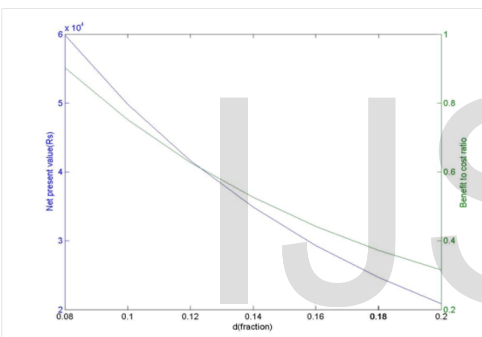
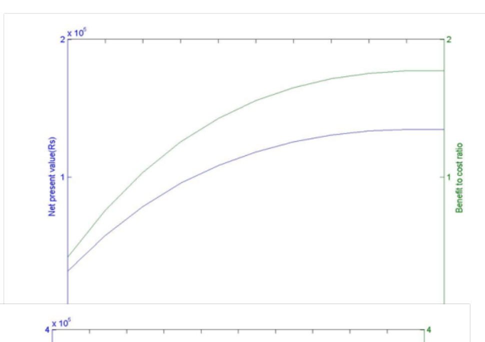


Fig. 4 – Effect of discount rate on NPV and B/C for SWHS having ETC

Fig. 5 and fig. 6 shows the effect of useful lifetime on NPV and B/C of SWHS having FPC and SWHS having ETC respectively. As the useful lifetime of SWHS increases, the amount of monetary benefit also increases.



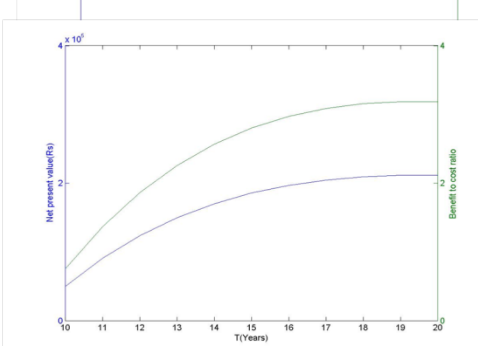


Fig. 5 – Effect of useful lifetime on NPV and B/C for SWHS having FPC

Fig. 6 – Effect of useful lifetime on NPV and B/C for SWHS having ETC

Similarly, the fig. 7 and fig. 8 shows the effect of variation on NPV and B/C for SWHS having FPC and SWHS having ETC respectively. It is obvious that the increase in capital cost will reduce the figure of monetary as well as life cycle savings.

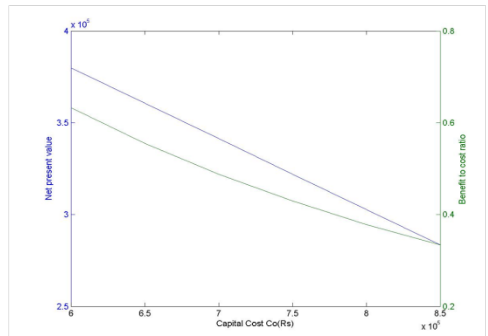


Fig. 7 – Effect of useful Capital cost on NPV and B/C for SWHS having FPC

So, this fig shows the effect of variation of capital cost in these terms, and it is seen that the results of SWHS having an ETC are better than the SWHS having FPC. The variation of NPV and B/C negative for both kinds of SWHSs and it was expected because the margin on the profit due to variation of capital cost has inverse relation.

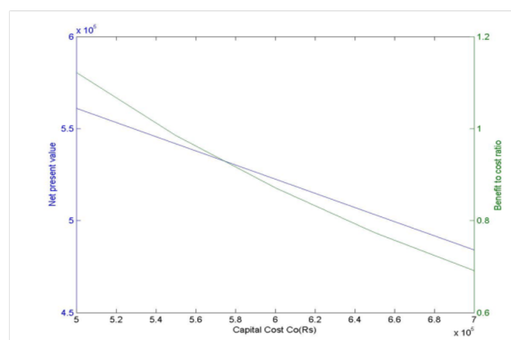


Fig. 8 – Effect of useful Capital cost on NPV and B/C for SWHS having ETC

6 Conclusion

In terms of the economic analysis, the government of India gives the subsidy of 30% or gives the soft loan at 80% of the benchmark cost with an interest rate of just 5% annually. So for such a high investment the second option will be beneficial of soft loan of 5% annual interest rate. Than after analyzing annually, this option can be recommended as the monetary benefit taken by the getting the decrease cost of electricity for heating the water. The variations of NPV and B/C with the discount rate, useful lifetime and capital cost are shown in this study, from which it can be seen that for any dynamic scenario, this system will be beneficial in maximum aspects. And the obvious reason for this recommendation is the environmental benefit of the SWHS, as it reduces the emission of greenhouse gases, which are emitted by the burning of fuel to directly heat the water of indirectly to produce the electricity. There is a wide scope in carrying out the economic feasibility of hybrid solar thermal sytems.

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