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Rural electrification programme with solar energy in remote region–a case study in an island

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Abstract

In the programme of total electrification, centralized supply of power generated by conventional methods using exhaustible resources is proving to be uneconomic and, more importantly, unmanageable so far as supply to rural areas, particularly remote places, are concerned. On the other hand, the decentralized approach based on supply of power produced with renewable energy resources available locally is, for various reasons, gradually being recognized as a viable alternative for such remote places. The present paper attempts to examine, from a broad-based socio-economic and environmental point of view, the feasibility of decentralized solar photovoltaic (SPV) system as a source of power compared to that from conventional sources in a remotely located island. The study, based on a sample survey, conducted in an island called 'Sagar Dweep' in West Bengal, India, shows that within a short spell of time of four years, there have been noticeable improvements and significant impact on education, trade and commerce, entertainment, health etc. as a result of supply of power from SPV power plants. Productivity level of some agricultural activities as well as women's participation in different economic activities (at night) other than household work have shown definite signs of betterment. The SPV system is also superior to other conventional systems on consideration of its environmental effects. Thus, on the whole, there seems to be a strong case for the locally installed SPV system in spite of its current unfavourable position in respect of the direct cost of production. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Rural electrification; Remote region; Solar photovoltaic power plant

1. Introduction

Development is a socio-economic-technological process having the main objective of raising the standard of living of the people. A crucial determinant for the success of this process is the smooth and adequate supply of energy required to accelerate the growth in every sector of the economy. Clearly, the development that is envisaged here needs to be not only sustainable but also acceptable from an environmental point of view.

The third world countries are characterized by a large share of national income originating from the villages dispersed over wide areas and engaged in agricultural and related activities. Unfortunately, however, these villages have to depend on firewood, animal dung and fossil fuels like kerosene and diesel, which have undesirable environmental effects, as their source of supply of energy. Not surprisingly, therefore, there is little prospect of improvement in the standard of living of the villagers from their present low level without the support of electricity. Presently, the households can enjoy only a limited number of hours of illumination based on kerosene or diesel. These are not cheap and also not affordable by a large majority of the rural masses. This restricts the range as well as the intensity of activities severely. But more importantly even if supply of power from these sources is available more abundantly, there is the problem of adverse environmental effects of such production, which are no longer being ignored. Hence, in the programme of rural electrification which is concerned primarily with supplying electric power in ever increasing quantum until complete electrification is achieved, both in terms of duration and quantum of supply, one should not remain confined, in decision making, to immediate cost considerations but take a comprehensive view of all the different aspects of the problem.

It may be noted that the supply of power produced by conventional methods to rural areas and remote villages

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is gradually being recognized as not only uneconomic but also unmanageable. Alternatively, the use of non-conventional renewable energies is proving to be viable and more efficient in the context of the programme of total electrification (Sinha and Kandpal, 1991). Among the abundant sources of alternative renewable energy like hydro, bio-mass, wind, the significance of solar energy may be further recognized as superior for its free and continuous flow. The development of modern technology, like solar photovoltaic (SPV) cell, has sparked its possible use both in terms of scale and geographic distribution linked to end use needs.

The main objectives of the present study, which is part of an ongoing bigger project, are to examine the feasibility of decentralized SPV system as a source of guaranteed supply of power in a remotely located island from the point of view of an impetus to growth, and to assess its impact on the socio-economic life of the people as well as on the environment. The supply of power to an island from the mainland, even if possible, is not economically viable because of the exorbitantly high cost of distribution and associated transmission loss. Production on the island itself, on the other hand, by conventional methods like coal based thermal system, may not also be economic because the total consumption on the island would perhaps not justify the setting up of a plant, even of a smaller size. There is also the requirement of a large amount of investment in such a case. As other alternatives, one may think of diesel-driven generators or of solar power. The present paper ultimately aims at carrying out an exercise of assessing the economic, social and environmental benefits of solar energy as a source of supply of electricity in such a region.

In the next section, a comparative analysis of the costs of power supply by conventional methods and also by SPV plant has been made in the context of rural electrification programme. In Section 3 the socio-economic impact of power supply on the life of the people of Sagar Dweep, an island in West Bengal in India, has been analysed as a case study, which consists of two subsections. Under Section 3 a brief description of the socio-economic profile of the island has been presented in the first sub-section. The next sub-section is devoted to a detailed presentation and analysis of the results of a sample survey carried out in the island. Finally, some concluding remarks have been made in Section 4.

2. Social, economic and environmental features of SPV power plants

2.1. Economic aspect

Use of power generated through off-grid power plants e.g., solar energy through SPV plant, has already been recognized as a possible alternative from the technological point of view. What is now needed is to assess, specifically, the economic and social viability of its use. So far as economic viability is concerned, one has to look at the cost structure of the production of solar energy and compare it with those of the major conventional sources, by taking into account both the direct and indirect costs incurred at different stages of production and distribution.

The cost of energy in the fossil fuel based centralized power stations consists of the generation, transmission and distribution costs, whereas in the decentralized power generating system energy cost is primarily the generation cost.

While a thermal power station (coal based) enjoys its economy of scale in generating power in large scale and distributing a significant part through high tension lines for industrial consumption, it suffers a diseconomy of scale in distributing power through medium/low tension line in rural areas and in places located far away from the centre. This high distribution cost is associated with high line loss which increases with the distance from the grid point and with low capacity utilization due to the lack of adequate demand for power specifically in the rural areas characterized by the absence of industrial activities on a large scale.

The per unit cost of generation of power by conventional systems, coal and diesel based, and also by the SPV system have been estimated and presented in Table 1 for a comparative study.[1] The result shows, quite expectedly, that the centralized thermal system produces power at the lowest cost compared to the other systems because of its large size resulting in scale economy and greater efficiency in generation which is not possible in a locally installed plant of smaller size adjusted according to the local demand. The cost in another conventional system, diesel generator, is comparatively high due to its high operation and maintenance cost, shorter system life and high fuel cost. This cost is highest in the SPV plant primarily due to its high capital cost.[2]

[1] The per unit generation cost in diesel based system and in SPV system have been estimated using information collected from the existing plants in the island considered in the study, 'Sagar Dweep'. Here, due to the high cost of diesel fuel, two out of three generators with 160 kW capacity run 4 h a day. On the other hand, all the SPV plants each with 26 kW capacity run 5 h a day. Hence, the estimated load factor is found to be very low in each of the cases.

[2] Theoretically, the generation cost in diesel based system would be cost effective as consumer demand increases because of higher load factor and greater capacity utilization. But in case of a remote region, due to the continuous increase in the price of diesel because of high transportation cost along with high import duties, the diesel system may not be cost effective in future compared to SPV system, the price of which is gradually declining as a result of the continuous development of technologies.

Table 1
Cost of generation of power through thermal, diesel generator and SPV systems in the Year 1999[a,b]

Generating system	Average cost/kW (Rs. 000)	Annual capital cost/kW (Rs. 000)	Annual O & M cost/kW (Rs. 000)	Annual generation at bus (000 kW h)	Annual fuel cost (Rs. 000)	Total cost (Rs. 000)	Cost of generation (Rs./kW h)
Thermal	40.00	4.97	1.00	5.52	7.10	13.07	2.37
Diesel	12.00	2.12	1.20	1.28	5.58	8.90	6.97
Solar	300.00	38.28	7.50	1.75	—	45.74	26.10

[a] *Source*: Information has been collected for thermal power system from West Bengal State Electricity Board; for diesel based and SPV systems from the existing plants in the island under consideration.

[b] *Notes*: (1) Annualized capital cost is based on capital recovery factor using (a) interest rate at 12 per cent, (b) discount rate at 12 per cent (c) system life as 30 years for thermal and 25 years for SPV systems and (d) annual O & M cost is 2.5 per cent of capital investment. (2) Average capital cost of 1 kW capacity thermal plant has been estimated from a plant of 100 MW capacity where the capital cost is Rs. 40 billion. (3) Coal price has been taken as Rs. 1.65/kg and consumption rate as 0.7 kg coal/kW h; (b) oil price has been taken as Rs. 12.5/l and consumption rate as 0.35 l/kW h. (4) PLF (load factor) has been taken as 70 per cent for thermal power station, 16.7 per cent for diesel based system and 20 per cent for SPV system. Internal consumption of power is assumed to be 10 per cent for thermal system and 3 per cent for diesel based system.

The cost incurred for the distribution of power from a centralized conventional system to distant areas from the 33 kV grid point, presented in Table 2, is quite high compared to its generation cost (which is zero in case of the decentralized SPV system. The cost of the distribution network depends on the length of the 11 kV line along with substation cost, transformer rating or peak demand and the demand of the area i.e. load factor. Assuming peak demand/ transformer rating to be 25 kW which is usually used for rural areas and 20 per cent load factor, it is observed that the distribution cost/kW h is sufficiently high and increases with the increase in the length of the line.[3] In addition to this, the cost of energy increases further due to heavy line losses at the time of transmission and distribution. These line losses have gone up steadily in India during the last two decades. The national average of the loss is now 21 per cent of the production whereas in the rural areas it may have gone up to even 40 per cent of the production.

As mentioned earlier, one has to have a critical minimum size power plant and there may be a loss due to excess production and supply of power for which there is no demand. It has been estimated that for supplying 1 kW h in rural areas a plant producing 1.67 kW h had to be set up (Sinha and Kandpal, 1991). Considering this amount of loss due to excess production, the cost of generation of utilized power from the grid in rural areas goes up to Rs. 3.95/kW h. Adding this cost to the amount due to the distribution network would give the cost of delivered power (presented in Table 3). A comparison of the direct cost per unit of delivered power from three sources indicates that the cost of conventional energy is much lower in the vicinity of the supply point. On the other hand, with the increase in the distance from the centralized supply point, the use of locally generated power from solar energy is gradually becoming more viable.

The most significant problem of supply of conventional power lies in its dependence on the limited exhaustible resources as against the unlimited supply of solar power in SPV plants. Even if we think globally, the existing quantity of fossil fuel may be used for some more years to generate energy (Saha, 1999). The UN conference in Reo-de-Janerio held in June 1992, addressed itself to the challenge of achieving worldwide sustainable development and it was felt that it cannot be achieved without major changes in the world's energy system. In countries like India, dependent mostly on the import of fuel, the rapid upward shift in the cost of imported oil has increased the cost of generation of electricity significantly over the years. On the other hand, the cost of SPV cells is declining progressively over time as a result of Research and Development (R & D) (see Table 4).[4] So a time would come when the per unit energy cost from the SPV plants would be comparable with that of the centralized system at all levels for a rural electrification programme.

Assuming the same rate of change of prices of capital goods and fossil fuels (given in Table 4) for the years up to 2010, the costs of delivered power supplied by coal based thermal plant, diesel based system and SPV plant have been estimated separately and have been presented in Table 5. The analysis of the results indicates that compared to the SPV system the use of diesel fuel in the power generating system will not be viable beyond 5 km distance even in the year 2005. As we will be depending on imported oil for consumption there is every

[3] The cost has been under-estimated because of the following assumptions included in the estimation: (1) the cost of supply up to the 33 kV grid point, which could be realized by supplying power for industrial consumption at a higher rate, has not been included in the distribution cost in the rural areas; (2) consideration of 20 per cent load factor as average demand, which is difficult to be realized in remote rural areas (Reddy et al., 1991).

[4] The present average cost of SPV plant of 1 kW capacity is Rs. 0.27 million which indicates a 10 per cent decrease in the price within the last one year.

Table 2
Distance-wise cost of distribution of power ($kW\,h^{-1}$) by the conventional system in the year 1999[a,b]

Item of expenditure	Cost of distribution by distance (km) from 33 kV grid point				
	5	10	15	20	25
Capital cost (Rs. Million)	1.5	3.0	4.5	6.0	7.5
Annual capital cost (Rs. Million)	0.20	0.40	0.60	0.80	1.00
O & M cost (Rs. Million)	0.04	0.08	0.11	0.15	0.19
Total cost (Rs. Million)	0.24	0.48	0.72	0.95	1.19
Cost/kW h (Rs.)	5.44	10.88	16.32	21.76	27.20

[a] *Source* : West Bengal Renewable Energy Development Agency.
[b] *Notes* : (1) Cost km^{-1} of distribution line (11 kV) from the 33 kV grid point is Rs. 0.3 million. (2) Rate of interest/discounting has been assumed as 12 per cent and O&M cost as 2.5 per cent of capital cost. Life of distribution line has been taken as 20 years. (3) Peak load has been taken as 25 kW where as the average load has been assumed as 20 per cent of peak load.

Table 3
Cost of delivered power in a remote village in the Year 1999[a]

Generating system	Cost of delivered power by distance (km) from 33 kV grid point				
	5	10	15	20	25
Thermal station	9.39	14.38	20.27	25.71	31.15
Diesel generator	14.12	19.56	25.00	30.44	35.88
Solar PV	26.10	26.10	26.10	26.10	26.10

[a] *Notes*: Cost of delivered power is the sum of generation cost of power supplied at bus and distribution cost including cost for line loss. The line loss as a percentage of production has been taken as 40 for thermal system, 21 for diesel based system and 0 for SPV system.

Table 4
Rate of change of cost of different items[a]

Item	Cost of items (Rs. 000 at 90–91 prices)		Rate of change per year (per cent)
	1990–91	1998–99	
‘A’ grade coal (ton^{-1})	0.74	1.02	5.20
Diesel (kl^{-1})	3.66	5.02	4.00
Thermal Power Plant (kW^{-1})	25.00	23.61	−0.70
Solar PV (kW^{-1})	400.00	177.04	−9.70
Distribution line cost (km^{-1})	200.00	177.04	−1.50

[a] *Source*: West Bengal State Electricity Board and West Bengal Renewable Energy Development Agency, Government of West Bengal, Bhatia and Pereira (1988).

possibility of increase in the price of oil enhancing the price of diesel fuel further.[5] On the other hand, the coal based thermal power plant would be viable up to the year 2005 only up to a 10 km distance. SPV system would be economically cheaper by the year 2010 than the coal based thermal system in remote rural areas even for a distance of 5 km. It may be further mentioned here that because of the continuous research on the development of thin film, the use of solar energy for power generation is expected to become more cost effective by the year 2005.

[5] The evidence from the specific case of the island shows that the price of diesel has gone up by nearly 18 per cent from 1999–2000.

However, the estimation of only the direct cost is not sufficient to justify the investment involved in each of the systems. One should also include the indirect impact of such investments of the cost of generation. One of the most significant indirect effects of investment in solar SPV power plant is the saving of exhaustible resources like coal/diesel needed for the generation of electricity. The generation of 1 kW h power using solar energy saves at least Rs. 4.38/kW h at 1999 price level by saving the consumption of 0.35 l of imported diesel oil resulting in a saving of foreign currency of about \$0.10 at the 1999 exchange rate. This saving amounts to Rs. 1.16 at 1999 prices by way of saving of 0.7 kg coal in generating 1 kW h power by the thermal system. Further, the high

Table 5
Distance-wise cost of delivered power for different power generating systems for the years 2005 and 2010

Sources of power generation	Cost of delivered power by distance (km) from 33 kV grid point				
	5	10	15	20	25
Year 2005					
Thermal	9.55	14.60	19.64	25.45	29.69
Diesel	14.85	19.90	24.94	30.75	34.99
Solar PV[a]	15.18	15.18	15.18	15.18	15.18
Year 2010					
Thermal	9.76	14.43	19.15	23.83	28.59
Diesel	15.76	20.43	25.15	29.83	34.54
Solar PV[a]	9.67	9.67	9.67	9.67	9.67

[a] Locally installed plant, see note below Table 3.

transmission and distribution losses over a long distance from the grid point to a remote area is also a social cost, the impact of which has to be taken care of at the time of estimation of production cost. On the other hand, supply from local centre through renewable sources is much more assured with almost zero loss in distribution.

2.2. *Environmental aspect*

The use of fossil fuel is increasingly being recognized as a prime threat to human health, environmentally one of the most disruptive human activities and one of the prime causes of global warming leading to the change in agricultural production and other catastrophic events. In our country the electricity generation sector alone contributes 40 per cent of the total emission of CO_2 from the use of the energy (Murthy et al., 1997). An estimate shows that emission of CO_2 to the atmosphere amounts to about 1.2 and 0.9 kg/kW h produced from coal and oil, respectively (Meidav, 1998). This environmental cost, called externality cost, of the generation of energy which has a negative impact on human health and habitat, is not included in the calculation of per unit production cost of energy. This cost may be estimated indirectly by considering the cost of remedial activities such as the cost of planting trees for absorbing CO_2 of an equivalent amount. The willingness to pay for the preservation of human habitat, or for avoiding damage to human health due to the environmental degradation are also ways of estimating the external cost. The estimates of external cost associated with different fuels, which are ($/kW h) 0.05 for coal, 0.03 for oil and 0.02 for natural gas indicate the significance of such costs, the inclusion of which in the production cost of energy through conventional systems would increase it to a significant level. The production of power from solar energy, like other non-conventional energy sources, is free from such pollutive consequences.

In another estimate by the World Health Organization, it is seen that the external effects account for more than 3.5 million deaths of children under the age of five years each year due to respiratory problems. The respiratory and other diseases associated with coal burning affect 14 per cent of China's population. The indoor air pollution for burning bio-mass fuel for cooking is not only high but also common in rural areas in a country like India. The high incidence of the use of biomass fuel is due to its easy availability and low or zero cost. The solar energy may not still be an economically viable source in this regard, but it can partially replace the use of oil for light, and may reduce, though in a limited scale, the adverse impact of oil burning on human health. Hence, the indirect costs associated with the production of energy by conventional systems, must be included in the estimation of production cost to obtain the true economic value. This would help in assessing the economic viability of the SPV system in the context of the rural electrification programme.

2.3. *Social aspect*

The most significant social benefit of the use of decentralized energy sources is that it can be made available to isolated and remote areas, like islands. In India in 18 000 villages, of which 900 villages are in the state of West Bengal, grid supply is very difficult due to the remoteness of location and/or being isolated from mainland. The cost of coal based electrification in such places, either from centralized network with high transmission and distribution loss or from localized centre with high cost of transportation of fossil fuel, is prohibitively high. The only possible source of conventional power from diesel generation on the island itself, adjustable with local demand, also does not prove to be viable due to the increasing price and high transportation cost of diesel. Under this situation, non-conventional power, like solar power, may be taken as the best possible means of power supply in such places. Admittedly, in places like the island under consideration, the demand is at present low primarily due to the low purchasing power of the local people. However, with the improvement in the standard of living of the people, the demand is expected to increase and one can imagine that the supply of energy is essential in bringing about such improvements. The supply of power is to be ensured for the development of small industries, to facilitate irrigation for agriculture, for promoting trade and business during extended hours, to help in studies and human capital formation and for many other developmental activities of sustainable nature. Remote regions may find that the local supplies, though more expensive from the point of view of financial cost than the grid connected electricity, is the only viable solution to electrification. The case of Sagar Dweep, an island in West Bengal, India, is an ideal case for a study of the socio-economic impact of power supplied by SPV plants.

3. Sagar Dweep—a case study

3.1. A socio-economic profile of the island

Sagar Dweep is an island, 96 km South west of Kolkata, in the Sundarbans in the state of West Bengal, India. The development of the island because of the improvement in the transportation system between Kolkata and Sagar Dweep and also because of the other developments within the island such as the development of agriculture, introduction of new commercial crops, fishing of prawn, etc. has raised the level of living in the island leading to an increase in the demand for power, the lack of which now seems to be a major bottleneck (Bhattacharjee, 1998). Like other rural areas, the people of Sagar Dweep also realize the need for electric power for home lighting, use of appliances such as fan, TV, radio etc., for community services like street lighting, lighting in schools, colleges, hospital, telephone communication, agriculture pumping, warehouse building for storing of agricultural products and for operating small and household industries. At present, the West Bengal State Electricity Board supplies electricity to the island by using diesel-driven generators. But the supply is limited to only 650 consumers concentrated in places along the side of the main artery road of the island and that too for 4 h a day. Furthermore, the continuous increase in the price of diesel has not only been pushing the production cost up but is also making any expansion programme, even for lighting only, unattractive to the authority.[6] The irrigation pumps are operated using diesel, which is also becoming more and more expensive. The development of any other activity which needs power, directly or indirectly, has become impossible.

The alternative of supply of power through the grid-connected plants from the mainland has also been considered undesirable because of technological and economic constraints. Thus, there is genuine problem of providing, perhaps the most important, infrastructural facilities needed for development. In a situation like this, the supply of power from solar energy, though at present on a small scale, has opened up the avenue for the much needed social and economic development of the island. A programme for introducing new lighting technology, solar lantern, in place of existing exhaustible resource based kerosene lamp, was launched in 1994 in this island (Roy and Jana, 1998). Encouraged by the favourable response an attempt was made in 1995 to supply power on a much broader scale and hence, to install an SPV power plant, for the first time, to supply electricity in the interior places of the island. The first such power plant was established towards the end of 1995 at Kamalpur(Ka) village and the supply of power started at the beginning of 1996. The next plant was installed in the year 1998 at Mrityunjoy Nagar (Mr) village and three others were started in the year 1999 at Khasmahal (Kh), Gayen Bazar (Gb) and Mahendragange (Ma). However, it has been possible, up to the beginning of 2000, to serve about 475 consumers, which contributes only 32 per cent of the households residing within the plant area[7] from the five plants for at least 5 h at night (see Table 6); to a significant number (about 68 per cent) power is out of reach due to the limited capacity of the plants.[8]

3.2. Analysis of the results

The study of the socio-economic impact of the use of energy has been done as a part of a bigger project using the primary data collected from a survey conducted in the year 2000. Samples were drawn from a list of users of solar power in each of the above mentioned five places. While the impact on actual development and, more importantly, on the perception of the people regarding the effects of supply of solar power on the process of development may not be properly assessed on the basis of information on the experience of the people for a maximum period of four years and that too on a limited scale, it seems that significant developments have taken place in Sagar Dweep in respect of various socio-economic and environmental aspects including

[6] At present the loss incurred by West Bengal State Electricity Board is about Rs. 0.25 million per month for operating diesel generator in the island.

[7] By ‘plant area’ we mean the area within the distribution line network of SPV plant.

[8] Almost all of them have expressed the desire for getting power and some of them have already placed their demand to the supplying authority.

Table 6
Distribution of households within the SPV plant area by type and by centre in the year 2000[a,b]

Type of households	No. of households by centre					All
	Ka	Kh	Mr	Gb	Mg	
Total households within the plant area	106	175	426	491	289	1487
Users of electricity	64	106	91	107	107	475
	(60)	(61)	(21)	(22)	(37)	(32)
Non-users of electricity	42	69	335	384	182	1012
	(40)	(39)	(79)	(78)	(63)	(68)

[a] *Source*: Survey, May 2000.
[b] *Note*: Figures in parentheses are percentages.

Table 7
Distribution of sample households using electricity from SPV plants by household particulars in the year 2000[a,b]

Household particulars	Centres with SPV plants					All
	Ka	Kh	Mr	Gb	Mg	
Average household size of the users	7	6	6	6	6	6
Principal occupation(% of total)						
(a) Agriculture	78	60	33	52	30	46
(b) Non Agriculture	22	40	67	48	70	54
Households having more than one occupation (% of total)	33	75	48	48	77	59
Ave. Cost of Kerosene per household (Rs./Month)	34	38	83	43	50	53
Households with no. of power points(% of total)						
(a) 3 points	39	88	30	90	75	65
(b) 5 points	61	12	70	10	25	35
Total no. of sample households	18	25	36	31	40	150

[a] *Source* : Survey, May 2000.
[b] *Note*: (1) Name of the centres—Ka, Kamalpur; Kh, Khasmahal; Mr, Mrityunjoy Nagar; Gb, Gayen Bazar; Mg, Mahendragang. (2) Figures in the last column for 'All' are the weighted sum of the figures for centres, weights being the share of centres in the total sample.

education, income generation, entertainment, social life and health.

The analysis of the survey results given in Table 7 indicates that the primary occupation of 46 per cent of sample households is agriculture, whereas the remaining 54 per cent are engaged in non-agricultural activities, mainly in trade and business. The availability of power at night has helped in the expansion of activities or extension of the work period of these activities compared to that in the pre-solar period. The supply of power has also encouraged the people of the island to start additional activities at night. About 59 per cent households are engaged with more than one occupation. They are now incurring a higher cost for consumption of electric power compared to the cost of kerosene (Rs. 53.0 per month per household), which was used for lighting before the availability of electric power. The charge for the use of solar power is at least Rs. 70.0 for three points and Rs. 120.0 for five points per month irrespective of whether they consume it or not.[9] There are some consumers who hold connections for more than five points for commercial use, like battery charging, running video hall etc. and have to pay accordingly. It should be mentioned that till now only a part of the total households residing within the radius of the supply zone of the plants are enjoying the benefit of having electric power. Table 8 describes the reasons given by the users for the demand for solar energy as a source of power supply. In the absence of any supply of electric power, the only alternative source was the privately owned diesel generated power, the cost of which was too high (Rs. 18.0–Rs. 22.0 per light point of 40 W) and supply was also restricted to 4 h. Solar power, in contrast, is available now more cheaply, which is the most important reason for its demand. The scarcity of kerosene is another reason for adopting it.

The availability of power for longer period and brightness of light compared to others are the other significant reasons stated by them for their demand of solar power.

Though there is little scope of developing various types of activities within the limited period of time of availability of power, the results depicted in Table 9 show that the power supply at night has helped society in at least four ways. It has helped (i) students to continue their study at night, (ii) shopkeepers,

[9] The funds for investment for installing the SPV plants, here, have been taken as loan from the World Bank at one per cent rate of interest, and the maintenance works are being done by the respective suppliers of the machines. Therefore, the cost of generation has been estimated at about Rs. 8.0 per unit , which is charged as price per unit of power delivered.

Table 8
Frequency distribution of sample households by reasons for taking connection from SPV power plant in the year 2000[a,b]

Reasons	Percentages of households with SPV connection					
	Centres					All
	Ka	Kh	Mr	Gb	Mg	
Low cost compared to Pvt. diesel generation	1	8	67	39	75	46
Scarcity of kerosene	39	20	14	39	15	23
Longer period of supply	0	0	39	45	18	23
Bright light	1	32	22	17	12	17

[a] *Source*: Survey data, May 2000.
[b] *Notes*: See Notes below Table 7.

Table 9
Frequency distribution of sample households by type of benefits derived for getting power from SPV plant in the year 2000[a,b]

Type of benefit	Percentage of households with SPV connection					
	Centres					All
	Ka	Kh	Mr	Gb	Mg	
Availability for longer period for study	67	80	28	54	30	47
Saving of time for cooking	56	80	17	48	13	38
Movement at night	6	4	8	29	0	9
Entertainment	17	28	39	13	8	21
Time for household work at night	6	48	22	10	2	17
Physical comfort	6	24	17	10	53	25
Doing of agriculture work at night	28	24	3	3	13	12
Availability for longer period for trade and business	17	4	75	35	68	46
Increase in income for extended hours of work	22	16	83	58	35	46

[a] *Source*: Survey data, May 2000.
[b] *Notes*: See Notes below Table 7.

cultivators of betel leaf to continue their work at night, (iii) people to avail themselves of the entertainment facilities and (iv) women to do household work. According to them (about 47 per cent of the sample households) the supply of power has helped children significantly in their studies. It should be pointed out that there is already a tutorial home working at night in Kamalpur village which has helped the students greatly. They have also mentioned that, on an average, they are now getting an extra 2.25 h per day for study. The cultivators, cultivating betel leaf, have also benefited from the power supply as a significant part of their work like arrangement of leaf for supply, watering in the field etc, can be done at night. The supply of power has also helped the commercial establishments to continue their activities at night for a longer period and to provide more services to the people. The production works like weaving, sewing etc., have also been carried out at night with the help of electric light.

The women of the households have reported that they are now able to continue their household work at night. The supply of power has saved their time spent for cooking compared to that at the time when kerosene was used. About 38 per cent have reported that, on an average, the use of power has helped to save cooking time at night by 1.5 h, which they can now use for other household works. Besides these, the supply of solar power has also helped, though on a small scale, to run the video hall, battery charging centre etc. As a result of extended hours of work in the existing activities and the initiation of new activities, there is likely to be an increase in income of the people of the island. This view has been supported by 46 per cent of the sample households.

Despite the higher cost, the people, irrespective of their income level, are demanding more power now for entertainment, comfort and development work. On the whole about 46 per cent of the households have expressed their willingness to pay even more than what is being charged at present for getting power (see Table 10). Though most of them (about 47 per cent) are willing to pay an additional amount of Rs. 6–15 per month over the current expenditure, for some of them (about 4 per cent) the additional amount was even more than Rs. 50 per month.

It is stated that the burning of kerosene oil for light and fuel has a number of adverse effects, both short and long term, on human health. However, while it is

Table 10
Frequency distribution of sample households willing to pay extra amount over the current charge by amount of additional payment in the year 2000[a,b]

No. of points Used	No. of households	% of households WTP more	Percentage of households willing to pay more by amount of additional payment					
			Rs. Up to 5	Rs. 6–15	Rs. 16–25	Rs. 26–50	Rs. Above 50	All
3 Points	100	48	15	50	25	8	2	100
5 Points	50	42	24	38	5	24	9	100
All	150	46	17	47	19	13	4	100

[a] *Source*: Survey data, May 2000.
[b] *Notes*: See notes below Table 7.

Table 11
Frequency distribution of sample households aware about different environmental aspects of the use of conventional resources in 2000[a,b]

Environmental aspects	Percentage of households with SPV connection					
	Centres					All
	Ka	Kh	Mr	Gb	Mg	
Problems in generating power from diesel	67	60	42	35	52	49
Suffering from eye problems for using the Kerosene	0	28	25	26	20	21

[a] *Source*: Survey data, May 2000.
[b] *Notes*: See notes below Table 7.

difficult to identify the long-term effect, one of the short-term effects is the eye problems. About 21 per cent have reported that their family members suffered from eye problems (see Table 11), which could have been avoided by using electric power. A more interesting observation is that a significant proportion of the sample households are aware of the fact that there exist environmental problems in generating power using diesel oil while the use of solar energy is free from such problems. As a result, they have expressed their willingness to continue the use of solar power, even if diesel power is available at low cost, to avoid the air and noise pollution caused by a diesel generator. Above all, the decentralized nature of production and distribution as well as the system of supervision through cooperatives make the whole system more efficient by reducing the loss of revenue owing to lapses in collection.

4. Concluding remarks

It may be concluded that while the production of solar power is still not viable in terms of financial cost calculation, it does assure significance which cannot be ignored from the point of view of the programme of total electrification. At the present stage of development of technologies solar power may not, in general, be taken as a substitute, but can serve as a complement to the fossil fuel based conventional power because of reasons mentioned earlier. As a result of the continuous development and research on solar power generating system, a time is expected to come when the supply of power using solar energy will be the only viable and sustainable solution for energy supply. The significance of the supply of power using solar energy would have already been realized in the context of conservation of exhaustible resources and ensuring a pollution free environment.

The social and economic significance of solar power is much higher in remote and distant rural areas, forest areas, and islands compared to those in the mainland. Sagar Dweep in West Bengal is an example of this. Of course, a maximum of four years of experience is not enough to draw firm conclusions on the social and economic impact of any developmental work. However, somewhat surprisingly, a noticeable improvement in education has been seen in Sagar Dweep even within this short spell of time. Significant development has been observed in the commercial activities also, as can be seen from the activities running for a longer time compared to the pre-SPV period. Productivity of the people has also increased, especially in case of cultivation of betel leaf. Other significant benefits that are being enjoyed by the women in the island are the facilities for their movement and carrying out of additional work at night, which were not possible earlier. Some of them have also got engaged in other work, like running a tea stall, sewing etc.

Besides the above, an SPV plant is also supplying power to run a hospital, the services of which are essential to society. Another essential service, the telephone booth, is being run with the help of solar energy in an individual capacity. Therefore, in addition to trying to estimate what the true cost of electricity generated by solar energy is, it would be useful to analyse how and in what ways availability of electric power influences the social and economic life of people in a remote area or in a place cut off from the mainland. It is not easy to make proper valuation of all the benefits but then these should not be ignored either.

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