Captive Energy Plantation for Renewable Energy in the Sundarbans, West Bengal, India

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ABSTRACT

Sundarbans in the eastern border of India and Bangladesh is the largest mangrove forest in the world. Island villages of the area suffer from lack of electricity. A project was undertaken to provide electricity to 30,000 inhabitants of five villages in an island from off-grid, stand alone, woodbased gasifier power plant. To achieve the objective, a GPS-based land use mapping was undertaken to identify common property resource to raise energy plantation; after testing the soil, selected energy plant species were raised in nursery and transplanted to the identified sites with people's participation. A working plan was drawn to ensure continuous supply of biomass using the same land area. The cost per unit of electricity produced by the method showed to be most effective. The success of the project has led the Ministry of Non-Conventional Energy, Government of India to adapt the same methodology to supply electricity to the villagers of this largest delta in the region. The paper provides details of the project from conceptualization to implementation.

1. INTRODUCTION

Sundarbans is the largest inter-tidal area of the world of approximately 26 000 km² formed by the meeting of two great river systems - Ganga and Brahmaputra with the Bay of Bengal along India and Bangladesh. The Indian part of Sundarbans covers an area of 9630 km², the rest being in Bangladesh. The area consists of a group of islands numbering 102 interspersed by innumerable rivulets, tidal rivers, and creeks. The area was originally covered by thick and impenetrable mangrove forest, which was gradually cleared from eighteenth century onward for habitation and settlement. At present 5430 km² of the area is inhabited.

Sundarbans in West Bengal is considered as a World Heritage Site besides being declared a Biosphere Reserve, Tiger Reserve (partly) and Bird Sanctuary (partly). However, the human society in the island groups still remains out of mainstream due to lack of transportation and telecommunications facilities. Furthermore, a vast area of Sundarbans still remains without electric power. Lack of educational facilities, health care, safe drinking water and sanitation continue to put hurdles to human development.

Sundarbans Biosphere Reserve has the largest human population among all biosphere reserves. Indian Sundarbans supports a population of 3.7 million, the overwhelming majority of which (94.6%) depends on agriculture while the rest depends on fishing and collection of forest produce. About 54.2% of the agrarian population is landless and 85.2% of the land owning families are small/marginal with an average land holding of 0.82 ha per family. Of the total 1060 villages in the region, at least 156 villages are likely to remain deprived of power from the main grid in the foreseeable future. They can only depend on alternative energy sources like solar energy, tidal energy, wind energy and biomass energy. To provide power at the most affordable cost, the West Bengal Renewable Energy Development Agency (WBREDA) has initiated a wood-based gasifier power project of 500 kW capacity in the Choto Mollakhali Island for five villages with estimated total population of 30,000. The present paper is based on experience of collaboration with WBREDA for providing an assured supply of biomass from captive plantation for gasification.

2. METHODOLOGY

2.1 Selection of Land

The area was surveyed by a team of experts from the Society for Environment and Development (ENDEV), Calcutta in the year 2000 to identify community land under the governance of Panchayat (a village-level body of elected representatives for self governance). A village map prepared with the help of Global Positioning System (GPS) showed the available land parcel suitable for energy plantation. The results of soil testing are shown in Table 1. After soil testing, five species of plants were selected for plantation to meet the demand of the gasification unit.

It is observed that homestead land, agricultural land and water bodies accounted for most of the total area. As such, the land available for plantation is largely along the road side, canal side and inner side of the river embankment. With the help of GPS, a survey was carried out to identify potential plantation areas; a total of 50 ha of land was found to be available for plantation.

2.2 Selection of Species and Rotation Cycle

To run the 500 kW-capacity unit for 24 hours, the daily requirement of fuelwood was estimated to be 5000 kg. The maximum and minimum suitable diameters of fuel for use in the gasifier plant are 7.62 mm and 1.27 mm, respectively. To meet the demand of wood biomass for the power plant, fast growing plants were selected, namely Eucalyptus (*Eucalyptus sp.*), Akshmani (*Acacia sp.*), Siris (*Albejia lebeck*), Rain tree (*Siamea saman*), Sissoo (*Dalbergis sissoo*), and Jarul (*Lagerstroemia speciosa*). Additionally, seeds of Babla (*Acacia arabica*) and Subabul (*Laucaena leucocephala*) were broadcast because of their known potential values as energy plants. Samplings were used for five selected species for plantation but seeds were also used for sowing in the periphery of the plantation area. Expected yields of biomass at the end of five-year rotation period (when the plants will be ready for harvesting) are shown in Table 2.

Soil	Texture (%)		Moisture	pН	Conductivity	Organic	Hardness	Available	Available	Potassium	
Туре	Sand	Clay	Silt	Content		(mmhos/cm)	Carbon	(mg/gm)	Phosphate	Nitrogen	(%)
		5		(%)			(%)		(mg/gm)	(mg/gm)	
Pale	30	60	10	25.5	7.47	0.82	2.51	270.0	0.21	0.20	14.5
Green											
Clay											
Туре											
Do	32	58	10	16.5	7.02	0.28	2.66	290.0	0.15	0.25	12.5
Do	40	55	05	24.0	6.68	0.20	2.64	262.0	0.19	0.22	15.0
Do	35	60	05	14.0	6.59	0.13	2.62	268.0	0.42	0.25	16.5
Do	29	59	12	14.5	7.02	0.20	2.42	156.0	0.17	0.26	14.0
Do	25	64	11	16.5	6.76	0.23	2.49	300.0	0.10	0.21	13.6
Do	24	65	11	14.5	6.95	0.27	2.72	310.0	0.15	0.24	12.5
Do	26	70	04	20.0	6.77	0.24	2.64	324.0	0.10	0.28	15.3
Do	27	68	05	18.0	7.01	0.16	2.72	350.0	0.19	0.25	25.8
Do	28	70	02	17.5	6.01	0.46	2.58	320.0	0.25	0.27	20.5
Do	28	65	07	16.5	6.91	0.17	2.61	282.0	0.22	0.22	19.8

Table 1 Results of Soil Testing from the Village Area

Sl.	Species	No. of species	Expected survival	No. of species per	Expected yield	Total yield
No.	species	per ha	percentage at 5th year	ha at 5th year	per tree (kg)	(kg)
1.	Eucalyptus	1000	50%	500	35	17 500
2.	Akashmani	400	50%	200	72	14 400
3.	Sissoo	200	50%	100	43	4300
4.	Siris & Rain tree	300	50%	150	69	10 350
5.	Jarul	100	50%	50	31	1550
	Total	2000	50%	1000		48 100

Table 2 Expected Yield of Plantation at Fifth Year over 1 ha Area

Therefore the expected yield per hectare is 48.1 metric tons (Mt). So to meet the annual requirement of 1825 Mt of fuelwood, an area of 38 ha will be required. As the plantation will be worked out on five years rotation, the total area required to run the power plant for 24 hours with 500 kW capacity is 190 ha (38 ha x 5 years).

2.3 Community Level Meetings

Two or three community level meetings were organized before plantation every year by ENDEV team with local people in the presence of WBREDA representative. In the meeting, the WBREDA representative explained the future program regarding the supply of electricity in the area and also made the local people aware as to why the plantation was raised in the Panchayat land. The ENDEV team and Panchayat member also made the people aware about the other benefits from energy plantation (other than fuelwood) such as collection of leaf biomass and the role of plantation in resisting/minimizing the impact of cyclone.

2.4 Raising Nursery and Plantation

Due to lack of time in the first year, plantation seedlings were procured from the Forest Nursery and planted in the plantation sites. But in the second year, a nursery was raised in Gosaba (land given by the WBREDA Project Authority of Gosaba) and seedlings were carried from the Gosaba Nursery to the selected sites for plantation. In the third year, a local citizen of the village of Hetalbari provided a 0.2 ha land for the nursery without any rent.

Different activities associated with the project were:

- Community level meetings for awareness campaign;
- Raising of nursery for 5 ha captive plantation;
- Planting of seedlings with mulching, de-weeding and fertilization;
- Protection work for plantation until it reaches above browsable height;
- In-filling the damaged plantation site; and
- Periodic supervision by Forestry experts and other experts from ENDEV team.

3. LABOR REQUIREMENT AND EMPLOYMENT GENERATION

A total of 6600 man-days of employment was generated through captive energy plantation project in three years for the protection work only, i.e., an average of 2200 man-days per year. The labor requirement during nursery bed preparation, transplanting, sowing of seeds, mulching, weeding, and fertilizing, appeared highly variable but in general, 150 man-days for this part of work was required. The average cost of a man-day was INR (Indian Rupee) 60 or US\$ 1.25. Therefore the total expenditure incurred for growing 30,000 energy plants (labor component only) was INR 405,000 or US\$ 8,438 with a direct benefit of generating employment for nearly 2300 man-days per year.

4. WOOD PRODUCTION COST

At the end of third year, the total project cost for creating captive plantation was INR 800,000 (US\$ 16,170). Considering the total projected produce of 720 Mt of dry wood, the price would be INR 1,111 (US\$ 23.15) per Mt, or INR 1.10 per kg (as against the procurement price for similar wood biomass at a range of INR 2.50/kg to INR 3.00/kg). Considering the replacement cost of diesel (80%) by wood biomass, a net saving of INR 515,000 (US\$ 10,730) per year could be noted in addition to the benefit of reduction of carbon emission. Therefore the cost of biomass per metric ton in this case appears to be much lower than projected (US\$ 5.60 to 7.80 per Mt or INR 50.60 to 70.80 per Mt) as presented in a current publication [1].

5. GASIFIER PLANT AND ELECTRICITY COST

The total hardware cost for 500 kW gasifier plant was INR 1.00 crore (US\$ 208,333.00). The fuel cost corresponding to 80% of the energy input from wood and 20% from diesel is estimated to be INR 2.90/kWh. Normally WBREDA supplies electricity at INR 4.50 per unit. When compared with the current rate per unit of solar power at INR 8.00 (even with 50% subsidy), the sale price of electricity from wood-based gasifier power plant would be much cheaper. In addition, the wind-based energy in Sundarbans of West Bengal is only sold to the State Electricity Board at an actual production cost of INR 5 per unit.

Further it is noted that only 500 liters of water is currently used from a dug-out pond located next to the power plant with an installed recirculation system. The total manpower (3 persons) employed for running the gasifier power plant is also very low.

Considering all alternatives for supply of renewable energy in the absence of grid power, the production cost and sale price of energy appears to be the cheapest through the use of wood-based gasifier power plant.

6. PROBLEMS ENCOUNTERED

The problems encountered during the project implementation are summarized as follows:

- Lack of stakeholders' commitment to save plantation on common property resources,
- Adverse impact on government-sponsored projects as a result of rivalry between ruling and opposition political parties on local self-government (Panchayat), and
- Lack of grazing land for local livestock leading to frequent problems of grazing and browsing in the young plantation sites.

In the first year, Panchayat-appointed personnel were engaged to protect plantation sites and ENDEV had no disciplinary control over their performance. The system was changed from the second year onward; only local village level community organizations were entrusted for protection work – instead of individuals. This had a significant impact towards survival rate of the plantation.

However, grazing and browsing activities could never be fully controlled. WBREDA on its part did not launch any awareness program to establish the linkage between the benefits of biomass from energy plantation with the assured supply of power. As a result stakeholders could never appreciate the importance of the energy saving plantation.

No serious problem has been encountered so far with regard to running the gasifier plant.

7. LESSONS LEARNED

The present project shows the feasibility of supplying power to all the 156 remote island villages of Sundarbans through stand-alone, off-grid, wood-based biomass, gasifier-based power plants. The methodology used for Choto Mollakhali is replicable; the project also offers the cheapest rate of supply. Considering the success of Choto Mollakhali Project, the Ministry of Non-Conventional Energy, Government of India assured the State of West Bengal a subsidy of 90% for similar projects to be undertaken in the future.

The intricate political balance of these islands may pose problems. Since the Panchayati Raj System (a decentralized system of governance introduced through 73rd and 74th Amendments of Constitution of India) is now an acknowledged form of local self-governance, the acceptance of projects by political party holding majority in each of the Panchayat appears crucial. However, sensitizing community over the issue of livelihood improvement through the potential benefit of power supply may create an ambience of acceptance; it may also lead to willingness to share responsibility to protect energy plantation in common property resources.

The role of NGOs in such ventures appears vital. NGOs can act as facilitator between the Government Department, Panchayat and the local community. Before any project is launched, the use of Participatory Rural Appraisal (PRA), Rapid Rural Appraisal (RRA) and other social tools will be most relevant to find out the people's priority for local development.

8. CONCLUSIONS

Land, being a scarce commodity in Sundarbans utilizing marginal lands by road and canal sides as a common property resource, can provide the necessary base for energy plantation.

The concept of wood-based gasifier power is gradually gaining ground in India [2]. Apprehension on the prospect and limitation of dendrothermal energy [3, 4] can only be removed through a well-designed plan for creating energy plantation without any impact on local environment and natural forest. An estimate of present and future power demand, analysis of soil, availability of water and land, along with careful selection of plant species can make such a plan realistic and implementable.

The Sundarbans experience clearly demonstrated the feasibility of such project in most remote and inaccessible island villages in a hostile environment.

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