A Study on the Impact of the Use of Electricity on Socio-economic Activities and Environmental Awareness of the Inhabitants of Sagar Dweep, an Island in West Bengal, India[*]

Snigdha Chakrabarti

Subhendu Chakrabarti

Amita Majumder

Robin Mukherjee

Indian Statistical Institute, Kolkata

[*]Address for correspondence

Snigdha Chakrabarti
Economic Research Unit, Indian Statistical Institute
203 B. T. Road, Kolkata 700 108, India
Email : snigdha@isical.ac.in

1. Introduction

Access to adequate as well as affordable power services is a necessary condition for socio-economic development of a society. In a country like India where the major economic activity is agriculture, supply of power, particularly to rural areas, is of great significance in accelerating growth. It is also needed to promote other economic activities for growth and development. The impressive, above the average, observed growth rate in the energy sector of many of the East and Southeast Asian countries during the last two decades proves that there is tremendous demand for power. But precisely what is lacking in underdeveloped and developing countries like India is the supply of power and this is what is constraining growth. Besides, supply of electric power has remained uneven here and the per capita availability of power in the least developed countries has remained below 400 kwh compared to that of 900 kwh in developed countries. It indicates that in spite of this rapid growth there is a large amount of un-served demand for power in these underdeveloped and developing countries. In this respect the adoption of rural electrification in India has been regarded as an essential step towards achievement of a high rate of growth. However, as the major source of energy is the conventional grid power produced from coal and to some extent from oil, the setting up of the long and costly transmission and distribution lines coupled with high transmission and distribution loss, increasing price of fossil fuels and high cost of centralized management system make the programme unattractive in many places, in some cases impossible. Also, there are financial and technological constraints due to lack of funds for investment to expand the capacity.

Alternatively, the use of non-conventional renewable energies is being recognised gradually as a source of supply of power in the programme of total electrification. In remote places and in some isolated regions, like islands, locally supplied non-conventional power, despite its inherent disadvantages, has been considered as a viable solution to the problem of power supply and as an alternative to living without power.

It is not possible to generate power on the main land and distribute it to places like islands. What is needed, therefore, is production in the island itself. In doing this,

production by conventional means may not be found economic because the total consumption on the island would perhaps not justify setting up of a plant, even of a smaller size. There is also requirement of a large amount of investment. Alternatively, one may think of another conventional system, the diesel based generator. But because of its dependence on exhaustible resources, like diesel oil, and its high transportation cost to carry to an island it too is not proving economic. Presently the households in these places can enjoy only a limited number of hours of illumination based on kerosene or diesel. However, these are not easily available and not affordable by majority of the rural masses.

Small-scale renewable energy plays an important role in this context as it can be produced according to the needs (Sinha and Kandpal, 1991). Among the abundant sources of alternative renewable energy like hydro, bio-mass, wind etc.,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 objective of the present study, based on a survey project, is to ascertain and assess the impact of guaranteed supply of power using SPV system, on the economic and social life of the people of an island, Sagar Dweep. The plan of this report is as follows.

In the next section the limitations of the conventional sources of power supply has been discussed briefly. This would help in appreciating the possibilities and potentialities of the use of non-conventional energy. The history of the use of solar power has been described in brief in the section three. A comparative analysis of costs of conventional methods of power supply and power from SPV plant has been presented in section four. A brief description of the socio-economic profile of the island, Sagar Dweep, has been presented in section five. Section six is devoted to a detailed presentation and analysis of the survey result. Finally, section seven presents the concluding remarks.

2. Limitation of the conventional sources

The first and most significant problem of supply of conventional power lies in the dependence on resources which are exhaustible. Even if we think globally, the existing quantity may be used for some more years to generate energy. But in countries like India, which do not have enough natural resources and have to depend 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. In India till now electricity has not reached in 80000 out of 576000 villages. On the other hand, the estimated coal and oil reserves are 66 billion tons and 770 million tons, respectively, and the corresponding per year requirements are 260 million tons of coal and 70 million tons of oil (Saha, 1999). It is clear from this that one single energy technology cannot be adequate to meet the energy requirement in India. So it is high time for us to identify which specific technology or which other sources of energy can be harvested to bridge the gap between demand and supply.

The second major problem is that the use of fossil fuel is increasingly recognized as a prime threat to human health resulting in disruption of normal human activities. Emission of CO_2, nitrogen oxide and sulfur dioxide react in the atmosphere to form acids, that fall as rain, snow or fog or turn to acid on direct contact corroding constructions and damaging vegetation, soils, rivers, lakes and crops.

Thirdly, though the necessity of power is unquestionably recognized, nearly half of the global population does not enjoy its benefit due to the distance from grid point or because of small local demand which does not justify the interconnections of locations that can not be connected readily. In India, in 18000 villages, of which 900 villages are in the state of West Bengal, grid supply is very difficult due to remoteness. The cost of centralized network of fossil fuel based electrification in such places would be prohibitively high. Even in the case of localized centre for power generation the cost of transportation of fossil fuel to remote areas should be compared with that of transmission cost for centralized electricity production. Therefore, as an alternative, or at least as a complementary to the grid power, decentralized small-scale and renewable energy

technologies can play a very important role in these regions in helping the process of development. 'To achieve energy self-sufficiency, rather than self reliance, is becoming new major development goal'(Penner and Icerman, 1975, ch.14).

It seems, therefore, that for the new supplies of energy, the possibilities of exploiting decentralized locally available non-conventional sources of energy, like solar energy, must be explored along with the conventional source of power. Apart from the economic, social, and environmental advantages, the use of such technologies may be justified in the following ways. Firstly, solar energy is a continuous flow of energy whether we use it or not. Secondly, the technologies based on such renewable resources are flexible, easy to understand and hence can be used without requiring highly skilled personnel. Thirdly, the technologies are matched both in terms of scale and geographic distribution linked to end use needs, and can take advantage of free distribution of natural energy flows. Further, these technologies can be operated at high capacity with low loss of power. Operation and maintenance are simple and do not need any raw materials or components except battery upkeeping and maintenance of a clean surface over the modules calling for attention from time to time. These features are attractive and conform to appropriate technology as necessary for remote places. SPV system judged from this aspect score as best amongst all other renewable resources.

3. History of Solar energy use

The use of solar energy is not new. It was there in ancient times, though on a limited scale. Solar heating was first done by J. Priestly in 1774. A unit producing a maximum of 6000 gallons of fresh water per day, using solar energy, was set up in the mines in the North Chillean desert in 1872 and it continued to supply fresh water for 40 years. Solar heated system boilers were developed and demonstrated in exhibition in 1878 in Paris. But the development of production of power using other energy sources like fossil fuels led to a neglect, so to say, in developing technologies based on solar energy, though the importance and efficiency of solar energy in remote areas were realized. It was only since around 1950's that modern technologies for production of solar energy started. The development of solar photovoltaic cell (SPV), the technology which is more modern and less sensitive to system size, is indeed an achievement. In this

technology solar photovoltaic cells convert solar light directly to electric current through the electronic structure. It can be used in a system as small as the size of a wrist watch or as large as a power station. The use of SPV in the space programme is now well recognized. It is being used directly in different fields viz.; domestic power supply, industrial power supply like garden lighting, communications, signal lighting, telephone, electric fencing etc. Apart from these the supply of grid quality power through SPV power plant has also started as an alternative to grid power though not in a large scale. A SPV plant consists of solar arrays, charge controller, battery system, inverters, distribution lines etc. The power generation arrangement does neither have any fuel input like in conventional system nor there is any rotating part to develop wear and tear. Exclusive of basic materials making solar cells which are imported, complete equipment is manufactured on indigenous technology and developed to international quality standard.

4. Comparative assessment of different modes of electric supply

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 (a) economic, (b) environmental and social viability of its use.

(a) Economic aspect

So far as the 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 lack of adequate demand for power specifically in the rural areas characterised by the absence of industrial activities in 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 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 SPV plant primarily due to its high capital cost[2].

The cost incurred for distribution of power from a centralized conventional system to the distant areas from 33KV grid point, presented in Table 2, is quite high compared to its generation cost (which is zero in case of decentralized SPV system). The cost of 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

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[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, the 'Sagar Dweep'. Here due to high cost of diesel fuel two out of three generators with 160 KW capacity run four hours a day. On the other hand, all the SPV plants each with 26 KW capacity run five hours 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 continuous increase in 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 continuous development of technologies.

rural areas and 20 per cent load factor, it is observed that the distribution cost /kwh 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 even to 40 percent 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 kwh in rural areas a plant producing 1.67 kwh has 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/kwh. Adding this cost to the amount due to distribution network would give the cost of delivered power (presented in Table 3). 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 U.N. conference in Rio-de-jenerio, 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

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[3] The cost has been under-estimated because of the following assumptions included in the estimation: (1) the cost of supply upto 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.

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 SPV system the use of diesel fuel in power generating system will not be viable beyond 5 km distance even in the year 2005. As we are to depend on imported oil for consumption there is every possibility of increase in price of oil enhancing the diesel fuel further[5]. On the other hand, 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 the power generation is expected to become more cost effective by the year 2005.

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 one kwh power using solar energy saves at least Rs. 4.38/kwh at 1999 price level by saving the consumption of

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

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

0.35 lt. of imported diesel oil resulting in the 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 0.7kg. coal in generating one kwh power by the thermal system. Further, the high 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.

(b) 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 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 carbon dioxide to the atmosphere amounts to about 1.2kg and 0.9 kg per kwh produced from coal and oil, respectively (Meidav, 1998). This environmental cost, called externality cost, of generation of energy which has 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 the CO_2 of 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 ($/kwh) 0.05 for coal, 0.03 for oil and 0.02 (Meidav, 1998) for natural gas indicate the significance of such costs, 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 of 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[11]. The indoor air pollution for burning of 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 owing 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 the 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 rural electrification programme.

(c) 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 18000 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, does not also prove to be viable for increasing price and high transportation cost of diesel. Under this situation non-conventional power like solar power may be taken as the best possible way 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 supply of energy is essential in bringing about such improvements. 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 in India, is an ideal case for a study of the socio-economic impact of power supplied by SPV plants.

5. Socio-economic profile of Sagar Dweep

5.1 General description of Sagar Dweep

The Sagar Dweep lying in the Sundarbans area in West Bengal is unusual in more ways than one. It is a part of the vast delta of the Ganga – an area characterised by mangrove swamps and islands interwoven by a network of small rivers and waterways. The tidal swamp forests of the delta with its unique eco-system is the habitat of the endangered Royal Bengal Tiger.

Sagar Dweep with an area of around 300 sq km, is a large island in the estuary, about 90 km south of Kolkata. It is accessible by road and a regular ferry service links Kacuberia, a village on the island, to the mainland, which is 6km away, across the Muriganga River. With a population of 1,50,000 spread over 16 villages, farming and fishing are the main occupations on the island. Besides the usual food crops like rice, lentils, bananas and vegetables, cash crops like betel leaves (pan), chillies, water melons, etc. are also grown. Prawn cultivation for export is a new development on the island and some Kolkata based business houses have already started their operations on Sagar.

Located at the point where the river Hoogly enters the Bay of Bengal, Ganga Sagar is also a sacred place of pilgrimage. It attracts thousands of devotees each year, especially during the annual Ganga Sagar Mela (fair) which is held during Makara Sankranti in mid January.

5.2. Existing sources of fuel and light

Presently, the households can enjoy only a limited number of hours of illumination based on kerosene and diesel. The West Bengal State Electricity Board (W.B.S.E.B.) supplies electricity through the diesel driven generators with a capacity of 300 KW to only 650 consumers concentrated in places along the side of the main artery road of the island for 4 hours a day. A programme for introducing new lightning technology, solar lantern, in place of existing exhaustible resource based kerosene lamp, was launched in 1994 in this island. The Lantern works for about 4 to 5 hours after full charging of the battery through solar photovoltaic module of capacity 12wp. The subsidised price of a solar lantern varies from Rs. 2,500.00 to Rs. 3,000.00. Besides this, home lightning system and solar-street has also been introduced in the island. The home lighting system comprises two light points and one portable TV point. This is the most popular Solar Photovolataic unit in the Sundarbans. Cost of a complete solar home lighting system varies from Rs.14,000.00 to Rs. 16,000.00 depending on the site of installation. Stand-alone solar street lighting system comprises a CF lamp, two modules, battery poles and other accessories. Generally the street light operates for 12 hours. The subsidised price of a solar photovoltic light varies from Rs. 13,000.00 to Rs. 14,000.00.

To supply power on a much larger scale and to electrify the interior places of the island the first SPV power plant was established towards the end of 1995 in Kamalpur village. The plant started supplying power at the beginning of 1996. The next plant was installed in the year 1998 at Mrityunjoy Nagar and three others were started in the year 1999 at Khasmahal, GayenBazar and Mahendragange. Each of these SPV power plants has a capacity of 25KW and can take a load of 3 light points and two plug points. The tariff structure for the SPV power plant is Rs. 120.00 per month for 5 hours of operation[6]. Till the beginning of 2000, 475 consumers have been served through these five SPV power plants.

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[6] The funds for investment for installing the SPV plants, here, have been taken as loan from 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 as about Rs. 8.0 per unit , which is charged as price per unit of power delivered.

6. Survey results

6.1. Data and Methodology

The study is based on a sample survey. A multistage sampling method was adopted to select the sample separately from solar-power users, diesel generator power (supplied by W.B.S.E.B) users and non-users.

Solar PV

Samples were collected from each of the five SPV centres. At the first stage of sampling a list of users along with their address was collected from the respective centres. Information was also collected on the purpose of use (e.g. domestic/ commercial). In the next step the users were stratified by these purposes. At the final stage samples were selected from each stratum in each of the five centres with sample proportion equal to the population proportion of the stratum. The overall sample size is 150.

Diesel Generator Centre (supplied by W.B.S.E.B.)

In this case an initial list of users by place of use was collected from the SEB office. Two types of stratification were made in the second step, viz, by place of use and then by purpose of use. In the next step three places were selected purposively. These are for getting a comparative analysis between solar and diesel users. But the sample selected from W.B.S.E.B. centres and those from solar centres are independent. The total sample of 150 users have been taken using the proportional sampling scheme mentioned above.

Solar-nonusers

In selecting samples from this group, we have considered only solar-nonusers as the characteristics of diesel non-users are similar. To get a full list of non-users, a listing schedule was canvassed among the establishments (households plus commercial) residing in the electoral booths rather than individual villages as the administrative boundary of a village is too large to make such a listing. In the next stage, the units were stratified into

two groups, those having and not-having electric line (solar or diesel) in their locality. Then an equal number of samples were selected from each of the two strata. Here again the total 150 samples were drawn using the above scheme. The distribution of sample households for all three cases has been shown in Table 6.

6.2 Analysis of the results

It should be noted that in the island the consumers of W.B.S.E.B. have been enjoining the benefit of power for quite a long time but for limited hours. As a result they might have better experience of the impact of electricity on their socio-economic life and environment. On the other hand, only few have a maximum of four years of experience with solar power on a limited scale with most of them having only two years of experience. Therefore, proper assessment of socio-economic impact of solar power on the people of the island may not be possible. However, it is observed from the results that solar power has induced significant development in the island with respect to various socio-economic and environmental aspects.

The results obtained from the survey data on solar as well as diesel users have been presented in different tables. Table 7a shows that the average household size of the solar users is 6, which is 7 in case of diesel users. It is interesting to note that the proportion of illiterates is much lower among solar users (7 percent) compared to diesel users (21 percent). Agriculture is the primary occupation of the 49 per cent of the sample households using solar power, whereas 51 per cent have non-agricultural occupations. The situation is reverse in case of diesel users where more households are engaged in agricultural activity (60 per cent) and the remaining are in non-agricultural activities as their principal occupation. In both the cases a substantial number of sample households have more than one occupation (59 per cent for solar users and 41 per cent for diesel users). It indicates that they are enjoying the benefit of power by engaging themselves in different economic activities.

It is seen from the table that solar users, at present, are willingly spending, on an average, Rs. 88 per month on electricity, which is much higher than that which they used to pay for kerosene before getting power (Rs. 53 per month). In case of diesel users these

costs are Rs.149 and Rs.94, respectively. From some additional information collected for the solar(domestic) users it is seen from Table 7b that about 71 per cent of the households live in kachha houses. Only a few (13 per cent) live in pacca houses and the remaining live in semi-pacca houses. The main sources of fuel for cooking for them are wood and cow-dung. About 43 per cent of them have latrine in their houses. For all of them tube well is the major source of drinking water, while some also use pond or other sources of water. It may also be noted that because of limited hours of supply, along with electric power they have to use kerosene for light. On the other hand, the proportion of kachha house is much lower in case of diesel users as they reside in a relatively urbanised area. But along with the others they too use wood and cow-dung as fuel for cooking. Surprisingly a few households have their own latrine. Majority of them (92 per cent) fetch drinking water from tube wells and none of them uses pond as a source of drinking water. Because of limited hours of services most of them (89 per cent) also use kerosene for light along with electricity.

The distribution of households by reasons for taking power connection is presented in Table 8. The reasons given by the solar users were as follows: as the authority postponed the programme of electrification by using diesel oil for high generation and distribution cost, there was only one alternative source of power supply which was through private diesel generator. The cost of that power was too high and supply was also restricted to 4 hours in the evening. Solar power was cheaper compared to that and the period of availability was longer.

Other important reasons for demand of solar power are the scarcity of kerosene and brightness of light. Though the cost of kerosene is lower (see Table 7) as it is obtained from public distribution system (PDS), it is not available regularly and the price is increasing over time with the scarcity in supply. On an average one consumer requires at least 12 litres of kerosene for lighting. The cost of this was Rs. 39 at PDS rate in 1999, while the open market price was Rs. 120 for the zone. At the present PDS price rate the cost is Rs. 96 for the same amount; but this is also higher than the for solar power. Besides these, the level of illumination from solar power is 12 times better than that from kerosene lamp. If this benefit is considered then the consumer may save a considerable amount from using solar power.

To the diesel users the longer duration of period as well as brightness of light compared to light from kerosene are two important reasons (64 per cent and 23 per cent respectively) for demand of diesel power. 19 per cent of the households has also mentioned the proximity to power plant as a reason for taking electric line. Like solar users, they have also mentioned about the high cost of electricity supplied from privately owned diesel generator.

Though the solar power plant has been supplying electricity since 1996, till the time of survey most of the users have gathered only two years of experience on the use of solar power. So it is difficult to develop various activities within this short spell of time. In spite of this like diesel users the solar users have been able to recognize the benefits they have obtained from the supply of solar power. Results depicted in Table 9 show that supply of solar power has been a great boon to the students in terms of longer study hours. They are now getting, on an average, an extra amount of 2.25 hours per day for their study. Further opening up of a tutorial home has helped the students to a large extent in carrying out their studies.

The solar users engaged in cultivation of betel leaf have also benefited from power supply as a significant part of their work like arrangement of leaf for supply, watering in the field etc. can be done now smoothly at night.

Like diesel users they have also mentioned that the higher illumination of solar light facilitates indoor work. Women can work easily at night and save time for cooking. This can save cooking time at night by 1.5 hours which can be used for other purpose.

Trade and business have been continuing their activities at night for a longer period and serving more customers. Markets have developed, though on a small scale, with new activities like small battery charging centre, video shops 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 both by solar users and diesel users. The supply of power has also helped the people to avail themselves of the entertainment facilities like television, musical system. They are also enjoying physical comfort by using electric fan.

It may be mentioned here that a large majority of diesel users, who have longer period of experience with light in the island, have reported that they have benefited from

entertainment and extended hours of work in business and trade (90 per cent and 94 per cent respectively). One can, therefore, expect that there will be social and economic development in the island in future by increasing the power supply from solar plant.

It is stated that 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 difficult to identify the long term effect, one of the short term effects is the eye problem. About 21 per cent of solar users and 7 per cent of diesel users have reported that their family members suffered from eye problems (see Table 10), which could have been avoided by using electric power. Another observation is that a significant proportion of the solar-user households (49 per cent) are aware of the fact that there exist environmental problems in generating power using oil, while the use of solar energy is free from such problems. But the more interesting observation is that, though 88 per cent of the diesel users are aware of this fact, most of them would not like to switch to solar power due to its high cost compared to diesel power (which is subsidised).

Despite higher cost, the people, irrespective of their income level, are demanding more power now for entertainment, comfort and development work. Presently solar users are paying Rs. 8.0- per unit. It is observed from Table 11 that about 57 per cent of the solar users is willing to pay an extra amount over and above the per unit charge they are paying now. More surprisingly, though about 75 per cent of them is willing to pay less than Rs. 2, about 14 per cent is ready to pay an extra amount of more than Rs. 5 over and above the current rate of payment. In case of diesel users, percentage of households willing to pay more for diesel power is about 93 which quite natural for its lower price. Among them 45 per cent is willing to pay more than Rs. 5 over and above the present per unit charge of Rs. 3.

From the above analysis it may be concluded that all users of power, be it diesel or solar, demand the service. Some of them are also willing to pay more over the current rate to continue with the service. An interesting feature to note is that though solar users are paying more than the diesel users, they would still like to continue receiving the service as they do not have any other alternative.

It has already mentioned that to find the demand for electric power another set of samples has been drawn from non-users within the solar power plant area whom we call solar-nonusers(SNU). An analysis using this sample shows that the general characteristics of the SNU are same as power users (both solar and diesel) (see Table 12). The average household size is 6 and percentage of illiterates is 17, which is relatively high compared to solar users. They mainly depend on kerosene for their light, average cost of which is Rs. 52 per month per household. Their major activity is agriculture and 45 per cent of them have more than one occupation, 83 per cent of the houses are kachha, only a few (4 per cent) are pacca houses. All of them use wood and cow dung as fuel for cooking, 99 per cent of the households use water for drinking from tube well and the average distance of source of drinking water is about 383 meters from home.

Table 13 depicts the reasons they have given for not taking power connection till date. 43 per cent gave economic reasons, that is relatively high cost of solar power, 60 per cent of the people gave reasons as insufficiency / non-existence of power supply. However, if the problems can be solved all would be willing to get the service.

The experience of the solar users in the neighbouring places has also helped them to realise the benefits of light. In their perception, they would be benefited in many ways like solar users if the service is provided to them (see table 14). The data also show that although they do not belong to beneficiaries, 14 per cent of them have expressed their willingness to pay an extra amount over the existing charge.

Regarding the choice of source of light, Table 15 shows that among the users of power as well as non-usersthose who are willing to get electricity, 39 per cent of them are in favour of diesel power supplied by W.B.S.E.B. because of its low price, though they are aware of the fact that there is a problem of pollution in generating power from diesel. However, 61 per cent prefer solar power to avoid the pollution problem.

It is observed from the above descriptive statistics that there is high demand for electricity among both the users and non-users of power. Many households are even

willing to pay an extra amount for the service. The average willingness to pay per unit over the existing rate by the respondents is Rs.2.09 for solar users, Rs.0.24 for diesel users and Rs 2.91 for non users (see Table 16). If all the users and non-users are considered then the respective values are Rs. 0.97, Rs. 0.18 and Rs. 0.41 per unit over the existing rate.

To find out the factors which may affect the willingness to pay higher than the existing rate separate logit models were fitted for solar users, diesel users and solar non users. We confine our attention to domestic users only to utilize the data on household related variables.

The dependent variable is a binary variable taking the value of 1 if the household is willing to pay more than the existing per unit charge for electricity, and 0 otherwise. The possible explanatory variables are taken to be

i) Households size (HHS)

ii) Occupation dummies defining six categories of occupations, viz oc1: agriculture; oc2 : services; oc3 : business; oc4 : teacher; oc5 : technical professional; oc6 : others.

iii) Dummy variable indicating whether or not the household has more than one occupation (OMO)

iv) Percentage of Illiterates in a household (PIL)

v) Perhousehold Expenditure on Electricity (PCE)

vi) Perhousehold Expenditure on Fuel (PCEF)

vii) Percentage of Students in a household (POS)

viii) Highest Education Level in the household (HYE)

ix) House Type – Pacca, Semipacca = 1; Kachha = 0 (HT)

x) Dummy variables indicating whether or not the household is aware of the pollution from diesel generated electric power (AW).

The Logit models for diesel users and non users of electricity failed to provide any significant explanation in terms of these variables. Possibly for these groups the

decision on willingness to pay is influenced by some other factors other than the ones listed here.

However, for solar users some plausible results were obtained. These results are presented in Table 17. The effects of HHS and PCE are significant at 5% level, while those of OMO, POS and HT turn out to be significant at 10% level. Coefficients of HHS, OMO, PCE and HT have positive sigh, indicating that (i) probability of willingness to pay increases with household size and perhousehold expenditure on electricity (i,e. those who are already paying more are likely to be willing to pay even more); (ii) households having more than one occupation and households with pacca houses are likely to pay more for solar power.

Coefficient of POS turns out to be negative. This implies that probability of willingness to pay decreases with an increase in the percentage of students in households. This may be due to the fact that as the household already incurs some expenditure on education, it is unlikely to be able to bear the extra cost for electricity.

7. Summary and Concluding Remarks

In rural India inadequate supply of electric power is the major constraint of development process. This is more severe in remote areas where supply through conventional system is either highly expensive or almost impossible. As a result the government's programme for total electrification in rural remote places could not be successful through the conventional system. Alternatively, an attempt is being made to electrify rural remote areas by abundant renewable resources like hydro, bio-mass, wind, solar etc. Amongst these, solar energy may be considered to be superior for its free and continuous flow. A comparative analysis shows that the production of solar power is not yet viable in terms of financial cost involved, but the social and economic significance is also much higher in the remote areas like forests, islands etc. This is important from the point of view of total electrification programme. Sagar Dweep in West Bengal, India is

an example in this regard. In this island the extension programme on power generation through conventional diesel generator system was postponed due to its increasing cost of production. As a result the solar system was implemented few years ago to meet the demand of the people of island.

Of course a maximum of four years of experience with solar light is not enough to study the social and economic impact of any development work. But a comparative analysis shows that even within this short spell of time solar power users have felt improvement in different fields. According to them there has been an increase in educational level of the people of the island, 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 being enjoyed by the women in the island are 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 tea stall, sewing etc.

Besides the above, a SPV plant is also supplying power to run a hospital, services of which is essential to the society. Another essential service, the telephone booth, is being run by the help of solar energy in an individual capacity.

Similar to diesel users the solar users are also demanding more power for entertainment, extra work despite of higher cost. Like diesel users they have also expressed their willingness to pay, although the factors affecting the decision for paying extra amount are different for different types of users.

Another noticeable feature observed from the analysis that irrespective of their preference for a particular type of supply of power almost all the users are aware of the environmental problem related to the generation of power through conventional system with diesel generator. Similar types of observation obtained from the non-users of power residing within the solar power plant region indicate growing demand for power in the island.

It may be concluded that when supply of electricity is a necessity for the development process and its supply through conventional system is almost impossible, decentralised non-conventional system like solar power should be implemented in remote

rural areas or areas cut off from the mainland even if it is not economically viable. In trying to estimate the true cost of electricity generated by solar energy, it would be useful to analyse how and in what ways availability of electric power influences the social and economic life of people in such places. It is not easy to make proper valuation of all the benefits but then these should not be ignored either.

Table 1: Cost of Generation of Power Through Thermal, Diesel Generator and SPV Systems in the Year 1999.

Generating system	Average cost/KW (Rs.'000)	Annual capital cost/KW (Rs.'000)	Annual O & M cost/KW (Rs.'000)	Annual generation at bus ('000kwh)	Annual fuel cost (Rs.'000)	Total cost (Rs.'000)	Cost of generation (Rs./kwh)
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

Source : Chakrabarti et al, 2001

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 operation and maintenance (O & M) costs are 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. (a) Coal price has been taken as Rs. 1.65/kg. and consumption rate as 0.7kg. coal/ kwh; (b) oil price has been taken as Rs. 12.5/lt. and consumption rate as .35 lt./ kwh

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.

Table 2: Distance-wise Cost of Distribution of Power (per kwh) by the Conventional System in the Year 1999.

Item of expenditure	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/Kwh (Rs)	5.44	10.88	16.32	21.76	27.20

Source : Chakrabarti et al, 2001..

Notes :

1. Cost per km 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 whereas the average load has been assumed as 20 per cent of peak load.

Table 3: Cost (Rs.) of Delivered Power in A Remote Village in the Year 1999

Generating system	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

Source : Chakrabarti et al, 2001.

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

Item	Cost of items (Rs.'000 at 90-91 prices)		Rate of change per year (per cent)
	1990 – 91	**1998 – 99**	
'A' grade coal (per ton)	0.74	1.02	5.20
Diesel(per kilo liter)	3.66	5.02	4.00
Thermal Power Plant (per kilo watt)	25.00	23.61	-0.70
Solar PV (per kilo watt)	400.00	177.04	-9.70
Distribution line cost (per km)	200.00	177.04	-1.50

Source : Chakrabarti et al, 2001..

Table 5 : Cost of Delivered Power by Distance for Different Power Generating Systems for the Years 2005 and 2010

Sources of Power Generation	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	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	9.67	9.67	9.67	9.67	9.67

Source : Chakrabarti et al, 2001.

Note : *** :** Locally installed plant,

See note below Table 3.

Table 6 : Distribution of Households by the Use of Electricity

	Type of users															Non-users
	Commercial							Non- Commercial								
	Solar					All	Diesel	Solar					All	Diesel	
	Centres							Centres								
	Ka	Kh	Mr	Gb	Mg			Ka	Kh	Mr	Gb	Mg			
No. of listed households	12	6	55	23	48	144	172	52	100	36	84	59	331	96	858
No. of Sample households	6	3	28	12	26	75	96	12	22	8	19	14	75	54	150

Notes : Ka: Kamalpur, Kh: Khasmahal, Mr : Mrityunjoy nagar, Gb : Gayanbazar, Mg : Mahendragang

Table 7 : Distribution of Sample user Households by household particulars
a)   All users (Domestic and Commercial)

Households Particulars	Solar User					All	Diesel Users
	Centers						
	Ka	Kh	Mr	Gb	Mg		
Average household size	7	6	6	7	6	6	7.21
Percentage of illiterates	7	6	16	10	1	8	21
Principal occupation (% of households) (a) Agriculture	78	54	36	47	30	49	60
(b) Non-agriculture	22	46	64	53	70	51	40
More than one occupation (% of households)	33	75	48	48	77	59	41
Av. Cost of kerosene per household before the use of electricity (Rs./month)	34	38	83	43	50	53	94
Average expenditure on electricity per household (Rs./month)	101	76	105	75	83	88	149

b) Domestic Users only

Households Particulars	Solar User					All	Diesel Users
	Centers						
	Ka	**Kh**	**Mr**	**Gb**	**Mg**		
Type of house (% of households)							
1. Kachha	58	82	50	95	42	71	47
2. Semi Pacca	33	14	13	0	29	16	23
3. Pacca	9	22	37	5	29	13	30
Fuel used for cooking (% of households)							
1. Wood & Cow-dung	100	100	100	100	100	100	100
2. Kerosene	0	27	25	0	21	15	26
3. others	8	23	0	37	42	25	11
Having latrine (% of households)	42	32	100	21	57	43	6
Drinking water							
1) Sources							
a) Tube well	100	100	100	100	100	100	92
b) Pond	50	0	0	0	0	8	0
c) Others	8	0	0	0	0	1	23
2) Average distance from house (meter)	563	264	231	228	257	312	162
Sources of light (% of households)							
a) Kerosene	100	100	12	68	71	77	89
b) Solar/Diesel	100	100	100	100	100	100	100

Source : Chakrabarti et al, 2001 and survey

Table 8: Distribution of Sample User Households by Reasons for Taking Connection from SPV Power Plant/Diesel Plant in the Year 2000.

Reasons	Percentages of households with SPV connection						Percentage of household with diesel connection
	Centres					All	
	Ka	Kh	Mr	Gb	Mg		
Low cost compared to Pvt. Diesel generation	1	8	67	39	75	46	26
Scarcity of Kerosene	39	20	14	39	15	23	-
Longer period of supply	0	0	39	45	18	23	64
Bright light compared to Kerosene	1	32	22	17	12	17	23
Pollution from Kerosene	-	-	-	-	-	-	7
Proximity to power plant	-	-	-	-	-	-	19

Source : see Table 7.

Table 9: Distribution of Sample User Households by Type of Benefits Derived from Getting Power from SPV Plant/Diesel Plant

| Type of Benefit | Percentage of households with SPV connection | | | | | | Percentage of households with diesel connection |
| | Centres | | | | | All | |
	Ka	Kh	Mr	Gb	Mg		
Availability for longer period for study	67	80	28	54	30	47	52
Saving of time for cooking	56	80	17	48	13	38	40
Movement at night	6	4	8	29	0	9	2
Entertainment	17	28	39	13	8	21	90
Time for household work at night	6	48	22	10	2	17	11
Physical comfort	6	24	17	10	53	25	39
Doing agriculture work at night	28	24	3	3	13	12	0
Availability for longer period for trade and business	17	4	75	35	68	46	94
Increase in income for extended hours of work	22	16	83	58	35	46	57

Source : See Table 7

Table 10: Distribution of Sample User Households Aware of Different Environmental Aspects of the Use of Conventional Resources

| Environmental aspects | Percentage of households with SPV connection | | | | | | Percentage of households with diesel connection |
| | Centres | | | | | All | |
	Ka	Kh	Mr	Gb	Mg		
Problems in generating power from diesel	67	60	42	35	52	49	88
Suffering from eye problems owing to use of Kerosene	0	28	25	26	20	21	7

Source : See Table 7

Table 11 : Distribution of Sample User Households Willing to Pay (WTP) Extra Amount Over the Current Per Unit Charge by Amount of Additional Payment:

Type of Users	No. of house-holds	% of households willing to pay more	Percentage of households willing to pay more by amount of additional payment				
			Less than Re. 1	Rs. 1 < Rs. 2	Rs. 2 < Rs. 3	Rs. 3 < Rs. 5	Rs. 5 and above
Solar users							
3 Points	100	54	46	30	7	2	15
5 Points	50	62	61	7	16	3	13
All	150	57	52	21	11	2	14
Diesel users	149	93	53	3	-	-	45

Source : See Table 7