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An assessment of a Biomass Gasification based Power Plant in the Sunderbans

Kakali Mukhopadhyay*

Center For Development and Environment Policy, Indian Institute of Management Calcutta, Joka, D.H.Road, Calcutta 700 104, India

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Abstract

A continued thrust towards wider use of renewable energy devices at domestic, commercial and industrial levels not only resulted in greater awareness but also significant installed capacities. The energy requirement in India is steadily increasing and this requirement is met both by commercial and renewable energy sources. India being a tropical country, renewable energy is seen as an effective option for ensuring access to modern energy services. So the objective of the present study is to evaluate the socio economic and environmental impact of the Biomass Gasification based Power Plant (BGBPP) in Chottomollakhali islands of Sunderbans set up by West Bengal Renewable Energy Development Authority (WBREDA). Four villages of Chottomollakhali Island are benefited with electricity from the power plant, which serves 225 consumers comprising household, commercial and industrial sectors. A simple cost benefit analysis has been used to estimate the impact of BGBPP.

The findings of the study indicate that BGBPP has made a very positive impact on the life of the villagers of Chottomollakhali Island. This has led to increased economic activities and more profitable turnover for the commercial consumers and improves quality of life for the household sector. All of them have showed willingness to pay a higher price to get 24 h of power supply. From the cost benefit analysis it has been found that the benefit cost ratio, internal rate of return and pay back period of the project are 1.68, 19% and 7 years, respectively. But environmental awareness is very poor among the villagers.

Keywords: Renewable energy; WBREDA; BGBPP; Chottomollakhali; Cost benefit analysis

Introduction

Even while city-dwellers fume and fret over power cuts, thousands living in rural India seem to have quietly resigned themselves to living without electricity—a basic amenity for quality life and a tool for development. But there is still a ray of hope for them. For, the government has chalked out a plan to provide electricity to the entire rural India by the year 2012.

According to the 2001 census [1], there are still 78 245 villages out of 587 258 villages in India that do not have electricity. By the end of the tenth 5-year plan, 60 245 villages will be electrified using conventional means by connecting the villages to the power grid. For the remaining 18 000 villages, which are remote and hence cannot be connected to the grid, the sole option is non-conventional sources of energy.

* Corresponding author. Tel.: +91-33-2467-4300/04; fax: +91-33-24678307.

E-mail addresses: kakali_mukhopadhyay@yahoo.co.in, kakali@iimcal.ac.in (K. Mukhopadhyay).

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In the tenth 5-year Plan, the MNES (Ministry of Non-Conventional Energy Sources) [2] proposes to electrify 5750 such remote villages through SPV (solar photovoltaic) power, biomass-generated power and hydropower.

Potential in India

India, a tropical country with a vast geographical area is richly endowed with renewable energy sources like solar, wind, biomass which can play a crucial role in meeting end use energy needs in a decentralised manner. It is known that the energy requirement in India is steadily increasing and this requirement is being met by both commercial and renewable energy sources. India, today, has a total installed capacity of about 3400 MW of power from renewables, which is over 3% of the total power generation capacity in the country, still leaving a large capacity untapped. Contribution in electricity generation during 1999–2000 was 499450 GWh from commercial sources and 1699 MW from renewable energy sources [2].

Currently, India is a fifth largest producer of wind power in the world with a wind power generation achievement of 1507 MW, of which 1444 MW comes from commercial projects. Supported by the government, India has one of the largest SPV markets and significant progress has been made in the deployment of small-capacity stand-alone PV systems in the country. Over 610 000 systems aggregating to over 20 MW have been installed. The potential for small hydro (up to 25 MW) is estimated to be 15 000 MW, mainly in the hilly areas of the sub Himalayas and the northeastern regions of India. There are over 420 small hydro projects aggregating 1423 MW in India.

As far as biomass-based power generation is concerned, the present capacity totals 358 MW (including cogeneration and biomass gasifiers). In the area of small-scale biomass gasification, significant developments in technology have made India a world leader. A total of 42.8 MW biomass gasifier power capacity has so far been installed in India, mainly for stand-alone applications. Biomass gasifiers capable of producing power from a few kilowatts up to 500 kW have been successfully developed indigenously and are also now being exported to the developing countries of Asia and Latin America, and also Europe and USA.

When biomass is used to produce power, the carbon dioxide released at the power plant is recycled back into the re-growth of new biomass. This renewable and recycling process makes it possible to generate power without adding to air emissions. Due to the non-availability of the sufficient resources and a considerable amount of emission of pollutants from commercial energy, it is now being felt that renewable energy has to be utilised to a greater extent. In India electric power generation is the largest source of GHG emissions and accounts for 48% of carbon emitted. These concerns point towards more rational energy use strategies.

The *purpose of the present study* is to assess the socio-economic and environmental impact of Biomass Gasification based Power Plant in Chottomollakhali island of Sunderbans. It was set up by West Bengal Renewable Energy Development Agency (WBREDA) under the auspices of the Ministry of Non-Conventional Energy Sources (MNES), Government of India, towards rural electrification. Structure of the paper is outlined below.

Section 1 reviews the selected literature. The village profile of Chottomollakhali Island is described in Section 2. Section 3 discusses the details of the installed BGBPP. Section 4 analyses the qualitative and quantitative aspects of economic benefits of the installed BGBPP. Section 5 presents the cost benefit analysis of BGBPP. Section 6 considers the environmental impact of BGBPP and finally Section 7 concludes the paper.

1. Literature survey

Literature in this field is limited in much of India. The core scientist's contribution in this respect is more than the social scientists because it is very much interdisciplinary. Selected studies are reviewed below.

Ravindranath and Hall [3] analysed the sources, end-uses, and socio-economic and environmental impacts of biomass energy and suggested measures for promoting sustainable yields, biodiversity, and community involvement in biomass production systems. They also described some of the financial and policy barriers; and present strategies for the promotion of bioenergy. The authors have outlined the fact that other developing countries like Indonesia, Brazil and those in Sub-Saharan Africa have between 8 and 50 times more forest area per capita than India, illustrates biomass-based energy options as theoretically even more feasible for the majority of developing countries. A study by Somasekhar et al. [4] presents a case study of a rural bioenergy centre for decentralised power generation in southern India (Hosahalli, Hanumanthanagarha). In each village they have shown the technical and operational feasibility of decentralised power generation system and the willingness of local community to pay for the services. Capacity utilisation and efficiency of operation of the power generation system are low and potential exists for improving both. Finally, the bioenergy system has generated socio economic and environmental benefits. Shukla [5] shows that realisation of biomass potential shall help many developing countries to make a smooth transition from the present inefficient biomass energy use in traditional sectors to a competitive and efficient biomass energy use in the future. This will reduce their energy imports and conserve scarce finances for national development. However, myriad economic, social, technological and institutional barriers remain to be overcome to rapidly transform the biomass into a viable commercial energy option. Removing these barriers is a key policy issue deserving the attention of policy makers in coming decades.

2. A profile of Chottomollakhali village

Chottomollakhali Island in Sunderbans is situated in the district of South 24 Parganas is about 130 km away from Kolkata. The Sundarbans delta is one of the world's most unique biomes. Area of Indian Sundarban is 9629 km^2. This entire area comprises 19 blocks having a population 4 000 000 (approx.).

The total area of the village is 1244.41 ha with a population of 9219 and the total number of households residing is 1726. The total main workers are 2299 out of which cultivators [1] belong to 728 and agricultural labourers [2] are 943. Nearest town is Canning, which is about 90 kms from this village [6].

Table 1
Spread of beneficiaries and non-beneficiaries

Category	No. of beneficiaries	Beneficiary covered by the survey	Non-beneficiary covered by the survey
Industry	1	1	—
Commercial	150	50	15
Household	74	50	20
Total	225	101	35

Source: Field survey, April–July, 2002.

It is difficult to extend grid electricity to Chhottomollakhali Island due to prohibitive cost involved in crossing of various rivers and creeks. In the absence of electricity, the economic activities of the island were suffering. The Biomass Gasifier based Power Plant (four modules of 125 KW each) on 29th June 2001 has been set up and it is catering to electricity needs of domestic, commercial and industrial users. Four villages (Chhottomollakhali, Taranagar, Kalidaspur, Bodo Mollakhali) of the island will be benefited with electricity from the power plant. The study is completely based on field survey and a detailed discussion is given below.

2.1. Field survey

A field survey based on direct interviews method was carried out during April–July 2002. The aim was to cover approximately 50% of the beneficiaries of the power plant. Existing number of connected beneficiaries is 225. The survey covered 101 beneficiaries as explained in Table 1. A few household and commercial sectors that were not converted have also been covered under the survey to get an idea about the response of the non-beneficiaries (35 in number).

Initially, a pilot survey was conducted to pre-test the questionnaire and people's response to it and it was modified wherever necessary. Four different sets of questionnaire were prepared and used for

[1] Cultivator who cultivates land. He may be a landowner or he may lease out land or he may lease in land.

[2] Agricultural labourers are wageworkers engaged in agricultural activities and are employed by landowners. Wage may be in kind or cash.

conducting the survey, i.e. 1. village profile, 2. household, 3. commercial, 4. non-beneficiaries.

2.2. Economic scenario

The main occupational pattern in the village is dominated by agriculture and pisciculture. However, a substantial number of the surveyed beneficiaries have trading as their main occupation, which includes selling readymade garments, grocery, stationery, Jewelry and medicine. On the whole the occupational structure reflects that the region is economically backward.

Regarding agriculture it is a mono crop region, two main crops are paddy and jute. Agriculture is mainly rainfed due to lack of surface and ground irrigation system. The village being an island is surrounded on all sides by saline river water. Diesel pumps are used to draw water from ponds for irrigation.

Income distribution pattern shows that 44% of the households belong to the monthly income of USD 20.47–USD 61.41 [3] class interval and 30% belongs to the group of USD 61.41–USD 122.83 and above USD 12.832 is very negligible (*Field Survey*, *April–July*, 2002).

2.3. Infrastructure facilities

Boats in the form of motorised and non-motorised are the only way to reach the island. The unique feature is that only modes of transport are bicycle and cycle vans for passenger transport as well as freights. Because most of the roads of the village are 'kuccha' (muddy) and very few of them are brick laid. Households mainly use kerosene for lighting purpose. BGBPP is used for supplementary lighting, as it is unable to meet the total demand for electricity. In the commercial sector the source of power is mainly BGBPP and supplementary is kerosene. There is one ice mill and for the running of this ice mill electricity is required which is supplied by BGBPP. WBREDA has installed a deep tube well and pump to provide water to the villagers. This pump runs on BGBPP power. This has reduced the problem of drinking water in the village island. The market place of the village is the main centre of economic activities. There is a wide range of commercial activities within the market place. Maximum economic transactions take place on 'haat bar' day (Monday). Therefore, adequate supply of power is specially required for this day. Increased power supply would be beneficial to improve the economic activities of the commercial units in general. In the post-gasifier period, many modern electric appliances like electric iron, photocopy machines are being used in the village (*Field Survey*, *April–July*, 2002).

[3] 1 USD = Rs. 48.85, 1 July 2002, Foreign exchange report, Government of India.

3. The Biomass Gasifier Plant and the basic process chemistry

3.1. Basic process chemistry of biomass gasification

Biomass gasification is basically conversion of solid biomass (i.e. wood/wood waste, agricultural residues etc.) into a combustible gas mixture normally called "Producer gas" (or low btu gas). The process is typically used for "woody" biomass and it involves partial combustion of such biomass. Partial combustion produces carbon monoxide (CO) as well as hydrogen (H_2), which are both combustible gases. Solid biomass fuels, which are usually inconvenient and have low efficiency of utilisation, can thus be converted into a high quality, gaseous fuel with associated convenience.

This is a downdraft gasifier coupled to a pilot assisted diesel engine and it is essentially a chemical reactor where various complex physical and chemical processes take place. Biomass gets dried, heated, pyrolysed, [4] partially oxidised and reduced in this reactor as it flows through it. Although there is a considerable overlap, each process can be considered to be occupying a separate zone in which fundamentally different chemical and thermal reactions take place. The power plant detail [7] is given in Table 2.

Average generated power is 400 kW. The generated capacity depends on the local demand factor. The curve of Fig. 1 clearly shows that the demand peaks on Monday (450 kW), which is a 'Hat baar' and falls to 350 kW on Sunday.

[4] Chemical decomposition of compounds caused by high temperatures. Here the conversion of wood into charcoal. Gas generated through gasification is cleaned and cooled with the help of water scrubber.

Table 2
Power plant in detail

Lifetime of the plant	15 years
Plant capacity	4 × 125 kW
Average power generation	400 kW
Internal loss	10% (40 kW)
Line loss	5% (20 kW)
Final selling average	340 kW
No. of consumers	225 (industry:1, commercial:74, household:150)
Hours of operation	5 PM to 11 PM
Fuel consumption pattern under full load condition	(a) Biomass (80%) (b) Diesel (20%)
Length of distribution line	HT line—5 kms and LT Line—7 kms
Substations	4
Name of the manufacturer of gasifier	M/S Ankur Scientific Energy Technologies Ltd. (ASCENT) Baroda, India

Source: WBREDA [7].

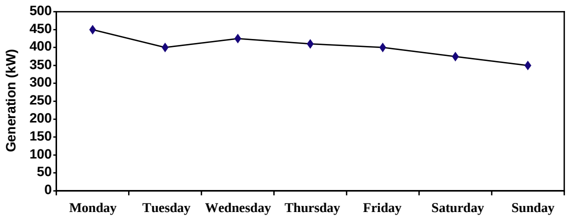

Fig. 1. Power generation chart of the BGBPP (22.07.2002–28.07.2002). Source: WBREDA [7].

3.2. Sources of woody biomass

To run the gasifier plant, woody biomass is being bought from local markets with an average price of Rs. USD 0.02/kg. This BGBPP needs on an average 1-kg woody biomass per unit of power generation (per kWh). The present requirement of wood is 400 kgs/day (drywood), which is met by the purchase from the local market. Since the woody biomass content moisture (10–15%) the amount of purchase is higher than 400 kg.

3.3. Energy plantation

To ensure steady supply of woody biomass for the project and the gasifier programme to be environmentally viable needs to be integrated to the plantation/afforestation programme to guarantee the source of raw material without a threat of deforestation. It will also help to maintain eco-balance through replantation. WBREDA has initiated the programme and planted quick growing plants like *eucalyptus*, *sirish*, *tetul and babla* (energy plants) in the riverine wasteland. In future, the wood from these trees will be used as one of the fuels for this plant. This program has also created employment opportunities and villagers are normally employed according to the requirements of the power plant. WBREDA has set up a 10 ha energy plantation in 2000–2002. The average cost to set up this plantation is USD 10235.41. Rotation period is estimated to be 5 years and the average production is 5 t ha^{-1} $year^{-1}$ as estimated.

3.4. Tariff structure

Tariff structure of the power plant was decided in consultation with the village community. Individual meters to the subscribers were provided by the WBREDA officials for accurate and efficient power consumption. Three types of tariff exist for three categories of consumers, i.e. USD 0.10/kW for industry, USD 0.09/kW for commercial and household are paying USD 0.08/kW.

Revenue collection is administered by WBREDA. Total average monthly revenue [5] generated varies from USD 511.77–USD 614.12. This amount is utilised in plant operation and maintenance (O&M) purpose. The deficit expenditure of plant's operation and maintenance is met by Government of West Bengal.

3.5. People's participation in power plant operation

To ensure smooth functioning of the power plant local people's participation is must according to senior officials of WBREDA. So a beneficiary committee has been organised comprising the renowned persons of

[5] The non-payment of the electricity bills by the beneficiaries (households and/or commercial) is a major factor for low revenue collection. So a gap always arises between a potential revenue (approx USD 1023.54) and collected monthly revenue (USD 614.12). The revenue collection figure is mentioned here as reported by WBREDA officials.

the village. This committee works as the interface between the subscriber base and the WBREDA officials. The responsibilities of this committee are (1) to provide the direction of the distribution line, (2) to ensure timely payment of the electricity bill, (3) to spread the technological awareness among the villagers and (4) to monitor the local demand. The committee members meet once in a month.

4. Economic benefits of the installed BGBPP

During the field survey it has been revealed that the gasifier has influenced the economic activities and quality of life of the villagers in a number of positive ways. Survey estimates reveal the benefits generated through the programme over the year. We discuss the various improvements from the perspectives of the households and the commercial units separately.

4.1. Benefits

Before the introduction of gasifier power for lighting, the commercial units used to depend on power supply from privately owned a few 10 kW-diesel power generator set. The household sector was completely depended on kerosene and in very rare cases on solar power. Use of kerosene is very inefficient use of fuel in India. It has already a high scarcity value and is very expensive. The additional scarcity value of diesel in the study area arises from the typical geographic location of it by way of high cost and problems in transportation of the fuel in a boat from the nearest mainland canning. The high scarcity value of diesel gets reflected in the high cost of unit of power generated by this privately owned generator supply. The inefficiency of diesel use per unit of power generation was USD 0.49. But the cost of per unit of gasifier-generated power is USD 0.09. Excess payment is an indicator of economic inefficiency. Not only the fuel efficiency of the diesel power generating sets are low they also have many environmental effects in terms of noise and air pollution. If we calculate the environmental impact then economic inefficiency goes up further and added to the social opportunity cost to diesel use in decentralised power generation in terms of its foregone efficiency gain from alternative use in transportation and centralised power generating units. The efficiency derived in case of fuel use pattern for cooking and lighting has been estimated from the field survey is discussed above in Table 3.

From the field survey it has been observed that domestic demand of fuelwood is gradually declining with the increasing use of alternatives like kerosene and LPG. Fuel uses pattern for cooking among surveyed household is shown in Table 3(a). The number of households using only chullah (smokeless)[6] is 6%. We have seen that 90% of the households are using kerosene stoves and in most cases they are supplemented by chullah (traditional type which needs cowdung and fuelwood). In some cases the kerosene stove is also supplemented by LPG, i.e. 19 households are using LPG and kerosene both out of total surveyed households. But the solar percentage is very negligible. A number of households maintain their traditional chullah not for domestic cooking but for boiling the paddy to produce the most common variety of rice for market and self-consumption. During the field

Table 3

Type of cooking appliances	No. of household surveyed	% of household surveyed
(a) *Fuel uses pattern for cooking*		
Chullah	37	74
Kerosene stove	45	90
LPG	19	38
Solar	3	6

Sources of power	Users (%)			
	Commercial		Household	
	Pre-gasifier	Post-gasifier	Pre-gasifier	Post-gasifier
(b) *Fuel uses pattern for lighting*				
Kerosene	None	None	83	None
Diesel	100	None	None	None
Solar	None	None	17	None
Gasifier	None	100	None	100

Source: Field survey, April–July, 2002.

[6] Chullahs are stoves that cook with increased efficiency, thus reducing the quantities of fuel wood required. These stoves are made from local materials (clay) and are also cheap.

survey it has been observed that traditional chullahs are used mostly by the agriculturists for this purpose. On the whole the market demand for fuelwood is gradually declining by the domestic users and will benefit a BGBPP in the long run.

Since kerosene is brought from outside the village and this involves transport cost. It raises the price per litre of kerosene. Further, the lightning by kerosene covers limited areas and also not bright enough compared to electricity. Moreover, the steady supply of kerosene is not always ensured. The gasifier power set could solve these problems of technical and economic inefficiencies to a very large extent, thus reducing the costs of power supply (Table 3b). This reduction in cost of power supply can be assessed from the savings in kerosene, diesel and by pulling out generator set that has been made possible by the gasifier power. In the post-gasifier period inefficient use of diesel generation set has been completely eliminated for the commercial units (Table 3b). As none of the commercial units are continuing with the decentralised diesel set using appliance. Very few of household and commercial sectors are still continuing with their use of kerosene (which is as an input to light the lamp power) as a source to supplement gasifier power to meet the unmet part of power demand from gasifiers. For the domestic sector the supplementary sources are kerosene and solar power. The cost of diesel use per unit of power generation is USD 0.49 but the introduction of the gasifier has reduced it to USD 0.09 per unit. Thus during the post-gasifier period commercial units as well as households are benefited. In terms of simple economic cost it can be said that holding all other components of cost of power generation constant the use of new technology has been successful in bringing down the fuel cost of power from USD 0.49 to USD 0.09 per unit of power generated.

This is an indicator of benefit from the installation of gasifier power. The gain in efficiency has been reflected through gain in consumer's welfare. The beneficiaries have expressed several kinds of benefits, tangible and intangible. The benefits which can be quantified and which have influenced the quality of life is discussed below.

The quantifiable benefits are those, which emerged due to gain in efficiency in generation, and hence reduction in price per unit of power supply set at the consumer end. The price paid by the consumers in the pre-gasifier period to the diesel generators was much higher and arbitrary. A policy with correct economic incentive will be one, which does not lead to overuse/wasteful use/overstress on existing supply set. Essentially an appliance type uniquely represents a particular level of power consumption at certain instants of time. Assuming identical supply quantity at the distributor end a consumer with 100-W bulb consumes 100-W/h of power, while one with a tube consumes 40 W/h of power. But under pre-gasifier regime since the different consumer categories were supposed to pay the uniform price per day both the categories as mentioned above had to pay the same price per day despite different levels of consumption. It is noteworthy that given the lump sum nature of the price charged there was no incentive to conserve power at the consumer end through use of efficient appliances. The pricing structure was unable to distinguish between efficient users and inefficient users giving rise to inefficient system of pricing and appliance choice. Inefficiency of pricing has been removed in the gasifier regime. Per unit price of gasifier power is less than that of diesel power. Tariff rate varies across the consumer category and level of consumption, which is given in Table 4.

Table 4
Electricity tariff structure in post-gasifier regime

Consumer category	Tariff rate per unit of consumption (USD)	Total monthly savings in electricity bills (USD)
	Gasifier power	Individual range (lowest/highest)
Household	0.08	1.02–6.14
Commercial	0.09	0.50–4.48
Industry	0.10	—

Source: Field survey, April–July, 2002.

An economically efficient tariff structure in post-gasifier regime has been successful in encouraging consumers to choose efficient appliances.[7] Although in post-gasifier regime their total units of power consumption has gone up due to more connected points. Still compared to the pre-gasifier their

[7] The electricity tariff rate in Chottomolakhalli is higher compared to the rate charged for other areas of West Bengal. However, the customers are paying the higher rate because of the benefits they are enjoying in such a remote place.

Table 5
Benefits of commercial units

Type of benefit	Number of units reporting		% in sample	
Savings in monthly exp (USD)				
0.02–1.02	9		18	
1.02–2.04	10		20	
2.04–3.07	15		30	
3.07–4.09	9		18	
4.09 and above	7		14	
Increase in business hours				
Nil	1		2	
< 1	6		12	
1–2	32		64	
> 2	11		22	
Connected points	Pre-gasifier	Post-gasifier	Pre-gasifier	Post-gasifier
1–4	45	12	90	24
5–10	5	35	10	70
> 10		3		6

Source: Field survey, April–July, 2002.

Table 6
Benefits to household

Type of benefit	Number of units reporting	% in sample
Savings in monthly exp. (Rs)		
1.02–2.04	16	32
2.04–3.07	18	36
3.07–4.09	11	22
4.09 and above	5	10

Source: Field survey, April–July, 2002.

total cost burden is much less. The table above indicates the range of actual monthly savings for beneficiaries. These results from efficient appliance choice by consumers as well as effective reduction in unit cost for gasifier power compared to diesel generated based power.

Commercial: All commercial units connected to the gasifier supply generate a collective illumination-giving rise to external benefits for the villagers. This has, in fact, given rise to business hours beyond 6:30 PM or even 7:00 PM, which was usually the standard closing time for the pre-gasifier period. Out of the total surveyed commercial units 70% have reported that increased business hour has been productive to them by way of increase in the total sales and hence a more profitable turn over. This qualitative improvement can be quantified in terms of gain in total turn over. Availability of gasifiers power at a cheaper rate has in turn given rise to power consumption through purchase and use of larger number of lighting appliances reflected through their demand for a larger number of connected points compared to pre-gasifier scenario.

Table 5 shows a significant saving in monthly expenditure of electric bill with an average of USD 2.67 for each commercial unit. At the same time, there has been a considerable increase in business hours and number of connected points leading to an average increase of monthly business turnover of USD 20.47. So on the whole post-gasifier period has brought in a propitious time for the commercial sector of this village island.

Household: Direct qualitative benefits gained by households can be seen from the savings in the monthly expenditure on power in Table 6. Some of the households could now afford to buy durable consumer goods like radio, T.V, electric iron etc with the savings generated by the installation of BGBPP. They are aware of children's comfort and enhancement of study hours during night.

From Table 6 we can conclude that the consumers are saving on an average USD 2.67/month in post-gasifier period. From the field survey it has also been noted that the household consumers are now using on average eight plug points. Prior to gasifier power to save kerosene or diesel power, nighttime activities of the villagers were almost non-existent. Now with gasifier power available upto 11:00 PM., usual household activities like watching T.V, socialisation, etc. have increased and thus improved the quality of life. The households are aware of the benefits and are demanding longer hours of service from the BGBPP. In this connection we have to mention that the benefit (or monthly saving) incurred from the BGBPP by the household will help them to switch over from traditional chullah to kerosene/LPG type (Table 3). More specifically, beneficiaries are now willing to spend the extra amount they have saved from electricity on the efficient type of fuel for cooking. Overall this benefit will indirectly save time and health costs for households.

Table 7
Willingness to pay (WTP) for the commercial units

WTP	No. of sampled units	%
USD 0.01 more	23	46
USD 0.02 more	21	42
More than USD 0.02	6	12

Source: Field survey, April–July, 2002.

Table 8
Willingness to pay (WTP) for households

WTP	No. of sampled units	%
USD 0.01 more	10	10
USD 0.02 more	35	70
More than USD 0.02	5	20

Source: Field survey, April–July, 2002.

The field survey as described above from the commercial point of view as well as from households derives that the demand for power from BGBPP will increase steadily and is elaborated below.

4.2. Demand for power

The field survey explored a huge potential demand for BGBPP power. Moreover problems also have been identified due to limited hours of power supply. Currently the gasifier supplies power for 6 h (5:00–11:00 PM). The surveyed beneficiaries have revealed that increased supply of power will enable them to increase the number of connected points. This increase in points will be utilised to operate different electric appliances. Thus, there is a future preference for the gasifier. All the surveyed beneficiaries and the non-beneficiaries have expressed their *willingness to pay* the existing rate of tariff despite their awareness that it is 2.5 times higher than conventional grid power tariff of West Bengal. Fifty percent of the surveyed non-beneficiaries have shown interest to take up the BGBPP lines but the lines have not yet been extended due to transmission and distribution constraints. Here, we have tried to make an assessment of the possibility of getting higher price for 24-h power supply.

Tables 7 and 8 clearly demonstrate the willingness to pay a higher rate for increased 24 h of supply. Whereas the commercial units are willing to pay on an average USD 0.01 more, the households on an average USD 0.02 more.

The field survey has explored a huge demand from potential consumers. It has been experienced from the survey that further extension of transmission and distribution would be justifiable given the density of settlements in the neighbouring areas. It was assessed from the survey that with increasing expansion of the T&D network unmet demand would be minimised in the process. The survey reports that all households and commercial beneficiaries would like to receive power increased from 6 to 24 h. This increased power supply will lead to more profitable turn over for the commercial sector. Though the average income of the household is not high still they are willing to pay more because it is expected that increased power supply will help the students to study for more hours comfortably and use of more electric appliances leading to further improvement of quality of life for the villagers. Due to concerns about sustainability of the biomass supply WBREDA officials are now proposing to set up Solar PV Power Plant integrated in hybrid mode with the existing BGBPP to ensure 12–14 h of power supply. Government of France is exploring options to finance this hybrid project. This will also provide irrigation water to strengthen agriculture possibilities.

The total benefits as derived from the field survey are gathered to make the cost benefit analysis discussed in the next section.

5. Cost benefit analysis (CBA) of BGBPP

The project appraisal through formal CBA is important for quantitative analysis in the decision making process. An area implementation capacity is a critical prerequisite for project success. This would depend for gasifier project on two things: First, the sufficiency of resources and actual observable cost and benefits generated by the project. We have conducted CBA for the gasifier project in terms of economic benefits accruing to the beneficiaries. On the basis of the following assumptions, we have calculated the benefit cost ratio (BCR), pay back period (PBP) and internal rate

Table 9
Estimated discounted cumulative cost and benefit of the BGBPP (USD)

Year	No. of. Years	Cumulative cost	Cumulative benefit
2001–02	1	265919.9	52019.24
2002–03	2	282705.1	104038.5
2003–04	3	299024.1	156057.7
2004–05	4	314889.8	208077
2005–06	5	330314.7	260096.2
2006–07	6	345311.2	312115.4
2007–08	**7**	**359891.1**	**364134.7**
2008–09	8	374066.1	416153.9
2009–10	9	387847.2	468173.1
2010–11	10	401245.6	520192.4
2011–12	11	414271.8	572211.6
2012–13	12	426936.1	624230.9
2013–14	13	439248.7	676250.1
2014–15	14	451219.2	728269.3
2015–16	15	462857.3	780288.6

BCR = 1.68580, Source: Author's calculation.

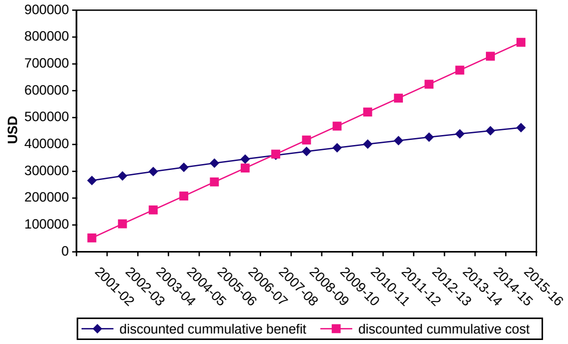

Fig. 2. Cummulative cost and benefit of BGBPP at Chotomollakhall.

of return (IRR) for the project.

(A) The initial project cost of the gasifier plant: USD 272732.9.
(B) Lifetime of the plant: 15 years.
(C) Operation and maintenance cost is the actual cost needed for the transmission line maintenance, maintenance of the power plant, labour, fuel cost (evaluated at the market price), etc.
  (1) Input raw material charges: USD 10161.72.
  (2) Labour charges: USD 4298.87.
  (3) Energy plantation: USD 5117.707.
  Total annual operation and maintenance cost USD 19578.3.
(D) The benefits are effectively generated in terms of the savings in electricity bills and increase in business hours of the commercial units.
(E) The discount rate of 8% has been assumed for calculating BCR.

Breakup of cost benefit scheme is given in Table 9.

For justification of the viability of the project the different criteria have been used. We have computed BCR defined as the ratio of discounted benefits to the discounted costs. The value obtained is 1.68 and it is greater than 1. We have also found the PBP, which represents the amount of time that it takes for a project to recover its initial cost. For this BGBPP project the PBP is seventh year which is outlined in Fig. 2. The IRR which is defined as a discount rate that produces the NPV as zero. In this case the IRR has been calculated as 19%, which is more than the cost of capital (8%). Thus considering all these criteria it can be concluded that the BGBPP is economically viable.

Due to lack of data the study is not able to cover the environmental impact in the benefit cost analysis. The detailed estimation in this regard is described in the next section.

6. Environmental impact of the BGBPP

Biomass generally contains less than 0.1% sulphur by weight compared to low sulfur coal with 0.5–4% sulphur. It keeps emissions of NO_x to a minimum when biomass is burnt to produce energy. However, it depends on operating (combustion) conditions. The final major environmental impact of biomass energy may be that of loss of biodiversity. Transforming natural ecosystems into energy plantations with a very small number of crops, as few as one, can drastically reduce the biodiversity of a region.

The key to successful biomass power development is to use the resources efficiently in modern conversion systems that maximise the energy produced and minimise the byproducts of the conversion processes. In modern times, the combination of improved technological efficiencies, scientific advances, increased environmental-awareness and environmental

Table 10
A comparison chart of emitted CO_2 & SO_2/day from diesel generator set and BGBPP

Type of power generation (400 kW)	Diesel consumed (l)	Emitted CO_2 (Kg)	Emitted SO_2 (g)
Diesel generator	1280	3392	107.52
BGBPP	80	212	6.72

Source: Field survey, April–July, 2002.

Table 11
Plant effluent details

Sl. No	Type of pollutant	Amt. in g/kg of moisture free biomass
1	Particulate + tar	1.45
2	BOD	0.14
3	COD	1.9
4	Phenol	0.077
5	Dissolved organic compounds	2.32
6	NH_3/NH_4^+	1.72

Source: WBREDA [8].

protection regulations have turned biomass conversion into a cleaner, more efficient process.

We have estimated from the field survey data the level of emitted CO_2 and SO_2 from diesel consumption by diesel generator set and BGBPP per day with a power generation capacity of 400 kW (average), which is shown in Table 10.

In the pre-gasifier period the capacity of diesel generator set was only 10 kW and used to consume 32 l of diesel per day, whereas, the BGBPP consumes daily 80 l of diesel per day and produces 400 kW of power daily on an average. The comparison highlights that the diesel consumption of BGBPP is very low compared to diesel generator set and hence the emission of CO_2 and SO_2 are significantly lower. The different effluents generated by the woody biomass intake of the BGBPP [8] are furnished in Table 11. It can be followed from Tables 10 and 11 that this BGBPP does not produce significant environmental pollution.

Sustainability of a biomass power plant generally depends on the participation of the beneficiaries in terms of increased environmental awareness by distinguishing biomass power and conventional grid power. During the field survey it was found out that very little environmental concerns exist among the villagers. They are ignorant of the negative impacts of deforestation, soil erosion, loss of biodiversity etc. They are also not willing to share the responsibility to plant more trees in their land to counter effect the negative impact that such BGBPP may generate or to maintain the sustainability.

7. Conclusion and policy recommendation

The findings of the study indicate the BGBPP has made a very positive impact on the life of the villagers of Chottomollakhali Island. This has led to increased economic activities and more profitable turn over for the commercial consumers and improved quality of life for the household sector. The consumers now are gaining in terms of lesser electric bill expenditure. All of them have shown a willingness to pay a higher price to get 24 h of power supply. From the BCA it is evident that the plant can recover its full investment after 7 years. It has also been observed that the BCR is greater than 1 (1.68). Moreover the IRR is 19%, which is more than the cost of capital (8%). Assessing above criteria we may conclude that the project is economically viable. Though the environmental benefits have not been measured in the CBA but the study finds that the BGBPP has a positive environmental impact. But the environmental awareness is very poor among the villagers.

Summing up all the aspects, we would present the following recommendations:

1. Assessment of resource base: An accurate estimate of the potential bioresource base should be done for implementation of a decentralised BGBPP. This strategy has been taken in the tenth 5-year plan.
2. R&D and technology development for BGBPP should be strengthened.
3. Excess generation capacity of the power plant, transmission and distribution network needs to be extended to the neighbouring villages.
4. If the power plant can increase the power supply from existing 6 h period to longer period then higher revenue can be generated which can meet the deficit operation and maintenance expenditure of the plant. Of course, this would be possible only if the non-payment factor can be minimised.

WBREDA should give much emphasise on this aspect.

5. The personnel as appointed by WBREDA are engaged in maintaining the plant needs to be more technically sound. Hence better training program should be arranged for them. They also can be taken in exposure trip to other successful biomass plants in other parts of India.
6. Environmental, technical awareness programmes among the rural villagers need to be more strengthened. Interventions of NGOs working in the Sundarbans to promote this can be solicited.

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