Solar power plants in Sunderban-A case of failure

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***Abstract*: There has been an increase in off grid power supply through renewable energy in the last decade in Sunderban region. But these plants are not working as they are supposed to be. High establishment and production cost, ever burdening subsidy, lack of maintenance and faulty energy sources have brought these plants a step forward to closure. After initial euphoria these plants seem to have failed in continuing the zeal and stand on the edge of an abyss. This paper tries to do an analysis of the feasibility of these projects on the basis of survey and tries to bring in front the problems faced by two systems of solar power in Sunderban. It also proposes a model that bodes well with the features and constraints of Sunderban region slacking up the resources as much as possible**

Keynote: Cost analysis, Gasifier, Renewable Energy, Sunderban

I.INTRODUCTION

A continued thrust towards wider use of renewable energy devices at domestic, commercial and industrial levels have not only resulted in greater awareness but also significant installed capacities in India. West Bengal Renewable Energy Development Agency (WBREDA) under the auspices of the Ministry of New and Renewable Energy had initiated an off-grid energy programme through solar photo-voltaic cells, solar lanterns, biomass and tidal energy in the Sunderban – a region criss-crossed by an intricate maze of rivers, tributaries, streams, channels, estuaries and creeks.

The electrification process first started in Sunderban with a central power station of 26-kW capacity at Kamalpur village at Sagardweep Island in 1996 though the power plant had been badly damaged due to the cyclone 'Aila' in 2009 and so currently rendered out of use. However, encouraged by the success of the solar plants, 15 central solar power stations of capacity between 25 and 110 kW have come up in different islands of Sunderban. Electrification with renewable energy systems provided a viable alternative here. The reliability of these systems, insignificant power transmission losses, potential consumer involvement and optimal use of indigenous resources had initially found favours not only among the consumers but also along corridors of power.

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Apart from solar power plants three gasifier power plants have been commissioned with a total capacity of 1400 kW and one off grid Wind Hybrid had also been installed. A tidal power plant in Durgaduani creek is currently under construction.

In this paper we present the facts that have been obtained by performing a primary research in the area of rural electrification in the Sunderban District of West Bengal, India. The purpose of the present study is to assess the economic and environmental impact of renewable energy power plants and suggest the best cost effective way of providing off grid electricity to those belonging to the lowest strata of the society.

We had examined two approaches to renewable electrification in Sunderban –

1. Off-grid decentralized systems using Solar PV or Solar Housing System (SHS).
2. Off-grid centralized systems using Solar PV technology.

Keeping in mind the geographical location of the concerned area where it is not feasible to bring grid power we are looking at the best possible balance to measure both the cost and benefit it has had on the people of the area.

The paper is divided into 5 sections. Section 2 literature survey discusses the literature based on papers discussing Sunderban power plants. Section 3 discusses methodology of the survey. Section 4 discusses the results of the survey divided into cases based on geographical area. Section 5 shows a comparative analysis of the benefits, problems and reasons of failure of the plants. Section 6 proposes an option that could help to make renewable energy viable in Sunderban area.

II. LITERATURE SURVEY

Rural electrification in Sunderban location has been a growing research area during last decade. Various papers have also been published regarding renewable energy expansion in developing countries.

Chakrabarti and Chakrabarti conducted a survey in 2000 in the SagarDeep island of Sunderban in the villages of Kamalpur, Mrityunjoy Nagar, Khasmahal, Gayen Bazar and Mahendragang and reported noticeable improvement and up gradation of rural living in post-solar photovoltaic period. Their study indicated the moderate cost association with the implementation which may not be a suitable option for rural electrification. Most of these power plants started operating from 1999(except Kamalpur) and survey was conducted within one year of plant commissioning and had showed quite promising then.

However Moharil and Kulkarni demonstrated that well-established technology, simple operation and maintenance, downward trend of cost, optimum resource availability in remote and island areas, environmental sustainability and good management systems are indications of large scale installations of solar power plants in near future at Sagardweep Island, where conventional power cannot reach as techno-economically viable proposition. SPV system will offer a competitive option there.

III. METHODOLOGY OF SURVEY

A field survey based on direct interviews method was carried out during May–July 2011. A representative sample of about 20 beneficiaries at least was drawn from each of the 11 villages.

Ideally, the way to measure the impact of electricity connection is to take the difference between the outcome after the intervention and that which would have resulted in without the intervention, a situation called the counterfactual (Ravillion, 2007). In the absence of a true counterfactual, we simulate one with the help of a control group.

Non electrified villages in the area are taken as the 'control' group to compare the variables such as increment in work hours, increment in study hours, cost of alternative energy vis-a vis kerosene and diesel used in non-electrified villages etc. We have taken distance from Kolkata, no. of educational institutions, income proxies such as presence of village 'haats', presence of clinics/hospitals/anganwadi centres, as control variables. This has helped us to mitigate recall period bias

Initially, a pilot survey was conducted to pre-test the questionnaire and people's response to it. Based on the pilot survey three different sets of questionnaire were prepared and used for conducting the survey, i.e. i) Village profile, ii) Household profile and iii) Individual profile. A mixture of data collection methods was employed during the fieldwork. This included transect walks, household interviews, observational data and semi-structured interviews with key local informants (such as the plant operators, teachers and panchayat pradhans),

All the plants considered here supply electricity to all the households within a fixed radius dependent on the plant size. The respondents were selected randomly from the list of beneficiaries of the plant. Systematic random sampling was used to draw the list of sampling units from the list of beneficiaries and hence self-selection bias was done away with.

IV.RESULTS OF SURVEY

A. SAGAR ISLAND-NOTENDRAPUR

Sagar Island is located in the south-western corner of the Ganges Delta, in West Bengal state of India. It is one of the largest of the hundreds of islands that make up the Sunderban. It is 96 km away from Kolkata by road and further 6 km distance is to be covered by river route. There are 46 villages in Sagardeep Island, where river Hoogly falls onto the sea at Bay of Bengal. The place is known for a large annual pilgrimage to Gangasagar, the main city of Sagar Island for a holy festival.

Till 1996 only a few diesel-generating sets were installed to provide power to the selected consumers only for few hours in the evening. However a central power station of 26-kWp capacity was set up at Kamalpur village at Sagardweep Island in 1996. The successful implementation of this unit was replicated in another village. Overall 10 villages in Sagardweep Island have solar power plant and all the units were supposed to run as regular off grid power supply centres for 5–6 hours in the evening.

In order to do a survey 1 village was randomly selected from the list of 10 villages to study the impact of electricity. Kamalpur-oldest solar plant was too badly damaged by Aila cyclone to be revived again. S Natendrapur has a population of 1,050 and its control village Bishnupur has a population of 5630.

About 23 beneficiaries were surveyed from each village.

But there has been a twist in the story. The power plant has remained closed for last 2 years due to lack of supply of battery. In fact almost all the solar power plants in SagarDweep power plants have remained closed for last 2 years providing electricity only for internal consumption of the plants, Plans are afoot to restart production from October 2011.But extension of grid electricity may sound death kneel for these plants.

Power was to be supplied till 12 midnight in the summer months (March–May). In rainy season power is supplied only for 4 hour. The Notendrapur plant with a 25 kW-installed capacity provided electricity to households within 4.5–5 km radius through low-tension (LT) distribution line. The plant has 120 consumers.. Electricity charges are based on a service connection cum fixed initial security deposit that is in the range of Rs.500 for 3 points and Rs1000 for 5 points. Monthly charges were Rs80 for 3 point and Rs120 for 5 points.

However electricity is not provided to local higher secondary school which lies within the radius of distribution network of the plant. Diesel generator and standalone photovoltaic cell is used for power inside school campus. No provision has been made for refrigeration facilities for important vaccines and anti-venoms.

A society was initially responsible for the selection of consumers, choosing routes for the distribution lines, and the setting of the tariff in consultation with WBREDA. But now WBREDA has given the plant to a private company to collect the revenue and work on maintenance. The project was funded by a combination of grants, loans, and revenue. Government of India: 50% (grant), State government: 20% (grant), other sources: 30% (includes revenue from consumers and loans).

In table no. 1 per unit cost of electricity is calculated for Notendrapur (25 kW) plant which started producing from Aug 2000. The cost of installation of the plant was Rs7.96 million which includes photo voltaic cell, battery, inverter and charge controller, and distribution cost. Annual cost of production

$(ACP)=C_{PV}*CRF_{PV}+C_{BATTERY}*CRF_{BATTERY}+C_{INV\&BAT}*CRF_{INV\&BAT}+C_{D\&I}*CRF_{D\&I}+O\&M+Labour\ cost.$

Capital recovery factor (CRF) is the ratio of a constant annuity to the present value of receiving that annuity for a given length of time.

TABLE NO 1: PER UNIT COST OF ELECTRICITY PRODUCTION OF NOTENDRAPUR SOLAR POWER PLANT

	Notendrapur
Capacity	25 kW
Total kWh per year	32850
Total cost of installation	Rs7096000
PV cost	Rs3375000
Battery	Rs675000

Inverter	Rs1450000
Charge controller	Rs300000
Distribution and Installation(D&I)	Rs1300000
Labour cost	Rs162000
O&M (.1 %)	Rs7096
PV* CRF(20,.10)	Rs396562.5
Battery*CRF(5,.10)	Rs178065
Inverter and charge controller*CRF(10,.10)	Rs284725
D&I*CRF(10,.10)	Rs211510
Total annual cost	Rs1239958
Unit cost with capital	Rs37.74

Source: Field survey and authors' calculation

No of days of operation in a year is taken to be 365 days and Capacity utilization factor is 0.9.Total kWh for Notendrapur has been calculated for 4 hours of utilization per day. Lifetime of solar PV cells is 20 years; lifetime of Charge controller and inverter is 10 years while lifetime of battery is 5 years. The discount rate is 10 %. Unit cost of production for Notendrapur plant comes out to be Rs37.74 which is quite high comparative to conventional thermal power Rs3 to Rs4 unit cost.

The consumers currently pay Rs80 for a three point system of 60W system

TABLE NO 2: CALCULATION OF PER UNIT COST PAID BY CONSUMERS

Monthly charge	Rs80
Power consumption per day	60W*4hrs=240WHrs
Monthly power consumption	7.20unit
Per unit cost	Rs11.11

Source: Field survey

The above calculation shows that a consumer in a poor village in the heartland of Sunderban paying a unit cost of Rs11.11 whereas a consumer in Mumbai pays Rs8.27 per (above 500 units) unit max.

Total annual revenue from electricity charges is Rs124800.

Annual financial deficit comes to Rs1115158 in 2011 prices. Financial subsidy amounts to 90 % of the total cost.

TABLE NO 3: KEROSENE USAGE OF NOTENDRAPUR AND CONTROL VILLAGE BISHNUPUR

Household particulars	Notendrapur	Bishnupur
No of households surveyed	17	16
Average Household size	5	6
Average usage of Kerosene of household(ltr/month)	3	7.5
No of shops surveyed	4	6
Average usage of Kerosene of shop(ltr/month)	2	5

Source: Field survey

Compared to non-electrified counterpart a consumer in Notendrapur village he saves 4.5*32Rs= Rs144 per month. After paying Rs80 for electricity he saves Rs64 per month.

TABLE NO 4: COMPARISON OF STUDY HOURS OF TWO VILLAGES

Parameters	Notendrapur	Bishnupur
Household surveyed	17	16
Avg no of children	2	2
Study hours at night	4	3

Source: Field survey

Table 4 shows the number of hours children were able to study in the electrified villages is 1 hour more compared to those of non-electrified villages Where the electrified villages showed 4 or 3.5 hours on an average given by children for studying purposes it was 3 and 2.5 hours respectively in the control villages which were non electrified. However it is not 2.25 h per day more as was found by Chakraborty and Chakraborty (2000). It may be due to better consciousness for education compared to 2000.

There is at present 3 employees for Notendrapur plant.

Though it seems that the power plants have done a good job of alleviating the problems, they are however saddled with problems which have been increasing as plant life increases. Availability for fewer hours is the most important problem. The plants were supposed to provide 6 hours of light. However lack of maintenance and other problems had led to gradual decrease in light hours to 4 hours daily.

It was nothing but sorry state of this ambitious project that the plants of Sagar Island have either stopped working due to some inherent fundamental problems or some were badly damaged by the cyclone Aila in 2009(Kamalpur).But they still continue to stay in disuse due to lack of will from the governing concerned authority.

B. KUMIRMARI

Kumirmari is a distant village in the heartland of Sunderban where a different type of renewable project had been initiated by WBREDA. Instead of setting up a centralized solar plant individual solar home system (SHS) has been distributed to 3356 households. The households paid a down payment of Rs2000 and received a subsidy amount of Rs11000 on each solar module. About 2756 solar modules were distributed before 2009 though 80% of them were damaged by Aila cyclone. 580 modules were distributed after Aila till July 2010. Beneficiaries were selected through a survey by local panchayat and WBREDA before allocation of solar system. Total subsidy amounted to Rs37015000.

However local higher school had not been provided with a solar cell.

TABLE NO 5: STUDY HOURS OF KUMIRMARI

Parameters	Kumirmari
Household surveyed	18
Avg no of children	3
Study hours at night	3.5

Source: Field survey

Average study hours at night for a Kumirmari student is 3.5 hours which is nearly 1.5 hours increase from non-electrified villages in the area.
Now let us see the kerosene usage of Kumirmari village

TABLE NO 6: KEROSENE USAGE OF KUMIRMARI VILLAGE

	Kumirmari
No of households surveyed	18
Average Household size	5
Average usage of Kerosene per household(ltr/month)	2
No of shops surveyed	6
Average usage of Kerosene per shop(ltr/month)	1

Source: Field survey

Savings from kerosene amounts to 6.5 litres per month which amounts to Rs32*6.5= Rs208 per month for households
However though it may seem that though those beneficiaries of the SHS system are happy but a strong undercurrent of discontent runs among the local people.
Training to 2 local people was imparted by WBREDA. However such training has proved to be inadequate for 3365 units. Street lights were also installed to stop the tigers from entering the village. However most of the street lights are damaged or stolen. High subsidy has also created a black market in neighbouring un-electrified villages for the solar cells. Besides the solar cells got badly damaged due to Aila and the private company refused to undertake free repairing though the systems were still within warranty period. According to the company damage from cyclone does not fall under purview of free repairing.
There were allegations of favouritism by the Panchayat while distribution of solar cells among the households.
This shows the ignorance by the hands of the authorities both on the government side which are also the regulators and the private players which are the ones who are directly responsible for the maintenance and smooth running.

IV.CRITICAL ANALYSIS

Electricity transmission in Sunderban is a little difficult and thus the society is largely energy deficient resulting into various repercussions over the economic, social, psychological, political; virtually each sphere of existence. Crossing many streams that take water to its ultimate goal one comes across poverty, unemployment and other curses of energy deficiency. However, in recent decades, the demand has been perceived by institutions in authority, turning Sunderban into an experimental geographical pocket testing implementing and rejecting various alternative sources of energy.
Here we will discuss the benefits, problems and failure of the projects in a brief manner

TABLE NO 7: FREQUENCY DISTRIBUTION OF BENEFITS REPORTED BY TWO VILLAGES

Benefits	Natendrapur	Kumirmari
Increased study hours	88.24%	88.89%
Increased business hours	46.67%	44.44%
Increased time for other activities	23.53%	25.00%
Entertainment	88.24%	55.56%
Comfort	58.82%	55.56%
Movement at night	52.94%	72.22%
Performing agricultural work	41.18%	16.67%

Source: Field survey

In case of Notendrapur plant we see almost 90% of the respondents were unanimous about increased study hours of children due to electrification. Apart from increased study hours entertainment (88%) and comfort (58%) are the two primary benefits. Performing agricultural work at night (41 %) also fared poorly in the benefits compared to entertainment and comfort.
Analysis on benefits of Kumirmari reveals the fact that the increased time which was devoted to studies (89%) has been one of the prime reasons of the success of some form for the electrification programme. The quotient of movement at night (72 %) which has insured safety in the village from the wild is also a positive spill over of the electrification which the households seem to have emphasized.

TABLE NO 8: FREQUENCY DISTRIBUTION OF PROBLEMS FACED BY HOUSEHOLDS

Problems	Natendrapur	Kumirmari
Availability for fewer hours	94.12%	11.11%
Frequent Breakdown	88.24%	11.11%
Light too dim for handicraft	52.94%	55.56%
Low wattage for running heavy tools	82.35%	72.22%
High cost	12.83%	27.78%

Source: Field survey

The above table clearly illustrates the fact that different village face different forms of problems when it comes down to the reasoning of the ill quality of electricity. Kumirmari on one hand has the problem of availability for fewer hours (11 %) but it was quite less compared to Natendrapur (94%).
The data on problems faced by both Kumirmari and Notendrapur beneficiaries seem to suggest that the most prominent reason that the household emphasize in terms of the problems in the electrification is the fact that the low wattage of electricity does not allow for economic activities to place (72% and 82 % resp.), especially with regards to the activities which involve use of heavy machinery in the rural context. It is truly not possible to run heavy

machineries such as rice mill, cold storage with a 40 W solar PV cell.

Frequent breakdown and availability of fewer hours is the main problem for Notendrapur plant. An explanation for this reason can be Kumirmari beneficiaries can use their solar cells whenever they like, but Notendrapur beneficiaries are dependent on the whims of plant workers. So they feel that lesser hours of electricity is available to them when in-fact almost same hours of electricity is available to both the systems.

TABLE NO 9: FREQUENCY DISTRIBUTION OF REASONS OF FAILURE

Reasons for failure	**Natendrapur**	**Kumirmari**
Lack of accountability	52.94%	0.00%
Low education of plant workers	70.59%	44.44%
Lack of maintainence	76.47%	33.33%

Source: Field survey

According to Notendrapur consumers the major reasons surrounding this misery were found to be lack of accountability (53%), low educational level and inefficiency of plant workers (71%) and lack of maintenance. The plant workers had studied till class 8.They had been given a basic training by WBREDA initially and no follow up training has been provided.

The reasons for the problems of the Kumirmari SHS system are corruption of panchayat in distribution of solar cells (50%) {not mentioned in the table} and ill trained workers (44%) .

A calculation for carbon credit required to make the Notendrapur plant viable is given in the next table

TABLE NO 10: A CALCULATION ON CARBON CREDIT OF NOTENDRAPUR SOLAR PLANT

Equivalent diesel saving	12166ltr
Lower carbon emission(@2.71kg CO_2/ltr) per year	32.971 tonne
Cost of production per year	Rs1239958
Cost of production per tonne of CO_2 reduction	Rs37607.8/ton
Max carbon credit possible	Rs1980/ton
Carbon credit needed to make plant financially viable	Rs34848/ton

Source: Field survey 2011

It is seen that to make plant financially viable a ridiculously high carbon credit of Rs34848/ton will be needed. Currently the maximum carbon credit possible is 30euro/tonne. Surely there are more cost effective ways to reduce global warming.

Kumirmari faces a problem which is inherent in any subsidized project. Due to absolute ownership of the individual solar PV a secondary market in neighbouring villages has been created where the beneficiaries can sell their solar PV cells at a profit and lower than unsubsidized solar PV.

V.PROPOSED MODEL AND CONCLUSION

The predominant technology used for individual households in off-grid projects is PV, mainly as SHSs. In World Bank projects, some 1.3 million PV systems for homes and community centres have been installed or are planned for installation, with a total capacity of more than 60MW at a total investment cost of about US$680 million across the world

To succeed, rural electrification programs should aim to generate new revenues and directly affect livelihoods not just providing comfort and entertainment –which are in fact two most important benefits as reported by the consumers of all power plants. Normal grid can support productive loads irrigation pumps and agri-processing on demand in contrast to the capacity constraints of small off-grid projects13 (TERI, 2009b)

The successful functioning of decentralized electrification model at Kumirmari is a case worth contemplating. But the lopsided division of cost of SHS such that the HHs paying Rs2000 and rest Rs11000 being borne by the government as subsidy has its own limitations. Subsidy amounts to 85% of initial cost. Apart from Mexico (90%) no other country in the world gives so higher subsidy.

However the main problems in Kumirmari boil down to i) Heavy initial costs in form of subsidy, ii) Entry barrier in the form of large down payment, iii) Possibility of corruption due to onetime flow of down payment and subsidy, iv) Overlooking the willingness to pay, v)The possibility of various moral hazards incurred due to free rider syndrome.

Thus, the alternative model can be made by differentiating the demand into low payers and relatively high payers. While low payers or the people below poverty line can be provided with basic SHS without any down payment but charging them at the rate of Rs100 per month for a period of say 60 months in sync with the guarantee period of the apparatus at a rate of 10% PVFA (Present Value Factor of Annuity) comes to be 47.0654 hence the Present Value of total realization will be Rs4706.54.

For high payers a provision of variable demand can be incorporated in such a way that the difference in the cost of basic model and the model demanded is to be paid as down payment by the user. On the same scale, present value of their monthly payment comes to be Rs7059.81

TABLE NO 11: TABLE SHOWING CALCULATIONS OF SUBSIDY IN CASE OF SOLAR HOME SYSTEM

	High Payers	**Low Payers**	**Present Model**
Cost of PV Module	C	13000	13000
Down Payment	C-13000	0	2000
Rate of Return (per annum)	10%	10%	
PVFA for 60 instalments	47.0654	47.0654	
Instalment value	150	100	

Present value of instalments	7059.81	4706.54	
Subsidy (per HH)	13000-7059.81 =**5940.19**	13000-4706.54 =**8293.46**	13000-2000 =**11000**

Very clearly this model has its own benefits on different problems which can be summarized as:

I) Initial costs in form of subsidy have been removed: Both the models for high payers and low payers increases Net Present Value for the government by reducing the amount of subsidy so that this program can be implemented on larger scale.

II) Entry barrier in the form of down payment: This model nicely removes the barrier for the people below poverty line giving the boost to the welfare purposes.

III) Possibility of corruption due to onetime flow of down payment and subsidy has lessened: In the present model fake representations can be made to siphon off the subsidy. The proposed model distributes the payment over a period of time making subsidy siphoning relatively tough.

IV) Willingness to pay has been taken into consideration: The proposed model is very much based upon the variability of willingness to pay. The system is properly guarded and adequately rational since the low payers are already incurring a cost between Rs60-80 upon low utility kerosene based energy. The probability of defaults on payment will fall greatly if the collection is channelized through village committees like Panchayat.

V) The possibility of various moral hazards incurred has been reduced: Since the proposed model confers lien of apparatus to the consumer and not the ownership till the payment of the last instalment, thus consumers will have a sense of responsibility and proper energy orientation while they are using energy at a monthly cost instead of freebie.

Moreover, to provide an impetus to self-sustained approach it may be considered at the end of 5th year that the instalments continue to be carried on in lieu of the battery replacement. In this case, the government would incur an extra expense of about Rs1000 at market cost in case of low payers while there will be similar gain of Rs 2000 from high payers in terms of Present Value after 5 years. (Considering the cost of new battery falls within Rs5000-6000)

It will also minimize the chance of creation of secondary market of selling subsidized solar plates. Though there is a chance of default by the consumers there should be a provision of confiscation of solar cells in case of default for 6 consecutive months.

In order to stimulate innovation and production of solar PV the government can give the project to the highest bidder providing the lowest cost of the PV cells. This will give rise to competition among manufacturers of PV cells. The government should provide a price higher than the cost of manufacture to initiate economic return on solar PV.

SHS however do not have sufficient capacity to serve small rural industries and groups of villages with 50-100kw demand profiles. Household expenditure on kerosene is the critical component for the willingness to adopt mini-grid connection. The probability of willingness increases significantly with the successive higher expenditure on kerosene. Households with higher monthly expenditure on kerosene are likely to opt for SPV mini-grid connection.(Amit K. Bhandari et al 2010)

In India and in the developing countries there is currently a race to increase the capacity from renewable energy. Targets have been set to electrify all the villages under RGGVY by 2012. But no targets or regulations are in place for maintenance of the plants after its commissioning. So we have seen that a ‘electrified village’ (such as Notendrapur) may remain unelectrified due to closure of plants due to lack of maintenance. We are favouring quantity over quality which is creating a problem. Rural electrification programme in India should not be a number and a target only.

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