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Economics of Biomass Energy a Case Study

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Abstract- Electricity price fixation has an important role in the power market. Biomass generation systems using gasification technology provides clean energy and is a dependable source of power to complement the main power supply. A generalized pricing method takes care of the demand variations and the market conditions. This paper proposes a model for determining the price of electrical energy from biomass based power plants considering operating constraints and the economic components that influence the electricity price. It incorporates Clean Development Mechanism (CDM) benefit, income from by-product and penalty factors for power quality and reliability issues in addition to the economic components. The proposed model is applied to a typical biomass gasifier generating unit in Tamilnadu, India for determining the electricity price.

Index Terms - **Energy pricing, CDM benefit, Biomass Gasifier, Power Quality, Penalty.**

I. INTRODUCTION

Biomass currently provides about 10% of the world's primary energy supplies, most being used in developing countries as fuel wood or charcoal for heating and cooking applications. Despite, the current minor contribution of modern bio-energy to the global energy mix, biomass has, in the long run, potential to contribute much more significantly to the global energy supply. India, being a tropical country, has tremendous potential for energy generation through biomass and its residues. Globally, India is in the fourth position in generating power through biomass with a huge potential of 16,000 MW [1]. Main barriers to widespread use of biomass for power generation are cost, low conversion efficiency and feedstock availability [2]. The energy situation in rural India is characterized by low quality of fuels, low efficiency of use, low reliability of electricity supply and access, leading to lower productivity from the use of land, water and human effort resulting in low quality of life and environmental degradation [3].

Biomass fuels include agricultural wastes, crop residues, wood and wood-wastes etc. Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbo n while growing. It is the cheapest eco-friendly renewable source of energy. Gasification is the process of converting solid fuels such as wood, agricultural residues and coal into a more convenient combustible gas. It is the cleanest and the most efficient combustion method known. This process is done in the gasifier, mainly comprising of a reactor where the combustible gas is generated and the gas is made available for power generation. Among different gasifiers, downdraft gasifiers are best suited for electricity generation because of the reduced tar content in the producer gas [4]. Each utility follows its own price fixing strategy. Out of the limitations and barriers that have been faced for promoting renewable energy based electricity generation, the pricing of power generated from renewable energy sources remains the most critical issue [5].

Electricity price has an important role in the power market. A generalized pricing method takes care of the demand variations and the market conditions. Peak and off peak period demand, quality of supply and reliability of service influence the electricity price. The average cost methods which are used mainly for conventional energy pricing cannot be used as such in the case of energy from renewable sources because they are capital intensive projects. Different state electricity regulatory commissions of India identify the cost components affecting the price of energy from biomass based power generators [6]-[9]. However CDM benefit income from by-product, penalty/incentive factors for power quality and reliability issues are not considered by them. In this paper, an attempt is made to incorporate these factors in the determination of the energy price. The model developed is applied to a typical biomass gasifier generating unit in TamilNadu, India for determining the electricity price under different conditions.

II. PROPOSED ENERGY PRICING MODEL

Capital cost and fuel cost are the two most significant cost components in Biomass energy generation. The proposed model is used for calculating the electricity price for different categories of biomass based gasifier generating plants - grid connected or stand alone type at any place. On the positive side, the by-product of the gasification process is a source of revenue. The proposed model incorporates CDM benefit, income from by-product, penalty/incentive factors for power quality and reliability issues in addition to the economic components such as capital cost, interest on loan, return on equity, fuel cost etc.

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The brief description of the different components is given below. The capital cost represents the overall cost of financing to the generating station. The generating company obtains the capital in the form of debt and equity based on the debt equity ratio decided by the generating station. The cost of debt is measured by the interest rate of loan (X_2). Depreciation (X_2) is the loss of value of an asset and it depends on the size, type and the useful life of the equipment. Return on investment/equity (X_3) is a measure of a company's ability to use its assets to generate additional value for its share holders. O and M expense (X4) generally depends on the capacity of the plant. It consists of expenditure on spares and repairs and other miscellaneous expenses for the upkeep of the building and machinery excluding fuel charges. O and M Expenses can be calculated by either rate method (usually used in case of biomass generators) or average method. Insurance (X_5) is an important factor in case of biomass power generation to protect the project owner from several risk aspects. Taxes (X_6) have to be paid by the generating company on the income and profit. A cost escalation factor **(X_7)** is included to accommodate any variation in the initial project cost due to unexpected events that may occur. The working capital is the amount of funds needed to cover the cost of operating the generating station. It is required for short term purpose for the purchase of raw materials, components and spares, the day-to-day expenses, fuel cost, office expenses etc. The interest on working capital is taken as **X_8**. The Service Charges (SC) include system operation and scheduling charges, charges for breakdown maintenance etc.The variable cost of energy depends on fuel price and quantity of fuel used. The cost of fuel varies with type of fuel used, calorific value of fuel, availability and transportation charges. It depends also on the seasonality. The quantity of fuel depends on Station Gross Heat rate (SGH) and gross Calorific Value of Fuel (CVF). The utility tries to maintain a high load factor to reduce the variable cost.

$$EG = PLF \times IC \times 365 \times 24 \quad (1)$$

where 'EG' is the total energy generated, 'PLF' is the Plant Load Factor and 'IC' is the Installed Capacity.

The Clean Development Mechanism (CDM) is a global mechanism under Kyoto Protocol that enables investors to receive credit towards their own Green House Gas (GHG) emission reduction initiatives. The emission reductions generated by a CDM project are the GHG emissions that are avoided by implementing the renewable energy alternative that displaces the electricity generation from power plants fuelled by coal, oil or natural gas. The GHG emission and CDM benefits determination are described in [10]

Penalties

Penalties are charged for not maintaining reactive power, frequency, scheduled energy etc within the specified limits. These parameters have to be within the specified limits for supplying quality power and reliability of supply. The Frequency Penalty (P_{d1}**)** is described in [11]. Generators supply reactive power within certain limits only, exceeding the limits invite reactive power penalty (P_{d2}**)**. Generating stations have to supply the scheduled energy to the grid to maintain the grid parameters within the specified limits. A 10% penalty for energy imbalance is normally charged. The penalty discourages unfavorable generator operating practices [12]. Penalty for variation in scheduled energy is taken as P_{d3}**.** Power quality refers to voltage or frequency abnormalities and harmonic distortion. Reliability of utility refers to adequacy and security of the system. Reliability is gauged utilizing indices for both the frequency and duration of service interruptions. When the Reliability Indices (RI) [13] are within the specified values, then utility charges additional price for the reliable electricity. Otherwise, the utility has to pay a cost of outages P_{d4} to the customer.

$$\text{Total Penalty } \lambda = P_{d1} + P_{d2} + P_{d3} + P_{d4} \quad (2)$$

The charging of penalty in lieu of reliability is applicable only when the Biomass unit operates as an independent power supplier. The gasification process generates valuable by-products such as high quality wood charcoal, coconut shell activated carbon, sludge etc. It depends on the fuel used. Income from by-product (C_b) is a significant component in the energy price.

Energy Price

Total Energy Price =

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + SC - B_{cdm} + \lambda + FC - C_b \quad (3)$$

$$\text{Net Energy Generated} = IC \times 365 \times 24 \times PLF(1 - Aux)$$

Energy Price/unit $$EP = \frac{(X1+X2+X3+X4+X5+X6+X7+X8+SC-B_{cdm}+\lambda+FC-C_b)}{IC \cdot 365 \cdot 24 \cdot PLF\,(1-Aux)} \quad (4)$$

III. CASE STUDY

For case study, data of various cost components and technical features were collected for 1 MW biomass gasification power project located in TamilNadu, India and price calculation for the energy generated was done. The details of the gasifier are given in Table 1.The coconut residues are the major fuel for this project which is available in abundant in the southern region. The biomass supplied to the two units of 500 kW gasifier is converted into producer gas, then the generated output is supplied to four 250 kW producer gas engines. The generated electricity is exported to TamilNadu Electricity Board (TNEB) grid. Fig.1 shows the monthly energy generation for one year and the corresponding fuel consumption. The fuel consumption varies linearly with the generation. Fig.2 gives the relationship between the fuel consumption per unit and the PLF. It is seen that as the load factor increases the fuel consumption per unit reduces. So if the plant load factor is high, the generation becomes more economical.

IV. RESULTS AND DISCUSSIONS

The developed model is applied to the 1MW grid connected biomass gasifier power plant for determination of energy price. The energy price per unit is calculated considering the total expenditure and the total energy generated. Calculation is done with and without CDM benefit and also with and without sale of by-product. The corresponding pay back periods are also determined for an energy price of Rs4.5/kWh from TNEB. The results are shown in Table 2. The quantity of by-product generated is 8% of the total fuel consumed. The by-product generated depends on the fuel used. Income from sale of by-product is a major factor in the determination of energy price. The model helps to decide which fuel has to be selected for economic operation when the prices of different fuels are known.

V. CONCLUSION

The proposed model gives a generalized method for pricing energy from biomass based power plants. It incorporates the CDM benefit, the income from by-product sale and also penalty factors for power quality and reliability studies in addition to the economic components. In this proposed methodology, the energy price is calculated depending on the energy generated and the plant outages are thus taken care automatically. The data were collected from a typical biomass plant in India. The biomass required for the power generation are taken from the nearby villages itself. From the results and discussion it is inferred that, with the income from by-product sale and CDM benefit, the biomass energy becomes more economical. In the proposed model start up and shut down costs and also cost of waste management are not included.

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APPENDIX

Table 1: Biomass Gasifier Power Plant Details

SNo	Financial and operating parameters	Values of the financial and operating parameters
1	Biomass gasifier power plant capacity	1MW
2	Total Project cost	Rs. 600 lacs
3	Debt – Equity Ratio	70 : 30
4	Project cost after subsidy of 150 Lacs	Rs.450 Lacs
5	Loan repayment period & Interest	10 years @ 9%
6	Return on Equity (RoE)	16%
7	O and M charges	4.5% of capital cost with 5% escalation
8	PLF as per collected data	80-85%
9	Insurance	0.75% of capital cost for the first five years with reduction

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		of 0f 0.5% every year thereafter
10	Depreciation	7.84% per annum on straight line method till the residual value is 10% of capital cost
11	Auxiliary consumption	9%
12	Working capital	Two months O&M cost and two months fuel stock
13	Interest on working capital	11%
14	Average fuel consumption	1.2 kg/kWh
15	Fuel cost	Rs.2.75/kg
16	Total cost incurred	Rs.362 Lacs
17	Total energy generated	66.92 Lac kWh
18	Quantity of by-product	8% of total fuel consumption
19	Cost of by-product	Rs.20/kg
20	CDM benefit	Rs.0.7/kWh (€ 12 per Certified Emission Reduction)

Table 2: Energy price under different conditions in Rs per kWh with coconut shell & wood chips as fuel

	Energy Price In Rs/kWh	Coconut shell @Rs.2.75/Kg	Pay back period
1	Energy Price from Government	4.5	
2	Energy Price with CDM benefit and By-Product sale	2.852	4.08yrs
3	Energy Price w/o CDM Benefit	3.552	7.09yrs
5	Energy Price w/o By-Product Sale	4.777	-

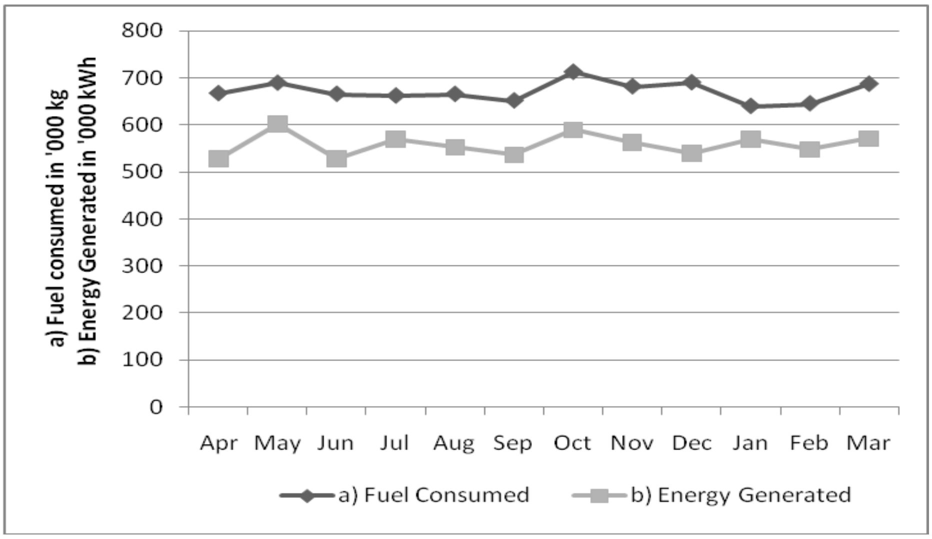

Fig 1. Fuel Consumption and Energy Generation in 1 MW Biomass Plant

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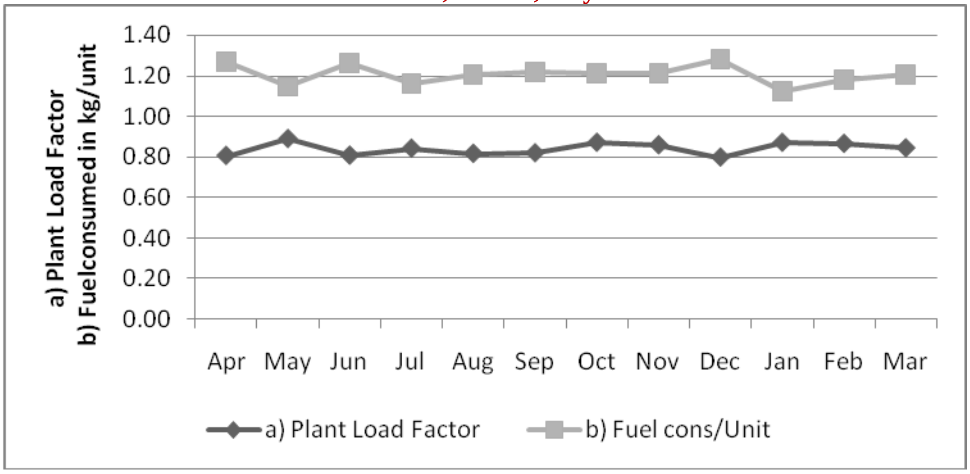

Fig 2. Plant Load Factor and Fuel Consumption per unit in 1 MW Biomass Plant