International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.3, Issue.3, May-June. 2013 pp-1272-1278 ISSN: 2249-6645

Prospect of bioenergy substitution in tea industries of North East India

M. Saikia, [1] R. Bhowmik, [2] D. Baruah, [3] B. J. Dutta, [4] D.C.Baruah[5]

[1]*Dibrugarh University Institute of Engineering and Technology, Dibrugarh, Assam*

[2, 3] *Grijananda Choudhury Inst of Management and Technology, Guwahati, Assam*

[4]*Udipta Energy, Sibsagor, Assam*

[5]*Department of Energy, Tezpur University, Napaam, Assam-784028, India*

Abstract: *Tea industry plays a major part in the economy of the North Eastern region of India. About 54% of the tea produced in India comes from North East region. The energy requirement of the industry is high and is being provided by utilization of conventional fuel till now. But the increasing prices of fossil fuel have affected the economy of the industry and the production prices have gone up. This study is aimed at investigation of the prospect of switching over from conventional fuels to bioenergy in tea industry to a possible degree. The major areas of energy usage in a tea estate could be categorized as (i) thermal energy for process heat, (ii) electricity for machine operations, (iii) petroleum fuel for transportation and plantation and (iv) thermal and electrical energy for domestic purposes. Process heat and electricity are two major energy consuming areas in the industry. Biomass could be a possible alternative for supplementing and replacing the conventional fuel for these areas. Surplus agro-residues from nearby areas can be used for process heat. Biodiesel from locally produced non-farm and non-edible oil seeds could be alternative to petroleum fuel provided related issues are appropriately addressed. Densification of locally available loose biomass in conjunction with improved cook stove could reduce the consumption of wood. The economic feasibilities of these bioenergy technologies in the thrust areas are analyzed.*

Key words: *Tea industry, bioenergy, economics, North East India*

I. Introduction

The eight states comprising the North Eastern part of India, *i.e.* Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim, covers about 262000 Sqkm., accounting for about 7.9% of India's total geographical area. The region is rich in natural, mineral and material resources, but these resources have not been tapped to their full potential. The population is mainly agrarian in nature with more than 70% engaged in agriculture. Agriculture however is not quite productive for this region and characterized by lower level of inputs, resulting lack of self-sufficiency of food grain and poor economy. Tea is a dominant cash crop of northeastern region, Assam being the major contributor of tea of this region (Table 1). Northeastern states produce around 54% of India's total tea production with Assam alone contributing 51% of India's total and about one-sixth of the tea produced in the world. India is the second largest producer of tea after China, so it is notable that tea industry presents a sizeable chunk in the economy of the country.

Table 1State-wise production of tea in North east India, (*Source- Tea Board of India*)

State	2001	2002	2003	2004	2005	2006	2007
	(Figures in thousand kgs.)						
Assam	453587	433327	434759	435649	487487	502041	511885
Tripura	6506	6632	8577	7168	7515	7128	7856
Arunachal Pradesh	1047	950	1745	2219	2624	3748	5842
Nagaland	75	206	195	190	190	191	191
Manipur	101	100	119	110	108	110	110
Sikkim	110	81	107	150	157	167	82
Meghalaya	41	35	81	99	99	139	259
Mizoram	41	45	78	72	73	75	75

Apart from its direct contribution to the national economy, tea industry also employs a large section of population directly in production and processing sectors. Having several competitors in global as well as in domestic markets, reduction of production cost becomes a serious requirements for the tea producer. However, the rising prices of the energy involved in tea production have caused difficulties to combat price rise. The average tea auction prices in Guwahati Tea Auction centre in 2006 was about Rs 68 per kg, however, average price in 2010 becomes Rs 110, i.e. an increase of 61% in just 4 years[2] Major part of the price hike is attributed to the rise in fuel prices.

With the crisis of conventional energy systems, advocacy of bio-energy options like gasification, biofuels, agro-residue utilization and briquetting have become noticeable in recent times. There have also been some encouraging results, particularly in the fields of successful demonstrations of bioenergy in industries in India as well as abroad (Jorapur and Rajvanshi 1997, Tippayawong et al. 2010). Such attempts could not been seen for the tea industry, particularly in northeastern region. It is believed that in-depth analysis of the possibilities of bioenergy application in tea industry could evolve some useful outcomes for the benefit of the tea industry.

The requirement of energy in tea processing industry is high with around 21% required as electrical energy and the remaining 79% supplied by conventional fuels (Baruah et al., 1996). It has been reported that the total specific thermal energy consumption in India varies between 4.45 to 6.84 kWh/kg of made tea while specific electrical energy consumption in India between 0.4 to 0.7kWh per kg of made tea (Sundaram et al.). The plantation and transportation sector in an estate also consumes a large amount of energy in the form of petro-fuels. And finally the working section of the industry also consumes energy for their household purpose in the form of firewood. Keeping in view of the above, the present investigation has been undertaken to analyze the feasibility of above-mentioned bioenergy options in tea industry both technologically and economically such that conventionally used fuels can be sustainably and economically be replaced.

II. Method and Materials

The present investigation aims to analyze the feasibility of bioenergy options in tea industry. This is done primarily through energy economic analyses as discussed below.

A. Biomass Gasification

Biomass gasification results fuel gas with prospect of utilization in process heating and electricity generation. The methods of estimating the economical feasibility for process heating and electricity generation are discussed below.

1) Process Heating: The details of the technology and other parameters considered for this option (Biomass gasification) of bioenergy are presented in Table 2.

Table 2: Parameters for analysis

Technology	Feed	Cost/kg (delivered at site as per 2010)	Thermal energy	Firing type
Coal-fired drier	Coal	Rs. 4.6	25 MJ/kg for North East coal	Indirect
Biomass gasifier based drier	Bamboo	Rs. 2	5 MJ/ m^3 of producer gas	Direct

Calculation is done considering the consumption of feed in both the routes to produce the same amount of thermal energy as per requirements of the mentioned tea estate. Bamboo is considered as feed for biomass gasification route as it is widely available in the North East region of India. Producer gas generation for woody biomass such as bamboo is about 2.5 m^3 per kg of feed. It may be added that the biomass consumption will be lower than as per above calculation as producer gas can be directly fired and flue gases can be used in the drier without contamination. Whereas in case of coal-firing, a heat exchanger becomes necessary as the flue gases from coal combustion cannot be directly used in the drier due to high degree of pollutants that would taint the tea.

2) Electricity Generation: Producer gas could be used for captive power generation. Two routes for power production are shown: one is by the use of dual fuel engines where producer gas can substitute up to more than 70% of the diesel, and the other is by utilization of producer gas to run 100% gas engines. In both cases, proper cleaning of gas is very necessary as the tar in producer gas tends to clog the inlets and valves of the engine. For the purpose of power generation by dual fuel engine mode, a 500 kW gasifier system with two units of 250 kW gensets is considered. Bamboo requirement for such a system is about 5 kg per litre of diesel replaced. Thus, bamboo and diesel consumption to meet the requirement are 350 kg per hour at the rate of Rs. 2 per kg and 30 liters at a rate of Rs 37 per litre respectively. Alternately, 100% gas engines can also be used to nullify the dependence on diesel but producer gas being a very low calorific value gas, there are a number of technical difficulties it its utilization. However, Cummins have recently made available commercial models of producer gas engines developed in conjunction with CGPL, IISc.

B. Process Heating in Tea Industry by Direct Firing of Agro Residue Route

Process heat can be produced via direct firing of paddy. Paddy available in nearby areas was assessed by multiplying area under rice cultivation and productivity per hectare. Using GIS technique the area under paddy crop cultivation in 14 development blocks of Sonitpur district was determined. Considering paddy straw yield of Sonitpur district to be 1487 kg per hectare [10], annual rice straw production was assessed. To compare cost effectiveness of direct paddy firing with coal fired systems, cost of production of thermal energy by both methods was determined.

Economic analysis of crop residue is done to determine the cost of rice straw. For the purpose, the costs of production, harvesting, collection, transportation and storage of the residue are taken into account.

1) Production Cost: A certain fraction of total cost of crop production is attributed to crop residue. Thus, crop residue production rate is the product of total cost of crop production and 5% residue fraction [10].
2) Harvesting Cost: Assuming harvesting is done manually, cost associated with harvesting can be determined by dividing daily wage rate (Rs per day) with harvesting capacity (Tonnes per day).
3) Collection Cost: The collection cost is estimated by dividing daily wage rate by carrying capacity (tonne per trip).
4) Transportation cost: Transportation cost can be determined by the method.

$$\frac{\text{Fuel consumption per hour of operation} \times \text{cost of fuel} + \text{drivers wage per hour}}{\text{Carrying capacity of transportive mode} \times \text{transportation speed (km/h)}}$$

5) Storage cost: Storage cost includes handling and capital invested for storage facility. Storage cost could be rental cost of the space or the cost incurred to cover the residues to protect them from rain. Generally residues are dumped in open space and immediately fed to the system. Therefore, cost of storage is assumed to be negligible.
6) Total cost:Total cost is sum of production, harvesting, collection, transportation and storage cost.

C. Economics of Biodiesel in Transportation Section of Tea Estate

The diesel demand in the surveyed estate is about 40000 litres annually. Replacing 20% of diesel fuel requires 8000 litre of biodiesel. In this study, we propose to cultivate non edible oil bearing plants in fencing area. From the very first beginning of cultivation to blending, all the cost incurred is considered for checking feasibility of three different species such as nahor (Mesua ferrea Linn), ratanjyot*(*Jatropha curcas) and karanja (Pongamia glabra). A pilot biodiesel plant of 50 lt per day running for 8 hrs per day is assumed for biodiesel production. During economic analysis of biodiesel production, the residual value of the machine is taken as 5% of the purchase price of the machine; rate of interest rate on investment is taken as 11.5% of the average price of the machine; rate of insurance and taxes is taken as 2% of the average price of the machine; housing and shelter is taken as 1.5 % of the average price of the machine. The operational cost of biodiesel production involves the fixed cost and the variable cost. Fixed cost is the cost incurred by the ownership with or without the running the machine which can be calculated taking into account i) depreciation ii) interest on investment iii) insurance and taxes iv)investment on shelter for machinery whereas variable cost involves the i) cost of chemicals ii)electricity iii)repair and maintenance iv) wages.

D. Procedure of Economic Analysis to Determine feasibility of Wet Briquetting and Improved Cook Stove as an Energy Saving Combustion Device

1) Wet Briquetting: It is a simple procedure which involves decomposition of biomass, pressing of decomposed matter and drying of pressed briquettes which can be used as cooking fuel instead of wood. Unlike the screw press and extrusion type technology, it requires small investment that is why wet briquetting is proposed for the temporary works in the referred tea estate.
2) Economic analysis procedure/ simple cost benefit analysis: The parameters considered for analysis are based on village energy consumption survey. The aim is to estimate cost of production per day per family taking into consideration of following parameters

Table 3: Parameters of economic analysis

Parameters	Value
Daily wood requirement for a family of 4 members	7
Cost of wood per kg(Taking average), Rs	5
Daily fuel wood cost, Rs	35
Worker cost ,Rs	150
Requirement of worker for the project	6
Maintenance and equipment cost added to worker cost,%	15

Now comparing the cost per day per family to the cost of fuel wood usage per day per family we can determine whether briquette production is feasible or not for this group.

3) Conservation assessment improved cook stove: In rural households, generally earthen cook stoves are used. In this study, the saving one could do in monetary terms simply by using improved cook stoves is assessed in the households. Per capita consumption before and after use of improved cook stove is compared to assess the saving in energy in general. The parameters taken for consideration are

Table 4: Parameters used in conservation determination calculation

Parameters	Value
Fuel wood consumption for a family of 5 members, kg	7
Fuel wood cost, Rs	5
Fuel wood consumption reduction by improved cook stoves, %	40

III. Results and Discussion

A. Biomass Gasification for Process Heat and Electricity

By surveying in referred tea estate, coal consumed per hour was assessed to be 190 kg per hour. From the coal consumption rate, the thermal requirements is calculated is 1.3 MW and cost of coal per hour is Rs 874. If we wish to substitute coal with gasification of bamboo for producing same amount of thermal energy, cost of fuel becomes Rs 754 per hour which shows clearly a saving of Rs120 per hour. The electrical consumption of the tea estate under study is about 894600 kWh monthly which includes the consumption in unit processes of manufacture and housing purposes. The monthly expenditure on electricity considering both grid charges and diesel consumption is around Rs.4.5 lakhs. The use of dual fuel engines, a 500kW gasifier system with two units of 250kW generator sets running with 70% substitution of diesel, shows a cost of Rs 4.35 Lakhs resulting in a saving of Rs15, 000. Calculation for 100% gas engines has not been done in this study due to unavailability of data.

B. Process Heating in Tea Industry by Direct Firing of Agro Residue Route

For the annual thermal energy need of 12592 GJ, total annual cost of coal for the factory reached Rs. 23 Lakhs for 2010 working year. Therefore, while thinking of using rice straw in place of coal, the cost of agro residue from field to factory should come at par with a price lesser than coal. The comparison of utilization of coal and rice straw for process heat in the tea industry is shown in table. The cost of coal and straw for process heating of tea is calculated by considering cost of coal and straw as Rs. 3.50 per kg and Rs. 1.37 per kg respectively. Thus, if coal is substituted by straw, the factory will make profit of approximately Rs. 11.6 lakhs annually.

Table 5: Comparison between utilization of coal and straw:

Parameters	Coal	Straw
Calorific value of fuel (MJ/kg)	25.00	14.50
Fuel requirement annually (MT)	504	869
Cost of fuel per kg (Rs.)	4.60	1.37
Fuel required per kg made tea (kg)	0.73	1.26
Cost of fuel annually approximately (Rs. in lakhs)	23.00	11.9
Approximately saving (Rs. in lakhs)		11.6

Though 132.26 million kg of straw is produced annually in this district, the straw available for energy purpose is estimated to be 116.19 million kg annually which is more than adequate. As rice straw has CV lower than that of coal, rice straw is required twice in amount that of coal and at a cost lower than coal.

Keeping in mind the above mentioned profits, Department of Energy of Tezpur University has developed a combustion device with heat exchanger which is compatible to tea dryer of the tea estate under study. Currently, the device is showing thermal efficiency of 61%. Further research on improvement is going on with additional insulation and modification to raise the thermal efficiency.

C. Use of Biodiesel Blended Fuel Transportation and Plantation

It is evident from the analysis that nahor (*Mesua ferrea linn*) and karanja (*Pongamia glabra*) among the three species taken for study have feasibility of meeting the demand of 20% substitution of petrodiesel.

Table 6: Brief analysis of biodiesel seed production with reference to Rupajuli tea estate:

Parameters	Nahor (**Mesua ferrea L**inn).	Ratanjyot(Jatropha curcas)	karanja (Pongamia glabra)
Tea plantation area, hectare	386.69	386.69	386.69
Tea plantation area, m^2	3866900	3866900	3866900
Length per side, m	1966	1966	1966
Plant spacing in meter, m	8	2.9	3
Total no of plants in fencing	976	2704	2616
Seed yield per plant per annum, kg	20	1.5	16
Percentage recovery,%	70	25	33
Total biodiesel available@ 85% sp.gr, litre	11614	861	11746

Table 7: Cost of biodiesel production economics

Parameters	Units	Values
Capacity	litre	50
Life of the machine	years	10
Cost of seed	Rs	10
Purchase price	Rs	500000
Total hourly fixed cost	Rs/l	7.57
Variable cost per litre of BD production	Rs/l	28.13
Total Cost per litre of BD production	Rs/l	35.70
Glycerol cost per litre of BD production	Rs/l	8.00
Cost per litre of BD production	Rs/l	27.70

As per Government of India, the price of biodiesel is Rs25 per litre [4] and if we go for biodiesel production taking a biodiesel plant capacity of 50litre per day running for 270 days taking seed cost as Rs10 per kg then also the production price comes to be around Rs 27.70 per litre (Table 7). Annual fuel cost saving after 20% replacement comes around Rs 74,400 in all types of species. But, considering the cultivation cost of non edible oil seed bearing plants nahor will be able to provide a feasible option of biodiesel cultivation and thereby production which could generate actual profit of around Rs 30,400 yearly taking into account the average cultivation cost.

D. Feasibility of Wet Briquette Technology and Fuel Saving by Use of Improved Cook Stove

1) Economic analysis of wet briquette technology: The low cost and guaranteed availability of densified biomass is the key motivation for fuel switch off. The economic analysis of wet briquetting project does satisfy the first criteria as briquettes could be provided at a much lower cost than wood. The fuel cost per day per family is estimated to be Rs 35. If briquette production cost is Rs 21 per family per day, than we can say the project is economically feasible. These projects engage a group of people. So, they have potential of being funded by Government under Swarnjayanti Gram Swarozgar Yojana [6].
2) Improved Cook Stoves for Fuel Economy and Betterment of Indoor Air Quality: Only fuel switching does not help in conservation of energy. Improved cook stoves with 40% reduction in wood consumption can lower fuel cost by 60% for a family. Moreover, it is seen that fuel consumption per head comes down from 2.8 kg to 0.56 kg. Government of India has taken steps in this direction and launched National Biomass Cook stoves Initiative (NCI) to develop next generation of cooking stoves having better feature of efficiency and fuel conservation. Apart from savings and fast operation, it helps to remove indoor air pollution by its exhaust removal features. This will surely relieve the women from frequent coughing and disease like asthma and other lung diseases.

IV. Conclusions

1. The possible substitution by gasification route showed a saving of Rs15, 000 by using bamboo as a feed material.
2. More than adequate availability of agro residue like rice straw in Sonitpur district has made direct firing of rice straw a lucrative option with a huge profit margin of Rs 11.6 Lakhs.
3. Similarly, in fuel use sector, by blending of diesel up to 20% saw a decrease in fuel cost by Rs 30,400.
4. Improved cook stoves with 40% reduction in wood consumption can lower fuel cost by 60% for a family.
5. Moreover, the above discussed thermal or power producing options are renewable and able to mitigate GHG and thereby making itself a good candidate for Clean Development Mechanism (CDM).

V. Acknowledgements

The authors sincerely acknowledge the staff of Rupajuli Tea Estate for their valuable suggestions and information on which this study is based. The authors would also like to thank Mr. Haradip Mahilary for providing the background for this work.

References

[1]. North Eastern Development Finance Corporation Limited, http://www.nedfi.com/
[2]. Tea Board of India, http:// www.teaboard.gov.in/
[3]. Ministry of Coal, Govt. of India. http://www.coal.nic.in.
[4]. Biodiesel purchase policy, Ministry of Petroleum and Natural Gas, Government of India, http://petroleum.nic.in/
[5]. National Rural Employment Guarantee Act 2005, http://www.nrega.nic.in/
[6]. Swarnajayanti Gram Swarozgar Yojana, Ministry of Rural Development, Government of India, http://rural.nic.in/
[7]. Sundaram E.G. & Kumar K.R.S., "Energy and Environmental Issues in Tea Industries: A Case Study", Department of Mechanical Engineering, Velammal Engineering College, Tamil Nadu, India.
[8]. Baruah D.C., Bhattacharya P.C. (1996), "Energy utilization pattern in the manufacture of black tea", Journal of Agricultural Mechanization in Asia, Africa and Latin America, Vol. 27 No.4, pp.65-70.

[9]. Das S; Jash T. (2009), "District-level biomass resource assessment: A case study of an Indian State West Bengal" Biomass & Bioenergy, 33, pp. 137–143.
[10]. Mahilary H. (2009), "Design and development of loose biomass fired furnace with an aim to substitute fossil fuel in tea industry", M.tech project thesis, Department of Energy, Tezpur University.
[11]. Singh J. & Gu S. (2010), "Biomass conversion to energy in India—A critique" Renewable and Sustainable Energy Reviews, vol 14, pp (1367–1378).
[12]. Grover P.D. (1996), "Biomass briquetting: Technology and practices", published by FAO Regional Wood Energy Development Programme in Asia, Bangkok, Thailand.
[13]. "Biomass Briquetting: An Overview", Bioenergy India, Issue 2, Dec 2009, pp. 21-27.
[14]. Venkataraman C., Sagar A.D., Habib G., Lam N., Smith K.R.(2010), " The Indian national initiative for advanced biomass cookstoves: The benefits of clean combustion", Energy for Susutainable Development, Vol 14, pp. 63-72
[15]. George Francis, Raphael Edinger and Klaus Becker, "A concept for simultaneous wasteland reclamation, fuel production, and socio-economic development in degraded areas in India: Need, potential and perspectives of Jatropha plantations", Natural Resources Forum, vol 29, pp. 12–24, 2005
[16]. Yogesh C. Sharma, Bhaskar Singh, John Korstad, "High Yield and Conversion of Biodiesel from a Nonedible Feedstock (Pongamia pinnata)". J.Agric. Food Chem., 2010 vol58, pp.242–247
[17]. Allen L. Robinson, Helle Junker, Larry L. Baxter "Pilot-Scale Investigation of the Influence of Coal-Biomass Cofiring on Ash Deposition" Energy & Fuels 2002, vol 16, pp 343-355, 2001
[18]. Thomas Nussbaumer "Combustion and Co-combustion of Biomass: Fundamentals, Technologies, and Primary Measures for Emission Reduction", Energy & Fuels, vol 17, pp 1510-1521, 2003.
[19]. N. Tippayawong , C . Chaichana, A. Promwangkwa, P. Rerkkriangkrai "Gasi fication of cashew nut shells for thermal application in local food processing factory" (in press) 2010
[20]. Ajeev jorapur, Anil K. Rajvanshi, "Sugarcane Leaf-Bagasse Gasifiers for Industrial Heating Applications" Biomass and Bioenergy, vol. 13, pp. 141-146. 1997