Development of Customized Formulae for Feasibility and Break-Even Analysis of Domestic Solar Water Heater

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Abstract-In this present paper, individual formulae have been developed to calculate the output variables such as: Discounted Payback Period, Net Present Value, and Benefit-Cost Ratio for a domestic solar water heater. A spread sheet based financial model has been developed and using secondary data from various published sources, these output variables have been calculated. Further for discounted cash flow based break-even analysis, separate formula has been designed for each of six input variables such as water inlet temperature, annual number of days of usage, capital cost, maintenance cost, volume of hot water required and fuel price. In depth sensitivity analysis has been carried out to understand effect of various input variables on above three mentioned output variables. The outcome from financial model, break-even analysis clearly showed that domestic solar water heater is a feasible option for east-coastal region of India. People need to be persuaded about this fact and motivated to invest on it in a large scale. This simple step has far reaching implication to address the energy crisis in present situation.

Keywords: Solar water heater, Sensitivity analysis, Discounted Payback Period, Net Present Value, Benefit cost ratio, DCF Break-even Analysis

1. Introduction

India is the second largest country in terms of population and seventh largest in terms Gross domestic product (GDP) globally and hence Indian economy directly affects world economy. Economists, politicians, policy makers and energy analysts have their special interest in every policy formulated in developing nations like India. Global warming, pollution, energy security, rural electrification are few key words received highest attention across the globe today. These are the symptoms but the real issues behind them are: gap between demand and supply of electricity and the conventional method of producing electricity using coal or gas. Attention should be focused on these two factors and policy should be formulated to address them. First two issues: global warming and pollution can be addressed by switching to renewable energy options rather tradition conventional power generation by fossil fuels such as coal or petroleum products. Energy security and rural electrification can be handled by mitigating the demand supply gap.

To handle those issues few ways can be thought of such as, to increase the electricity generation capacity, decentralized generation and promotion of application specific product like domestic solar water heater (DSWH), reduction in consumption of electricity etc. Each method has its merits and demerits. Switching to application specific products like DSWH and other renewable energy products has a tremendous potential which can significantly contribute to shorten the demand supply gap without causing any harm to environment. Next obvious question is that if it so helpful then it should spread like a virus to each and every home, but in reality this is not happening. To understand the reason behind this, an initial pilot survey has been carried out in few cities in eastern region of India which revealed that there is a strong perception among people that approximately ₹ 20,000 to ₹ 25,000 initial investment just to get hot water sounds like an unjustified decision to them. Hence, solar energy products in general and the DSWH in particular is not a cost effective option.

To address this issue government of India used to provide subsidy till 2014.Subsidy on decentralized solar thermal application under Jawaharlal Nehru National solar mission (JNNSM) discontinued from 1st Oct 2014 [1].After that manufacturers have tried to cut down the cost to remain competitive in the market. The quotation obtained from few vendors revealed that price of a DSWH of 100 liter capacity ranges around ₹ 20,000 to ₹ 22,000[2].Considering the merits of DSWH like longer service life, very less maintenance, eco-friendly product, electricity saving potential, the big question is that whether the society is ready to accept it or not. In case DSWH becomes popular in every household without putting any burden on the economy and without polluting environment two main issues: global warming and pollution discussed can be addressed to some extent. Around 4% to 5% electricity is consumed for getting hot water in India, which amounts to 39649.2 GWh [3]. At least fraction this amount of energy could be saved with the use of DSWH.

The literature review is concerned with understanding the frameworks to analyze the economic feasibility of a DSWH. The Key variables that affect feasibility of DSWH have been studied extensively. Another aim is to find out the reasons behind failure of dissemination of DSWH in society.

The economic analysis is location specific as it involves climatic data, capital cost, and economic data. In USA 120 billion kWh electricity is consumed per year for getting hot water. A DSWH system will save 1600-2600 kWh of electricity per year in USA which amounts to $100 to $300 saving annually [4-8].There are various dimensions to viability: economic, technical, commercial, social& behavioral .For wider adoption of DSWH, it has to be viable with respect to all dimensions but most important one is economic viability [9].The factors acting as hindrance to penetration of renewable energy technologies have been classified in to: economic, technological, market and institutional factors. A survey among the households of Maharashtra revealed that (a) high capital cost (b) non availability (c)low electricity tariff (d) uncertainty of climate thereby electricity saving and (e) awareness and information are the main factors acting as hindrance to penetration of DSWH [10]. The assumptions based on which a financial model is developed plays a vital role for its feasibility. To minimize the risk profile sensitivity analysis and break-even analysis should be carried out before taking final decision about an investment project [11]. There are 25 project evaluation techniques classified in to five categories: net present value (NPV) method, rate of return method, ratio method, payback method and accounting method [12]. A survey among 33 fortune 500 companies revealed that for project feasibility Net present value (NPV) is the widely used tool followed by internal rate of return (IRR) [13].Country specific techno-economic analysis or feasibility study has been conducted for: India, Greece, Jordan, Vietnam and New Zealand for a DSWH .In India DSWH is a feasible option but due to low income percentage of population having capability to invest for it is less. NPV, IRR, simple payback period (SPP),discounted payback period(DPP),benefit-cost ratio(B/C ratio) are one single set of parameters to assess viability of a DSWH and Life cycle costing(LCC) is another one. In Vietnam DSWH is not feasible as domestic electricity is highly subsidized [14-18]. A comparison has been made between various options: electric water heating option, gas water heating option, DSWH in terms of economic aspects. DSWH has high initial cost but low operational cost but other options have low initial cost and high operation cost. LCC methodology is applied to choose the best option in terms of lower overall cost [19-20]. The global scenario of solar water heater is discussed briefly [21]. The mentioned work reported on a techno economic analysis of SWH, which shows that the economic feasibility is equally important as technical feasibility for its implementation. Optimum selection criteria for domestic solar water heating (SWH) systems based on the techno-economic aspects of evacuated tube and glazed flat plat solar collectors has been evaluated [22]. The findings demonstrated that a higher number of occupants gives a lower payback period and a higher benefit to cost ratio; as long as the number of collectors are not increased to a limit where higher initial cost dominates and decreases the economic viability of the project. Modelling and simulation of solar water heater with various parameters were conducted using commercial software TRNSYS [23].

It has been observed that pollution free operation is the main motivating factor but high initial cost is the main penetration barrier of DSWH. Due to heavy subsidy on fuels (Electricity & LPG), DSWH is not feasible in some countries. However, without considering subsidy, it is definitely a viable option. Viability of DSWH is location specific or more precisely climate specific. For colder regions it is more attractive due to more number of days of operation. Economic viability analysis of a DSWH can be obtained by life cycle costing framework and Project Appraisal Tools: simple payback period (SPP), discounted payback period (DPP), NPV, IRR, B/C ratio.

As for as authors' knowledge, dedicated formulae to calculate variables such as: DPP, NPV, Benefit-Cost ratio for a DSWH were not found in literature which could be easy to understand and analyze. Hence in this paper formulae have been derived to calculate them. Moreover, though discounted cash flow based break-even analysis is a very important part of any feasibility study but it was not found in literature. In this paper a set of separate formulae have been formulated to find out breakeven value of each input variables such as: water inlet temperature, annual number of days of usage, capital cost, maintenance cost, volume of hot water required and fuel price. Comparison has been made between two scenarios i.e. Electric water heating system substituted by DSWH (Scenario 1) and LPG water heating system substituted by DSWH (Scenario 2). Sensitivity analysis is carried out to understand the risk profile. This paper aims at persuading common man to use these formulae to find out feasibility of DSWH using regional data and find out whether DSWH is feasible or not at their respective locations. Simply because a product is expensive does not mean that it is not feasible, this misconception has to be clarified.

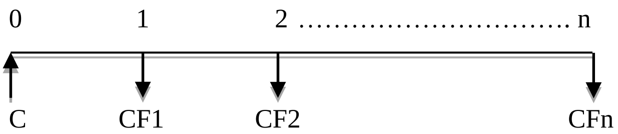
2. Key Economics Parameters

Generally any project is analyzed technically, economically and commercially. Investors are always searching for economically viable projects. All options that qualify technical as well as commercial test have to pass through economic test. Using various tools for economic viability, it is possible to rank various options. There are few key concepts to be discussed before going for an in depth analysis which are discussed below.

2.1. Concept of Time Value of money

Two basic principles such as time factor and risk factor motivate the investors for suitable investment. The return expected by an investor consists of two parts, to compensate for time and to compensate for risk.

2.2. Cash flow diagram



C: Initial investment (negative)
CF1, CF2…CFn: Cash inflows (positive)

Fig.1. Cash flow diagram

Two statements represents this time value of money concept as mentioned here:

- A rupee today is worth more than a rupee tomorrow [24]
- A safe rupee is worth more than a risky one [24]

Fig.1 shows the entire cash flows of project during its life time. The initial investment is made at time zero, which is present time. This investment is negative cash outlay. The cash flows at time period: - 1, 2, 3…….n represents cash inflow at various time periods, which are positive.

2.3 Opportunity Cost of Capital or Discount rate

This is the single key variable which may affect the result of any financial model. In simple words it is the discount rate for discounting the cash flows. The discount rate of a project is the minimum required rate of return on funds invested in the project. The discount rate is the rate of return foregone by investing in the project rather than investing in securities of comparable risk in the capital market [25].

In this model, it has been considered 100 percent equity, which means entire money to be paid by the customer from his pocket without taking any loan. So cost of capital becomes cost of Equity. Now the next question is that assessment of risk profile of a DSWH considering a common man as an investor. There is no single and clear cut answer to this question. So logical judgment is used for this purpose As per Central Electricity Regulatory Commission (CERC), Indian discount rate is 16% for roof top solar PV projects. It has been taken as 14% in this paper which is reasonable for a retail investor point of view.

3. DSWH Investment Evaluation Criteria

Following tools are used for financial appraisal for investment projects. Sound decision can be taken if multiple tools give similar results.

- Simple Payback period (SPP)
- Discounted Payback period (DPP)
- Net present value(NPV)
- Internal rate of return(IRR)
- Benefit-cost ratio (B/C ratio)

3.1. Simple Payback Period

The simple payback period (SPP) is the number of years in which the initial investment is recovered. The SPP is ratio of Initial investment to annual saving. Mathematically it can be written as [26].

$$\sum_{n=0}^{n=n_{sp}} \left(B_n - C_n \right) = 0 \qquad (1)$$

In an Energy Conservation Option (ECO) usually the annual money saving is due to energy savings and hence it is the product of the energy saved and the price of energy. This is the simplest and easy way to understand but it does not give us the real picture as it does not consider time value of money and also cash flows occurring after payback period. There is no clear cut rule regarding minimum value of simple payback period to accept the project. So the decision to accept or reject is highly subjective.

3.2. Discounted Payback period (DPP)

In DPP the cash flows should be discounted to calculate payback. The discounted payback period is the number of years on a discounted cash flow basis to recover the initial cost. But it also does not take in to account the cash flows after recovery of original investment. Again just like SPP no minimum benchmark DPP is available to compare and take a decision. So we can calculate these values, but it is difficult to take any decision based on the results. The formula used to calculate DPP is:

$$\mathrm{DPP} = \frac{\ln\left[1 - \dfrac{c\left(k-g\right)}{\left(\dfrac{p_f f v \rho c_p \left(T_o - T_i\right) N}{c_v \eta_f}\right) - \left(mc\right)}\right]}{\ln\left[\dfrac{1+g}{1+k}\right]} \qquad (2)$$

3.3. Profitability Index (Benefit-Cost Ratio)

This tool considers the concept of time value of money. It is defined as the ratio of present value of benefits to the present value of cost. The cash flows occurring at various time period needs to be discounted at opportunity cost to present time and obviously the cost is at the present time period. If this ratio is greater than one, total benefit is greater than total cost thereby the project can be accepted. Unlike SPP and DPP it takes in to consideration all the cash flows occurring throughout the entire service life. The below mentioned formula represents benefit-cost ratio for DSWH. By using geographical and economic data feasibility of a DSWH can be tested for any location using this formula.

$$B/C=\left[\frac{1}{c}\right]\left[\frac{\left(\frac{p_f fv\rho c_p\left(T_o-T_i\right)N}{c_v\eta_f}\right)-(mc)}{k-g}\right]\left[1-\left(\frac{1+g}{1+k}\right)^n\right] \tag{3}$$

3.4. Net present value

The net present value (NPV) method is the classic economic method of evaluating the investment proposals. It is a DCF technique that explicitly recognizes the time value of money. It correctly postulates that cash flows arising at different time periods differ in value and are comparable only when their equivalents- present values- are found out.

$$NPV=\left(\frac{c_1}{(1+k)^1}+\frac{c_2}{(1+k)^2}+.....+\frac{c_n}{(1+k)^n}\right)-c \quad [25] \tag{4}$$

where $C_1, C_{2,\ldots}$ represent net cash inflows in year 1, 2….k is the opportunity cost of capital, C is the initial cost of the investment and n is the expected life of the investment. It should be noted that the cost of capital, k is assumed to be known and is constant. In the context of a solar water heating system the formula for NPV is:

$$NPV=\left[\frac{\left(\frac{p_f fv\rho c_p\left(T_o-T_i\right)N}{c_v\eta_f}\right)-(mc)}{k-g}\right]\left[1-\left(\frac{1+g}{1+k}\right)^n\right]-c \tag{5}$$

3.5. Internal Rate of Return (IRR)

The IRR is another tool for project appraisal which considers effect of magnitude and timing of cash flow. In simple terms it is that discount rate at which total benefit is equal to total cost of a project. In other words it is the discount rate at which NPV=0.

$$NPV=\left(\frac{c_1}{(1+k)^1}+\frac{c_2}{(1+k)^2}+....+\frac{c_n}{(1+k)^n}\right)-c \quad [25] \tag{6}$$

In this equation that value of K for which NPV is equal to zero is known as the IRR.

4. Break-even Analysis

It is imperative that every project appraisal report should cover a thorough break-even analysis. It is merely a tool to manage and understand risk of being not feasible. Break-even analysis is of two types:

- *Accounting Break-even*:

It refers to the value of input variables corresponding to zero profit situation. A company should understand minimum how many units it needs to produce and sell in the market so as to avoid the risk of going in to loss. It is defined as fixed cost divided by contribution ratio. But it does not take in to consideration concepts like: time value of money and opportunity cost of capital. Accounting Break-even deals with operating at no profit and/or no loss, it does not recognize time value of money, discount rate etc. So the problem is that a project may be operating above break-even point but still losing money [25].

- *Discounted Cash flow Break-even*:

It refers to the value of a particular input variable, corresponding to zero NPV, keeping others constant. In this study DCF break-even analysis has been conducted. It will give the result as the cutoff value of the variables for the project to be acceptable. Obviously one will want to know regarding the break-even point in terms of water inlet temperature, numbers of days of usage, capital cost, maintenance cost, fuel price, for the project to become profitable. A list of formulae to find out DCF Break-even point for a solar water heater has been developed:

Water inlet temperature:

$$T_i=T_o-\left[\left(\frac{c(k-g)}{1-\left(\frac{1+g}{1+k}\right)^n}\right)+(mc)\right]\left[\frac{c_v\eta_f}{fv\rho c_p p_f N}\right] \tag{7}$$

Annual number of days of usage:

$$N=\left[\left(\frac{c(k-g)}{1-\left(\frac{1+g}{1+k}\right)^n}\right)+(mc)\right]\left[\frac{c_v\eta_f}{fv\rho c_p p_f\left(T_o-T_i\right)}\right] \tag{8}$$

Capital cost:

$$c=\frac{\left[p_f fv\rho c_p\left(T_o-T_i\right)N\right]}{\left[\left(\frac{k-g}{1-\left(\frac{1+g}{1+k}\right)^n}\right)+(m)\right]} \tag{9}$$

Maintenance cost:

$$m = \left[\frac{p_f f v \rho c_p \left(T_o - T_i\right) N}{c c_v \eta_f}\right] - \left[\frac{k-g}{1-\left(\frac{1+g}{1+k}\right)^n}\right] \tag{10}$$

Vol. of hot water required:

$$v = \left[\left(\frac{c\left(k-g\right)}{1-\left(\frac{1+g}{1+k}\right)^n}\right) + \left(mc\right)\right]\left[\frac{c_v \eta_f}{p_f f \rho c_p \left(T_o - T_i\right) N}\right] \tag{11}$$

Fuel Price:

$$p_f = \left[\left(\frac{c\left(k-g\right)}{1-\left(\frac{1+g}{1+k}\right)^n}\right) + \left(mc\right)\right]\left[\frac{c_v \eta_f}{f v \rho c_p \left(T_o - T_i\right) N}\right] \tag{12}$$

5. Steps for feasibility appraisal of DSWH

Following steps should be followed to find out the feasibility study of DSWH. Multiple output variables such as NPV, IRR, B/C ratio, DPP should be calculated which aids in decision making process.

1. Quotation should be collected from vendors as the price is location specific.
2. The electricity and LPG tariff should be collected for that state.
3. Weather data has to be collected.
4. MNRE website should be checked to get the statistics about number of days of usage of DSWH at that location.
5. List of modeling assumptions should be noted down.
6. All the project appraisal tools: DPP, NPV, IRR, B/C ratio should be calculated sing spread sheet. It may be validated using the above equations.
7. In case NPV is greater than zero, B/C ratio is greater than one as per theory project can be accepted. But further analysis is required to understand the risk aspects.
8. Sensitivity analysis with respect to each variables has to be carried out, highly sensitive variables has to be listed out as a small change in their value will cause a large change in NPV.
9. Discounted cash flow break-even analysis has to be carried out.
10. Finally take a decision whether to buy a DSWH or not based on the results.

6. Results and Discussion

The accuracy of any financial model and consequent result depends upon the assumptions made as well as the data used. This is an area in financial modeling where the judgment and reasoning skill of the analyst plays a vital role. As far as possible a financial projection should reflect the real life scenario. Although it is not possible for any analyst to exactly predict the future scenario but the assumptions should be logical. Many values taken are highly subjective which depends on the logical insight of the analyst. The assumptions which affect the results are mentioned in Table 1.

Table 1. Key assumptions in the feasibility analysis of DSWH

Sl. No.	Variable Name	Value	Unit	Explanation
1	Useful Life(n)	12	years	Life span of a DSWH spreads in between 10-15 years generally. But it may be higher than that also. Conservatively it has been taken to be 12 years [27].
2	Capacity	100	Liters	For an Indian family with 3-4 members 100 liter capacity is sufficient [27].
3	Number of days of hot water requirement	200	days	This value is critical in this model and it is subjective. For eastern region it will be 200 days per year [28]. It varies from place to place. Most people need hot water around in between 8AM-9AM for bathing purpose. So we need water heater for around 6-7 months in East coastal region.

4	Price of Electricity per unit	5.5	₹ /kWh	Reasonably Average cost of Electricity can be taken to be Rs.5.5
5	Price of LPG Cylinder	600	₹/cylinder	Price of 1 cylinder is around ₹ 600.This value is also not constant it varies regularly.
6	Inflation for Electricity and LPG	4	percentage	The inflation rate for fuel price can be taken as 4% on an average [14]
7	Calorific Value of LPG	45	MJ/kg	The calorific value of LPG is constant at 45 MJ/kg [14]
8	Efficiency of Electric water heater	90	percentage	The efficiency of electric water heater can be taken as 90% [14]
9	Efficiency of LPG water heater	60	percentage	The efficiency of LPG water heater system can be taken as 60%[14]
10	Cost	22000	₹	[2]
11	Maintenance Cost	4	Percentage of capital cost	DSWH do not need significant maintenance. Occasional leakage in the plumbing could be handled by common plumbers. Scale deposit in the collector (which may result over the years) may be handled by the supplier [14]
12	Discount rate	14	percentage	Explained above

Table 2. Summary of output result

Output	Unit	Value for	Value for
NPV	₹	5288	2698
B/C	number	1.24	1.12
DPP	years	8.42	9.84
IRR	percentage	18.82	16.51

The results are mentioned in Table 2. The decision making tools: NPV, B/C ratio, DPP, IRR are giving a green signal to the investment project for A DSWH. NPV is greater than zero, B/C ratio is greater than one. But DPP seems to be on a higher side. IRR is a very easy tool for a common man to understand. In simple words it is the return earned by the investment through its life time. The IRR value is 18.82% and 16.51% respectively, which is very attractive for a renewable energy option. These results are based on the value of input variables taken in Table 1. But it is imperative to analyze how these output variables respond to change in input variables.

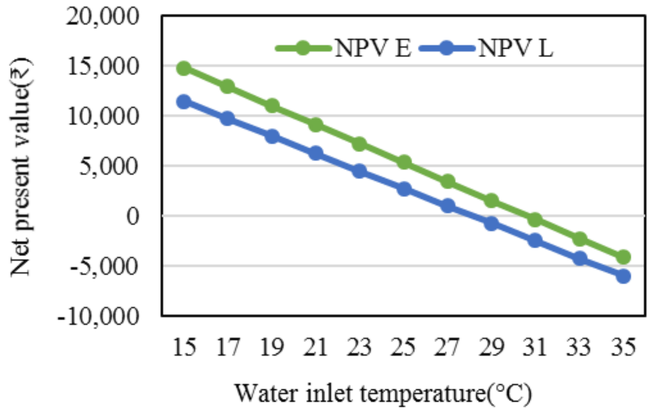
6.1. Sensitivity Analysis

It is an integral part of any project appraisal. It helps the analyst to understand how NPV/IRR/DPP/B/C ratio responds to change in input variables. It also helps to analyze the risk factor of the project. In case the input variables changes their value, what will be impact on feasibility of the project, these kind of questions can be answered by this sensitivity analysis.

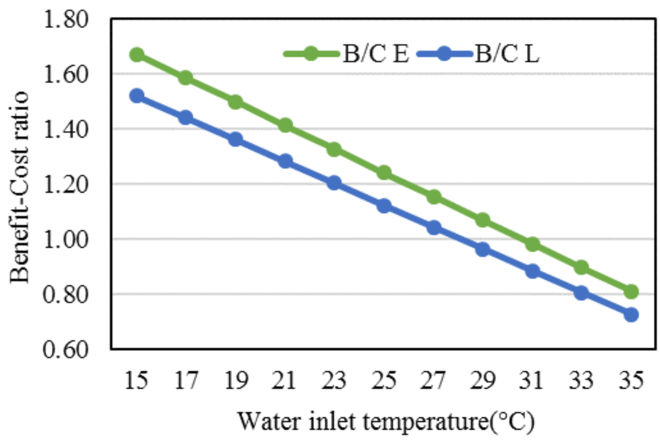
6.1.1. Effect of water inlet temperature (T_i) on various output variables

The value of water inlet temperature depends upon the local weather condition. The spread in water inlet temperature considered in this study is 15 ᵒ C to 35 ᵒ C.

Fig.2 (a) & Fig.2 (b) indicate that, for a given water outlet temperature, the output variables: NPV, B/C ratio show a gradual reduction with increase in water inlet temperature for both the scenarios. But Fig. 2(c) shows that DPP increases with higher water inlet temperature. To get a higher temperature difference between inlet and outlet, more amount of energy is required which is saved. So more amount of fuel and money is saved, giving rise to more amount of cash flow. The physical significance of these graphs is related with location, as water inlet temperature varies location wise.



2(a)



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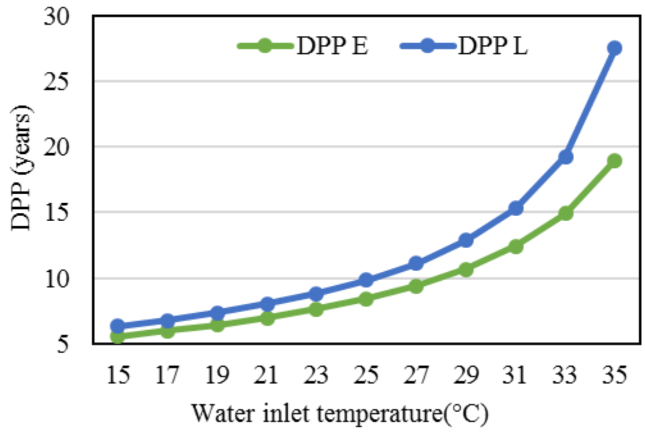
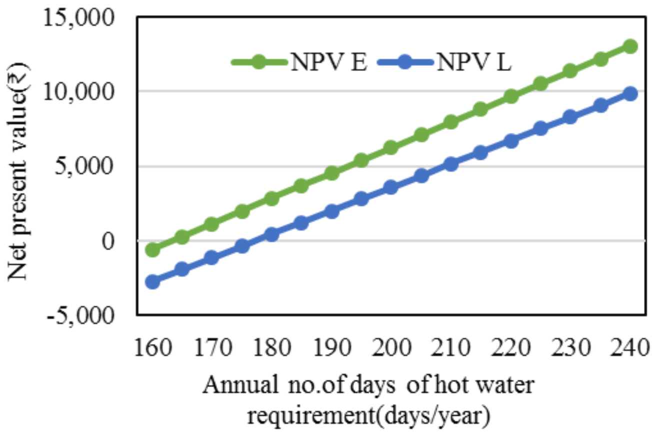


2(c)

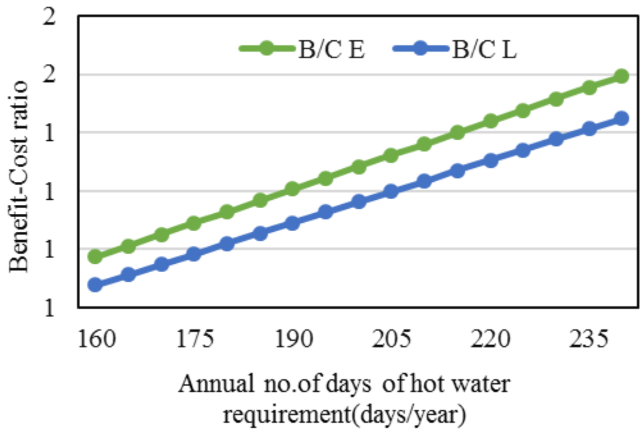
Fig.2. Effect of water inlet temperature on (a) NPV (b) B/C ratio (c) DPP

6.1.2. Effect of Annual number of days of hot water requirement (N) on various output variables

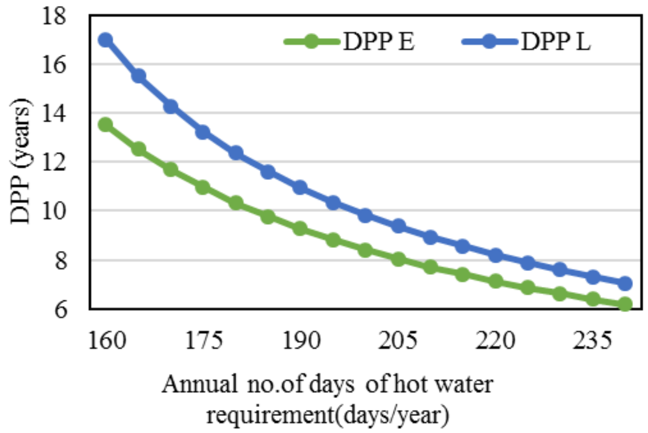
The number of days of hot water requirement depends upon the climatic condition of the location. Therefore it varies location wise. So a wider range from 160 days/year to 240 days/year is considered. In MNRE website there is a list, describing the value of number of days of hot water requirement location wise. Fig.3 (a) and Fig.3 (b) also depict locations where solar water heater will be economically feasible. Depending upon the temperature of a place, number of days of usage for a DSWH is fixed and It is found that as number of days of usage increases, the value of output variables: NPV, B/C ratio increases but DPP decreases. Fig. 3(c) clearly shows variations in DPP .



3(a)



3(b)



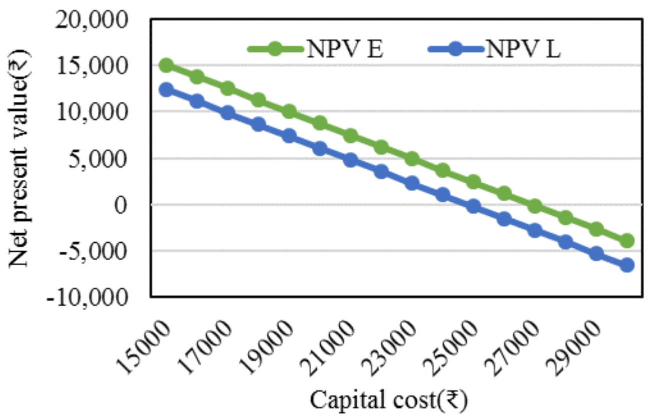
3(c)

Fig. 3. Effect of annual number of days of hot water requirement on (a) NPV (b) B/C ratio (c) DPP

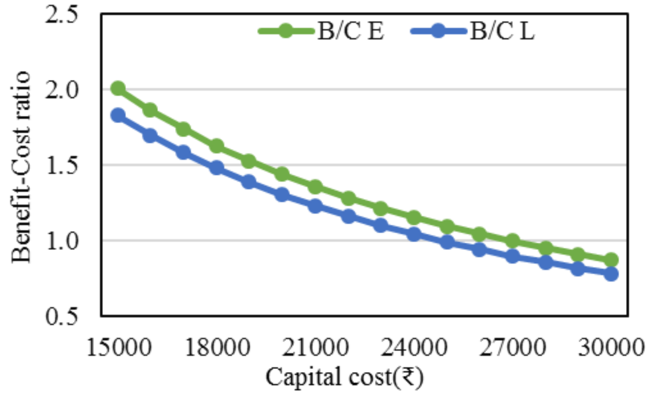
It is expected also because for cold regions, a number day of hot water requirement is more than that of hot regions and hence, it would be more beneficial.

6.1.3. Effect of Capital cost (C) on various output variables

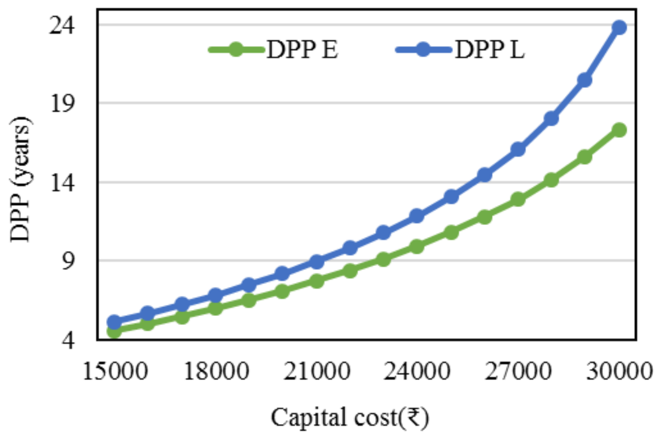
The capital cost is a key variable in the study which depends upon the market price of DSWH. The range taken for capital cost is ₹15,000 to ₹30,000. Fig.4 (a) and Fig.4 (b) clearly shows that with increases of capital cost there is a reduction of NPV and B/C ratio for both the system. But the nature of variation is different. For NPV it is linear, for B/C ratio it is a curve. Fig. 4(c) reflects that in case of DPP there is a gradual increase with increase of capital cost



4(a)



4(b)

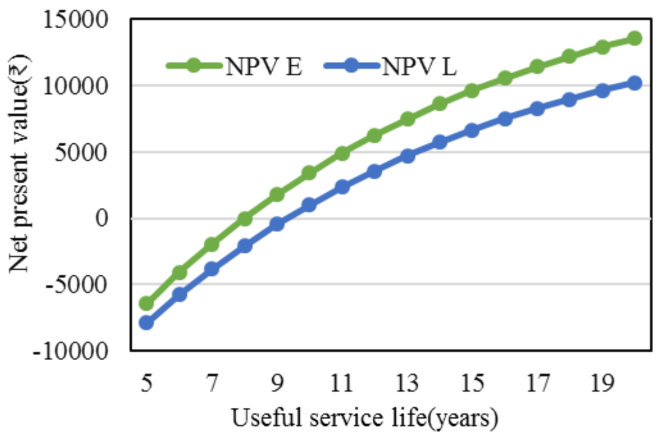


4(c)

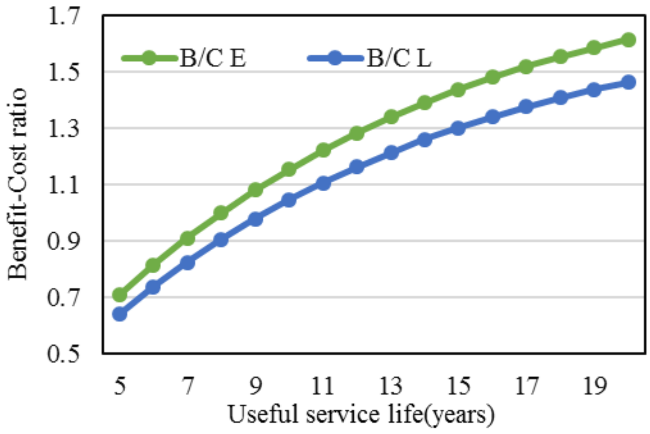
Fig. 4. Effect of Capital cost on (a) NPV (b) B/C ratio (c) DPP

6.1.4. Effect of Useful service life (n) on various output variables

Generally for all renewable energy projects, higher service life is an attractive feature. Useful service life is varied from 5 years to 20 years. Fig. 5(a) and Fig. 5(b) shows that value of output variables increases with useful life for both cases and the increasing trend is a curve in nature.



5(a)



5(b)

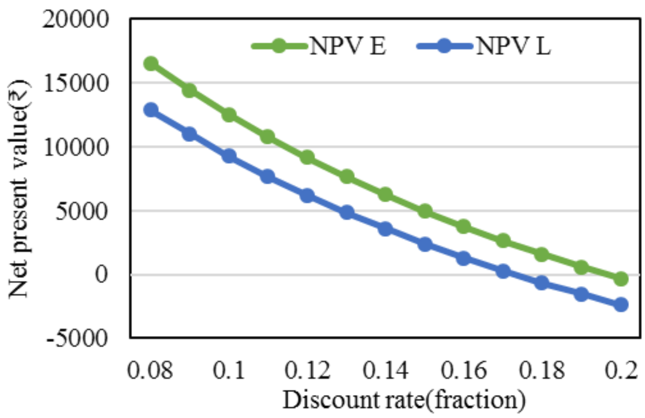
Fig. 5. Effect of useful service life on (a) NPV E (b) B/C E

6.1.5. Effect of Discount rate (k) on various output variables

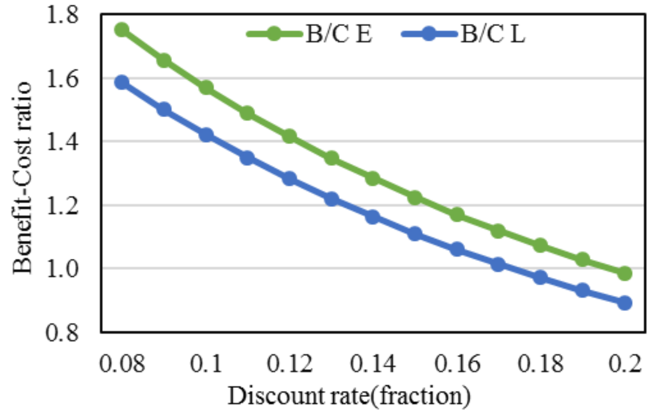
This variables is related to the general economic condition, especially yield earned by securities in capital market. During economic boom discount rate goes up, NPV and B/C ratio both declines. It has been varied from 8% to 20% which is shown in Fig. 6(a), Fig.6 (b) and Fig.6(c). With increase in discount rate, the present value of cash flows declines in a curvilinear manner. Hence output variables: NPV and B/C ratio show a reduction in their value in "Fig. 6(a)" and Fig. 6(b) but DPP shows an upward trend following a curve in Fig.6(c).

6.1.6. Effect of Maintenance cost per year (m) on various output variables

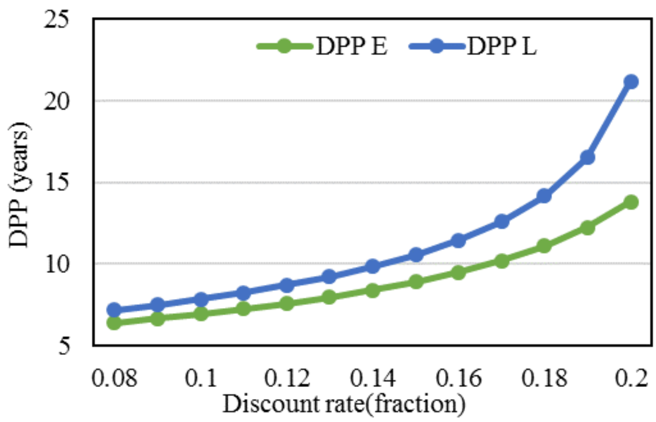
Lower operation and maintenance cost is a unique feature of solar water heater. Maintenance cost is varied from 0% to 6% of capital cost. As the maintenance cost increases cash flow increases, hence output variables: NPV, B/C ratio show a decline in their value in Fig. 7(a) and Fig.7 (b) whereas DPP shows an increase in its value in Fig.7(c).



6(a)

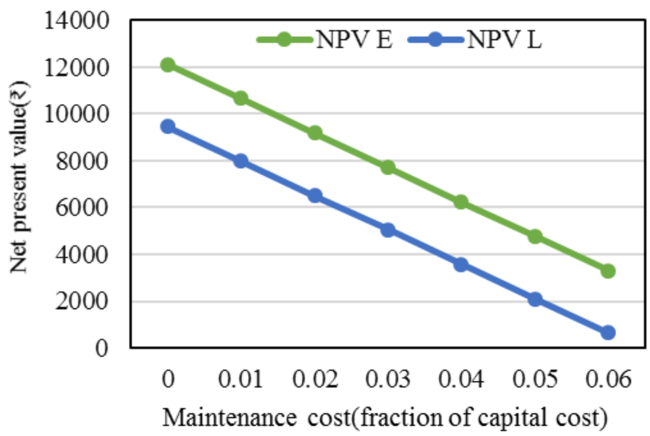


6(b)

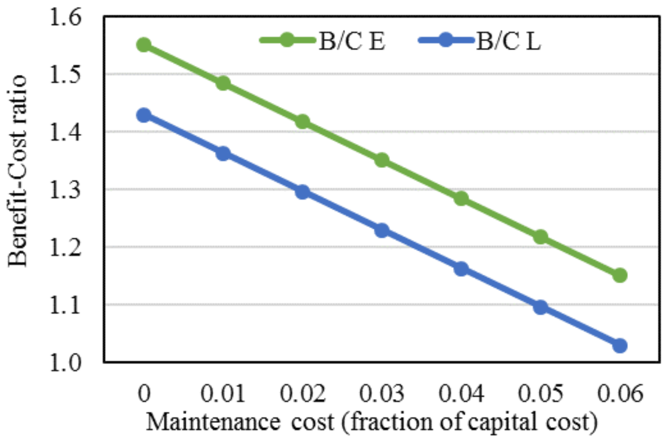


6(c)

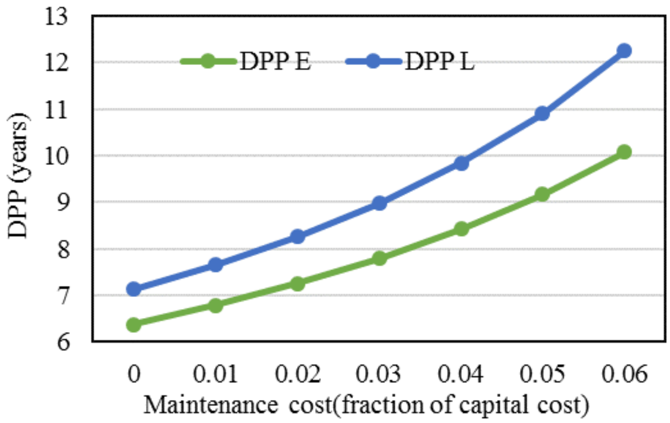
Fig. 6. Effect of discount rate on (a) NPV (b) B/C ratio (c) DPP



7(a)



7(b)



7(c)

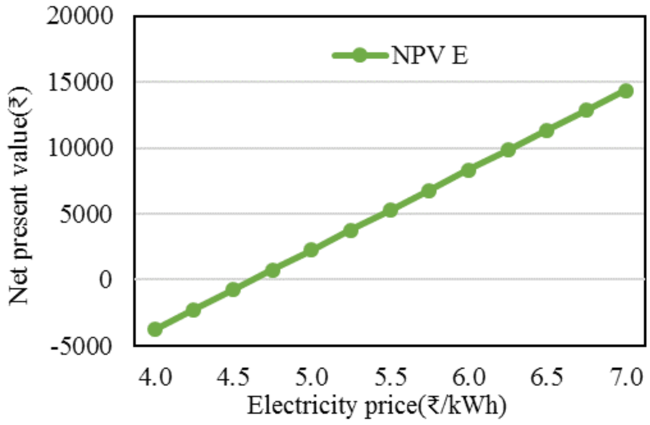
Fig. 7. Effect of maintenance cost on (a) NPV (b) B/C ratio (c) DPP

6.1.7. Effect of Unit price of electricity $P_f(E)$ on various output variables

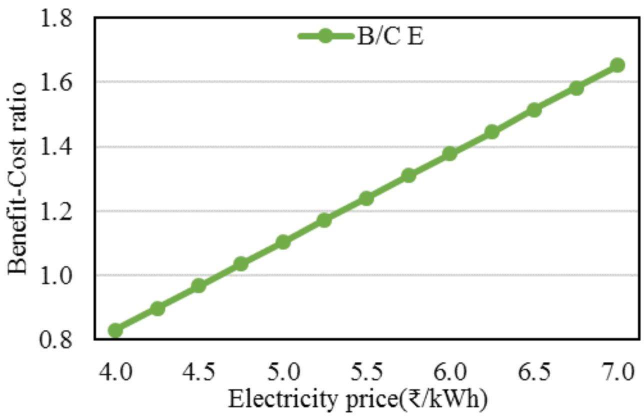
This variable is one of the most important one in any renewable energy project, because the cash flow and money saved depend on the unit price of electricity. The electricity price is varied from 4 ₹/kWh to 7 ₹/kWh. Higher the price, higher is value of cash flow. Fig. 8(a) and Fig.8 (b) prove this and the trend is almost linear whereas in Fig.8(c), DPP declines with increase in electricity price.

6.1.8. Effect of LPG price per cylinder $P_f(L)$ on various output variables

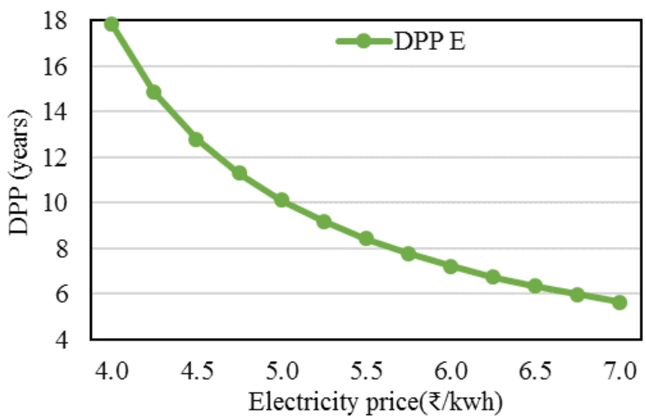
This variable also plays an important role in feasibility analysis of solar water heater because the cash flow and money saved depend upon price of LPG per cylinder. As shown in the graph LPG price is varied from 450 ₹/cylinder to 700 ₹/cylinder without taking in to account the subsidy. Higher the price, higher is value of cash flow. Fig. 9(a) and Fig.9 (b) prove this and the trend is almost linear. From Fig. 9(c) it is clear that DPP declines as LPG price goes up.



8(a)

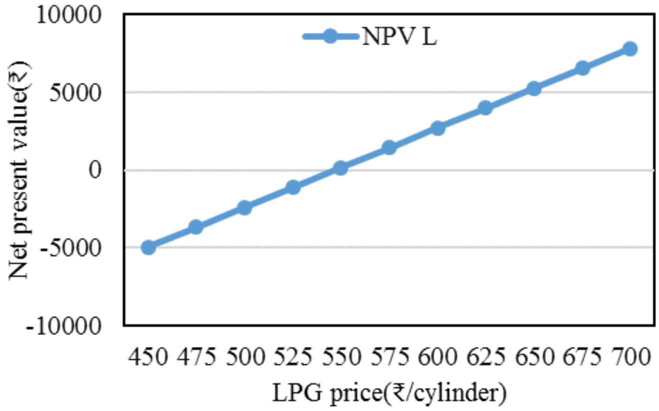


8(b)

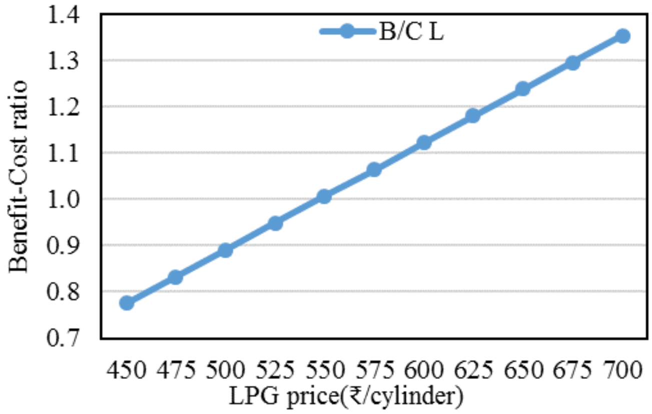


8(c)

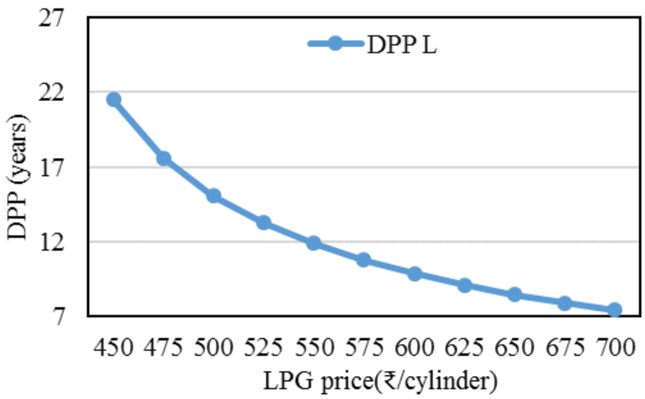
Fig. 8. Effect of electricity price on (a) NPV (b) B/C ratio (c) DPP



9(a)



9(b)



9(c)

Fig. 9. Effect of LPG price on (a) NPV (b) B/C ratio (c) DPP

6.2. DCF Break-Even Analysis

The output result of discounted cash flow analysis is mentioned below. There is very less difference between the values obtained between scenario 1 and scenario 2.The main hindrance behind commercialization of DSWH is its initial cost. For scenario1 the break-even cost is ₹26174 whereas the real cost is ₹22000.The difference is 18%.So obviously there is almost nil probability that price of DSWH will go up by 18% and it will be unviable. For scenario2 the difference is 9%.Further manufacturers are trying to reduce the cost to capture market share. So from capital cost context there is no risk. The break-even value of annual number of days of usage is around six months. Obviously in east coastal region people need DSWH for 200days. So this variable is also not a risk creator. The break-even value of the next variable maintenance cost as a fraction is higher than its conventional value, so there is no risk from it. The historic trend reveals that electricity price in India is increasing and in future it may go up. There is a 16% gap in between current value of electricity price (₹5.5) taken in this study and the break-even value (₹4.62). So no risk from its end. But the last variable LPG cylinder price is relatively volatile which changes each month. In case it goes below ₹547 scenario 2 will not be feasible. But an in-depth analysis shows that it this will not last for a longer period of time. These are short term fluctuations in the economy. So it is concluded that outcome of DCF break-even analysis supports the inference that for east costal region of India DSWH is a feasible option for both the scenarios. These are mentioned in Table 3.

Table 3. Output summary of break-even analysis

Variable	Unit	Value for Scenario 1	Value for Scenario 2
T_i	°C	30.58°C	28.09°C
N	Days/year	168	182
C	₹	₹26174	₹24129
n	year	8.42years	9.84years
m	percentage	7.6%	5.84%
v	Liters/day	84	91
P_f (E)	₹/kWh	₹4.62	---
P_f (L)	₹/cylinder		₹547

7. Conclusion

i. Feasibility of a DSWH depends upon location and time.

ii. Customized formulae for DPP, B/C ratio, NPV have been developed from first principle, which is ready to use type for a common man. Anybody without having knowledge of finance and economics can collect regional data and use these formulae to find out feasibility of DSWH in their regional area.

iii. Further customized formulae has been developed for break-even analysis which can be used by anybody.

iv. Data has been collected for East coastal region of India and it is concluded that DSWH is a feasible option for this region.

v. Sensitivity analysis and DCF break-even analysis has been carried out understand the risk aspects of feasibility. It is found that it is almost a risk free investment for East coastal region of India.

vi. Now it is high time for society to accept DSWH widely and make it an integral part of their daily life. This simple step has far reaching implication: reduce the demand supply gap for electricity, reduce peak demand for electricity, reduction in pollution and global warming, and no burden on national budget as people will invest from their pocket. Out of 39649.2 GWh of electricity consumed in India per year for getting hot water, a big chunk can be saved. This small step will be a win-win situation for all the stakeholders.

Nomenclature:

B/C	:	Benefit-cost ratio
B/C E	:	Benefit-cost ratio for scenario 1
B/C L	:	Benefit-cost ratio for scenario 2
B_n	:	Benefits (cash receipts) (₹)
C_n	:	Cost (cash expenses) (₹)
C	:	Capital cost of solar water heater (₹)
C_p	:	Specific heat (kJ/kg-K)
C_v	:	Calorific value of the fuel saved (kJ/kg)
DPP	:	Discounted payback period (years) DPP E
DPP E	:	Discounted payback period for scenario 1
DPP L	:	Discounted payback period for scenario 2
DSWH	:	Domestic solar water heater
ρ	:	Density of working fluid water (kg/m^3)
EWH	:	Electric water heating system
f	:	Fraction of energy provided by the DSWH
g	:	Cash flow growth rate (percentage)
K	:	Discount rate (percentage)
Lpd	:	Liters of hot water handled per day
LWH	:	LPG water heating system
m	:	Maintenance cost per year (fraction)
n	:	Useful service life (years)
N	:	Annual number of days of hot water usage
NPV	:	Net present value (₹)
NPV E	:	Net present value of scenario 1(₹)
NPV L	:	Net present value of scenario 2 (₹)
P_f	:	Fuel price (₹)
P_f(L)	:	Unit price of electricity (₹)
P_f(E)	:	Unit price of LPG per cylinder (₹)
ROI	:	Return on Investment (percentage)
Scenario1:		Electric water heating system is being replaced by solar water heater
Scenario2:		LPG water heating system being replaced by solar water heater
SPP	:	Simple payback period (years)
SWH	:	Solar water heater
T_i	:	Inlet temperature of working fluid to the tank (water in this case) (°C)
T_o	:	Outlet temperature of working fluid to the tank (water in this case) (°C)
V	:	Volume of hot water requirement by a household on a daily basis
WACC	:	Weighted average cost of capital
η_f	:	Efficiency of the device to be substituted
₹	:	Indian National Rupee

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