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Cost Benefit Modelling of Solar Energy Technology

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Abstract:- The fundamental economic reality of fossil fuels is that such fuels are found only in a relatively small number of locations across the globe, yet are consumed everywhere. The economic reality, by contrast, is that solar resources are available, in varying degrees, all over the world. Therefore, this study concentrates on solar power as a renewable source of energy. It has many benefits compared to fossil fuels. It is clean and green, non-polluting and everlasting energy. For this reason it has attracted more attention than other alternative sources of energy in recent years. It tries to throw light on the cost of solar energy devices like solar water heaters and solar photovoltaic street light etc. and their benefits to households and corporate. Hence primary data has been collected through interview and questionnaire methods. The result of the study shows that benefits accrued from the 100 LPD solar water heaters definitely yields not only profit to the individual who owns the module but also to the society by way of pollution free environment**.**

Keywords:- Energy, Solar energy, Solar Devices, Environment**,** Cost Benefit

I. INTRODUCTION

For as long as the global economy continues to operate on the basis of the limited energy and material supplies, its future prospects will be bleak. There are two incontrovertible reasons for this. Firstly, supply of fossil and mineral resources are limited; and secondly, the processes in which these resources are used inevitably also overstretch, damage and even destroy those limited planetary resources on which our lives depend: water, land and atmosphere. With respect to energy consumption, this second reason has become literally a burning issue. The fundamental economic reality of fossil fuels is that such fuels are found only in a relatively small number of locations across the globe, yet are consumed everywhere. The economic reality, by contrast, is that solar resources are available, in varying degrees, all over the world. Fossil fuel and solar resource use are thus poles apart – not just because of the environmental effects, but also because of the fundamentally different economical, logical and differing political, social and cultural consequences. These differences must be acknowledged if the full spectrum of opportunity for solar resources is to be exploited. Therefore, this study concentrates on solar power as a renewable source of energy. It has many benefits compared to fossil fuels. It is clean and green, non-polluting and everlasting energy. For this reason it has attracted more attention than other alternative sources of energy in recent years. Many energy economists say that solar energy is going to play an increasingly important role in all our lives. To highlight the importance of such a source of energy becomes not only important but also inevitable. Solar energy has the greatest potential among all other energy sources, as it will be available always, though all other energy sources may get depleted. The amount of solar power entering into earth's atmosphere is 17^{17} watt whereas on earth's surface it is 10^{16} watt. The world energy requirement at present is 10^{13} watt. Therefore, if we harness even one percent of solar power, it will be 10 times more than our requirement. The energy available to us on a clear sunny day is 1 kW per sq. meter, on an average, and may vary from 550 to 1000 watt per sq. m, from place to place and season to season. This can be harnessed by raising temperature to 50^o C, 60^o C, 100^o C or more and even up to 5000^o C to generate electricity through the thermal route. India has a total land mass of 3.28×10^{11} square meters. Even if 1% of this radiation is utilized by employing solar devices with as little as 10% efficiency, we can get 492×10^9 kwh/ year of electricity. This clearly indicates the scale of the task before us to tap this energy for the betterment of the public. This needs an innovative mind and a strong commitment in routing solar energy to suit the current life style of the masses. In fact, solar energy is clean, efficient and environment friendly, thus making the technologies also suitable where human settlements enjoy the never-ending source of energy [1].

II. METHODOLOGY

A. Review of Literature

Muhopadhyay et al. (1993) have done a comparative study of solar PV presented against a kerosene lantern for a life period of 25 years. This centralized charging system with solar PV provides self-employment and economical feasibility. A proper design and fabrication of the central charging station along with matching portable solar PV lantern has also been discussed in detail. This approach for central charging of the PV lanterns appears to be reliable and provides cost effective lighting to rural sectors especially in developing countries[2].

Kumar et al (1996) have estimated that India is endowed with abundant solar energy resource. The average intensity of solar radiation received in India is 200MW/ km. Even if 10 percent of the available area can be used, the available solar energy would be 8 – million mega watts. This is equivalent to 5909 million tones of energy per year. Considering the ever-increasing demands of the country, this resource can be gainfully utilized, especially for meeting the electrical needs of rural poor, who are not likely to be served by the grid; and for meeting thermal energy requirements of domestic, industrial and commercial sectors. He has stated that in the last three decades, a lot of developmental work was carried out in India, in the field of solar thermal and solar photovoltaic technologies[3].

B. Objectives of the Study

1. To examine the utility of solar energy with efficient devices and appropriate technology.
2. To analyze the social cost benefits of solar energy in the study area.

C. Hypotheses of the Study

1. There is no significant difference in benefits accrued by using two types and 100 LPD sizes of solar water heaters.

D. Sample Selection

The total sample size is 592, of which 296 consists of users of solar energy devices and 296 samples consists of non-users of solar energy devices. For selection of samples, the purposive sampling technique has been adopted. Purposive sampling has been deliberately used in the place of popular methods such as multi-stage stratified random sampling technique. The researcher tries to probe into sustainable energy features therefore, this study attempts to find out whether solar energy devices are economically viable to the users. It tries to throw light on the cost of solar energy devices like solar water heaters and solar photovoltaic street light etc. and their benefits to households and corporate. Hence primary data has been collected through interview and questionnaire methods.

E. Statistical Tools

Social Cost Benefit Analysis

Cost: cost depends upon the capacity of the module, brand and the type of solar device.

Fixed cost (FC) + Recurring Cost (RC)

FC = (cost of the module + installation cost)

RC = (maintenance cost)

Benefits: benefits are measured in terms of units of electricity saved on using solar devices when compared to other electrical appliances.

The discount factor is

$$D = \frac{1}{(1 + i)\, t}$$

Where i = social discount rate.

t = time period

To check the feasibility of the modules the following techniques were adopted in the present study.

i Payback Period

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Annual cash in flow}}$$

ii Benefit Cost Ratio

Benefit cost ratio = Benefits / Cost

iii Net Present value

Net present value = Discounted benefit – Discounted cost

iv Internal Rate of Return

$$\text{Internal rate of return} = \frac{\text{Net Annual Benefits}}{\text{Capital investment}} \times 100$$

III. RESULT AND DISCUSSION

Energy in the form of heat is an important requirement in domestic, agricultural, industrial and commercial sectors of our economy. In the domestic sector, thermal energy is needed for cooking, heating water and for drying purposes. In the industrial sector there is a need for hot water for cooking to provide catering to the workers, for cleaning purposes, for different stages of production etc. In the commercial sector viz., hotels, hospitals, offices, hostels etc. need thermal energy for variety of applications like cooking, laundry and steam for sterilization, kitchen activities, washing and bathing etc. Normally, these requirements for both domestic and corporate sectors are being met by burning of coal, wood, kerosene, LPG and use of electricity. Many of these conventional sources of energy can be replaced by solar energy.

Various solar and photovoltaic devices and systems are available and are proven to be useful in the field. They have been commercialized and are finding wide and increasing applications. The benefits thus accrued through application of solar devices comprise the crux of this research study.

Solar device installation needs open space and also accessories that require some area to absorb sunlight. It is also evident that 100 percent of the non users have own house. Therefore, installation of solar devices would actually benefit them, if motivated and encouraged properly. Moreover, solar water heaters and solar street light needs less space and easy to remove module, therefore even respondents living in rented house can easily install solar device.

Table 1 Type of Solar Device

S.NO	Type of device used	Category of Sector	
		Domestic	**Corporate**
1	Solar water heater	200 (95.2)	43 (50.0)
2	Solar street light	10 (4.8)	43 (50.0)
Total		**210 (100.0)**	**86 (100.0)**

Source: Compiled by researcher from collected data

Table.1 shows the type of solar device owned by the users. There are two types of solar device which incorporates solar energy technology from two routes i.e., solar thermal route and solar photovoltaic route. The above table shows that solar water heater which incorporates solar thermal power is more (243 installations) prevalent among the users when compared to that of solar street lights which incorporates solar photovoltaic technology. This could be due to more benefits enjoyed with installation of solar water heaters compared to solar street lights (which is discussed in detail in the following section).

Table. 2 Size of Solar Water Heater

S. NO	Size of SWH	Category of Sector	
		Domestic	**Corporate**
1	100 LPD	116 (58.0)	1 (2.3)
2	200 LPD	53 (26.5)	-
3	300 LPD	31 (15.5)	1 (2.3)
4	500 LPD	-	13 (30.2)
5	1000 LPD	-	15 (34.9)
6	Above 1000 LPD	-	13 (30.2)

Total	**200 (100.0)**	**43 (100.0)**

Source: Compiled by researcher from collected data

The choice of the size of solar water heater is also an important aspect when considering the study of the solar energy system installed among user sample respondents. This could be due to difference in cost incurred, benefits accrued, income of the households and also the size of the domestic/corporate sectors. Table 2 shows the size of the solar water heater chosen from the users. Up to 300 LPD SWH were installed by the domestic sector. It clearly shows that for domestic purpose minimum capacity of 100 LPD is sufficient. Almost 58 percent of the households have installed 100 LPD, whereas in corporate sector more than 90 percent users prefer a size of 300 LPD and above.

A noticeable feature observed is that the number of sample households using solar water heaters with a capacity of 100 litres is gradually increasing. An interesting fact is that despite the temperate climate with most of the months being hot not requiring hot water for bathing purpose in the study area, solar water heaters have been quite successful. This should speak of the existing scope for smaller capacity SWH which can match the requirements of the small households.

Table 3 Configuration of Solar Street Light

S.No	Description	Technical details	Domestic	Corporate
1.	Module	74 Watts	10 **(100.0)**	43 **(100.0)**
2.	Operation	12 Hours		
3.	Autonomy	3 Days		
4.	Control	**Auto On/ O Ff**		
Total			**10 (100.0)**	**43 (100.0)**

Source: Compiled by researcher from collected data

The above table no.3 reveals the details about the solar street lights, in which the notable point is that only 10 respondents of the domestic users have installed solar street light and 43 respondents in the corporate sector installed solar street light. This shows that solar street lights are not popular among domestic users when compared to that of solar water heaters as shown in the earlier table. This may be because the benefits incurred compared to operational costs may not be attractive for the domestic sector or the value of installing solar street lights has not been realized by the domestic respondents which will help them in reducing the monthly maintenance cost being shelled out for lighting purpose outside their homes. In solar street light 74 watts module have 12 hours of operation with 3 days battery back-up. It has an automatic switching (on / off) condition. This gives an uninterrupted usage of three days.

Table 4 Fuel Used Before the Installation of Solar Device

S.No	Fuel	DOMESTIC		CORPORATE		TOTAL
		DSWH	DSSL	CSWH	CSSL	
1.	Electricity	127 (60.4)	10 (4.7)	30 (14.2)	43 (20.4)	210 (100.0)
2.	LPG	42 (84.0)	-	8 (16.0)	-	50 (100.0)
3.	Coal	6 (66.6)	-	3 (33.4)	-	9 (100.0)

4.	Kerosene	7 (100.0)	-	-	-	7 (100.0)
5.	Fire wood	18 (90.0)	-	2 (10.0)	-	20 (100.0)
Total		200 (67.5)	10 (3.3)	43 (14.5)	43 (14.3)	296 (100.0)

Source: Compiled by researcher from collected data

The above table 4 shows the different forms of fossil fuels used before the installation of solar devices, 210 user respondents used electricity, 50 user respondents used LPG, 20 user respondents used firewood, and 9 and 7 respondents used coal and kerosene respectively for their fuel requirements.

Table 5 Annual Savings with the Use of Solar Device

S.No	**Type of Fuel**	**SAVINGS OF FUEL (per year)**	
		SWH (100 LPD)	**SSL (74 watts)**
1.	Electricity (units)	**1500**	**175.3**
2.	LPG (kg)	**265**	**-**
3.	Coal (kg)	**891**	**-**
4.	Kerosene (litre)	**760**	**-**
5.	Fire wood (kg)	**2129**	

Source: Compiled by researcher from collected data

The table 5 shows the savings of fuel by solar water heater and solar street light. This clearly depicts that electricity consumption through other non-renewable energy devices can be brought down drastically by solar device substitution, which forms the crux of this research study. It is thus directly proved that solar devices reduce other fossil fuels consumption particularly electricity consumption to a large extent and hence its usage will be highly beneficial not only to the individual users but to the economy as a whole in power saving when more citizens, organizations and institutions are brought within the orbit of using solar devices.

The following tables examine the hypothesis among the two types and 100 LPD sizes of solar devices with discounted costs and discounted benefits.

1. Cost benefit analysis for Flat Plate collector

Table 6 Flat Plate Collector of 100 LPD

No. of Years	**Total cost**	**Discounted Factor**	**Discounted Cost**	**Total Benefit**	**Discounted Benefit**	**B - C**
(a)	**(b)**	**(c)**	**(d) (b x c)**	**(e)**	**(f) (e x c)**	**(g) (f – d)**
1	20,000	0.9099	18,198	4,500	4094.55	-14,103
2	2500	0.826	2,065	4,500	3717	1,652
3	500	0.751	376	4,500	3379.5	3,004
4	500	0.683	342	4,500	3073.5	2,732
5	500	0.621	311	4,500	2794.5	2,484
6	500	0.564	282	4,500	2538	2,256
7	500	0.513	257	4,500	2308.5	2,052
8	500	0.467	234	4,500	2101.5	1,868
9	500	0.424	212	4,500	1908	1,696

10	500	0.386	193	4,500	1737	1,544
11	500	0.35	175	4,500	1575	1,400
12	500	0.319	160	4,500	1435.5	1,276
13	500	0.29	145	4,500	1305	1,160
14	500	0.263	132	4,500	1183.5	1,052
15	500	0.239	120	5,500	1314.5	1,195
		Total	**23,198**		**34465.55**	**11,268**

Source: Calculated by researcher from collected data

The above table 6 explains 100 LPD FLAT Plate collector's systematic comparison of social costs and benefits, quantified in money terms with 15 years of lifetime evaluation depicting very clearly its feasibility. The total discounted benefit of Rs. 34465.55 is higher than the total discounted cost Rs. 23,198 to the domestic solar water heater users. Therefore the benefits accrued from the 100 LPD solar water heaters definitely yields not only profit to the individual who owns the module but also to the society by way of pollution free environment.

2. Cost benefit analysis for Evacuated tube collector

Table 7 Evacuated tube collector of 100 LPD

No. of Years	Total cost	Discounted Factor	Discounted Cost	Total Benefit	Discounted Benefit	B - C
(a)	**(b)**	**(c)**	**(d) (b x c)**	**(e)**	**(f) (e x c)**	**(g) (f-d)**
1	18,500	0.9099	16,833	4,500	4094.55	-12,739
2	2300	0.826	1,900	4,500	3717	1,817
3	300	0.751	225	4,500	3379.5	3,154
4	300	0.683	205	4,500	3073.5	2,869
5	300	0.621	186	4,500	2794.5	2,608
6	300	0.564	169	4,500	2538	2,369
7	300	0.513	154	4,500	2308.5	2,155
8	300	0.467	140	4,500	2101.5	1,961
9	300	0.424	127	4,500	1908	1,781
10	300	0.386	116	4,500	1737	1,621
11	300	0.35	105	4,500	1575	1,470
12	300	0.319	96	4,500	1435.5	1,340
13	300	0.29	87	4,500	1305	1,218
14	300	0.263	79	4,500	1183.5	1,105
15	300	0.239	72	4,800	1147.2	1,076
Total			**20,494**		**34298.25**	**13,804**

Source: Calculated by researcher from collected data

In the table 7 100 LPD Evacuated tube collector's systematic comparison of social costs and benefits are charted. Quantified in money terms with 15 years of lifetime evaluation the table depicts very clearly about its feasibility. The total discounted benefit of Rs. 34298.25 is higher than the total discounted cost Rs 20,494. Therefore the benefits accrued from the SWH definitely yields not only profit to the individual who owns the module but also to the society in terms of pollution free environment in the study area.

IV. CONCLUSION

Solar energy is an essentially inexhaustible source, potentially capable of meeting a significant portion of the nation's future energy needs with a minimum of adverse environmental consequences. The indications are that solar energy is the most promising of the unconventional energy sources. Despite this encouraging assessment of the potential of solar energy, considerable technical and economical problems must be solved before large-scale utilization of solar energy can occur. The future of solar power development will depend on how we deal with a number of serious constraints, including scientific and technological problems, marketing and financial limitations, and political and legislative actions favouring conventional and nuclear power.

REFERENCES

[1]. P. Radhakrishna, "Solar Thermal Devices for Industrial Applications" –clean and efficient , Renewable Energy Science Series -11-c, fifth printed , '2002, Government of India , Ministry of non-conventional Energy sources, pp5-9.

[2]. Muhopadhyay K, Sensarma B. and Saha H. "Solar PV lanterns with Centralized charging system- a new concept for rural lighting in the developing nations", 'Solar Energy Materials and Solar Cells, Vol.31, pp 437-446. 1993.

[3]. Kumar A., et al , "Potential of Solar Energy in India, Tata Energy Research institute publications, New Delhi, 1996.