Proceedings of IOE Graduate Conference, 2015
pp. 293–297

Financial Evaluation of Biomass Based Power Generation System in Nepal

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Abstract

Globally renewable resources are considered as clean fuel for electrical and thermal energy. Among the renewable resources, biomass holds a special promise due to their inherent ability to store solar energy and converting them into solid, liquid and gaseous fuels or other marketable commodities. Biomass gasification has yet to consolidate its position compared to other techniques for exploiting biomass energy. Neither the research conducted nor the plants built in recent decades, nor even government support for this technology, have provided a sufficient boost to increase the level of implementation of gasification despite its advantages in aspects such as greater efficiency and the reduction in CO_2 emissions. In this paper a preliminary financial evaluation of biomass gasifier based power generation in Nepal was undertaken. Simple cost functions were developed for this purpose. The study shows that the cost of the plant is reduced on increasing plant size.

Keywords

Biomass Gasifier – Power Generation – Cost function – Financial Evaluation

1. Introduction

Biomass is a renewable energy resource when used sustainably. Bio-energy is one form of indirect solar energy, since it is derived from sunlight via photosynthesis. Definition: "Recent organic matter originally derived from plants as a result of the photosynthetic conversion process, or from animals, and which is destined to be utilized as a store of chemical energy to provide heat, electricity, or transport fuels". Recent means short cycle carbon to distinguish bio-energy from fossil fuels and peat where carbon has been removed from the short cycle [1]. Gasification of woody biomass has been a well known technology for more than five decades (Bungay, 1981). However, it is only in the last 10 years or so that its use for decentralised power generation has received considerable attention from planners, researchers and entrepreneurs [2]. The heat needed for the reactions to occur is usually provided by the partial combustion of a portion of the feedstock in the reactor with a controlled amount of air, oxygen, or oxygen enriched air [3]. Heat can also be provided from external sources using superheated steam, heated bed materials, and by burning some of the chars or gases separately.

It is in this context that the present study was undertaken in which an attempt has been made to analyses the cost of biomass-gasifier-based power generation systems in Nepal. Cost functions taking into account the effect of the capacity of power generation system on its cost have been developed for the designs of a leading biomass-gasifier manufacturer in India (M/s Enserol Biopower, Jaypur, India). The operation and maintenance costs have been estimated on the basis of the studies reported in the literature. Finally, the cost of power generation has been estimated and its sensitivity to the values of several input parameters has also been studied.

The technology related to electricity generation using Biomass Gasification is relatively new for Nepal. Biomass resources can be used to generate electricity in two ways:

1. Gasification for generating combustible syngas and using engine-alternator to generate electricity, and
2. Directly burning the biomass in furnaces for steam generation and using the steam to drive steam engine for generating electricity. Though different organizations have initiated Biomass Gasification

for electricity generation in the past, there are no such plants providing electricity to rural communities in Nepal. There are only few Biomass Gasifier for thermal application installed in some industries. AEPC/REDP/RERL initiated a pilot project on Biomass Gasifier based rural electrification in 2011. The electro-mechanical equipment was imported from India. The plant is running successfully and serving 122 household of Madhuban Goth VDC of Sarlahi district.

Nepal heavily relies on biomass for much of its energy need for cooking and heating. Figure 1 shows the share of energy consumptionin Nepal by fuel type. The figure clearly shows that biomass alone caters for about 87% of the total energy demand of Nepal [4].

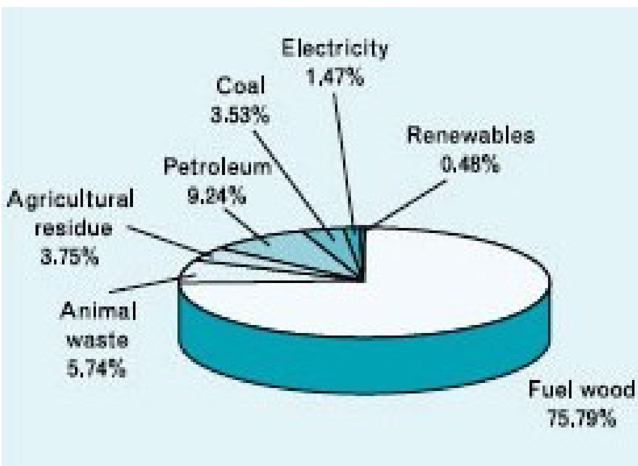

Figure 1: Share of the energy consumption

2. Gasifier Technology

In gasification technology, the solid bio-residues converted to gaseous fuel by thermochemical conversion which is further conditioned and made suitable to operate in an engine as shown in figure 2. Gasification involves partial combustion of biomass under controlled air supply, leading to the generation of producer gas constituting of combustible gases H_2 (>15%) CO(>20%), CH_4(>4%), CO_2(>11%) and N_2(remaining). The energy value of producer gas is about 5.0 MJ/m^3. In this gasifier, different kind of biomass fuels can be used in the same gasifier without changing its orientation and technology. It uses available bio-resources such as forest residue, agricultural residue etc and converts them into a clean gas that could be utilized in dual fuel or gas engines for power generation.

Power generation through an engine is possible by substituting diesel in a diesel engine by 100% producer gas.

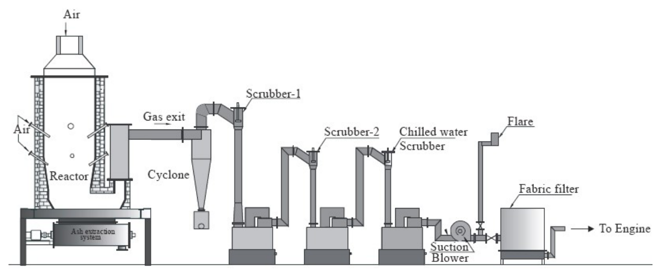

Figure 2: Gasifier technology with its components

3. Objective

The main objective of this paper is financial evaluation of biomass gasifier based power generation in Nepal while the specific objectives are:

1. To develop cost function for different capacity of Biomass gasifier based power generation systems.
2. To perform financial evaluation on the basis of initial investment, installation cost and operation cost.

4. Research Methodology

Huge variations are found in the literature on the cost of electricity generation from biomass gasifier projects. This is primarily due to difference in the input parameters used by various researchers such as difference in cost, fuel price, operation and maintenance costs, and variation in financial and fiscal incentives considered for the analysis. The road map in this study is shown below:

4.1 Financial Analysis

4.1.1 Capital Cost

The total capital cost of a biomass gasifier based power generation system comprises the cost of the gasifier unit and the generator set (DG set), and also the installation cost. Table1 presents the coefficients for cost functions of the form aP^b for biomass gasifier based power generation system. Cost function of the form are therefore, attempted for representing the cost of biomass gasifier based power generation systems in Nepal, where C is the capital cost, P (in kW) is the power rating, and a and b are coefficients obtained through regression as shown in Table1.

Table 1: The coefficient for cost functions of the form aP^b for biomass gasifier based power generation

Power Range(kW)	Coefficients		Max. r.m.s. error(%)
	a	b	
3 – 20	300000	0.895	
40 – 100	250000	0.931	

The various components of biomass gasifier systems, i.e. biomass gasifier, cooling and cleaning unit, air mixing unit, diesel engine, electrical generator, etc. are coupled with appropriate pipe fittings. Table 2 presents the capital cost of the entire system as provided by M/s Enserol Biopower Company, Jaypur-India a leading manufacturer of biomass gasifier in India for different capacity ratings varying from 3 kW to 100 kW.

Table 2: Capital Cost of biomass gasifier based power generation systems

Power (kW)	Cost of Gasifier (NRs. in thousands)	Per kW Cost (NRs. in thousands)
3	800	266
5	1250	250
10	2350	235
20	4350	217
40	7500	187
60	11000	183
183	18000	180

The graphical representation of capital cost and power rating is shown in figure 3. As well as reduction in per kW cost on increasing plant size is shown in figure 4.

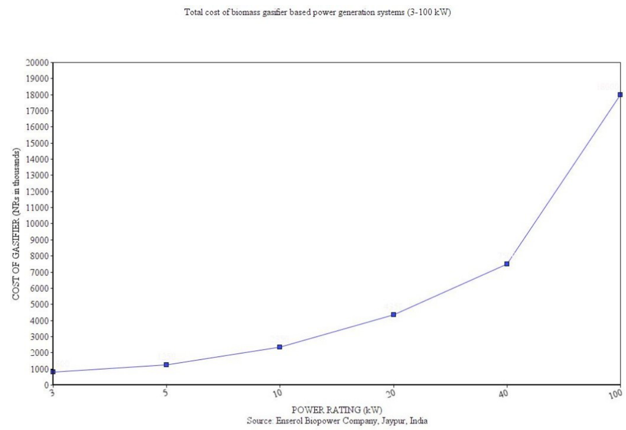

Figure 3: Capital cost of biomass gasifier based power generation systems (3-100 kW)

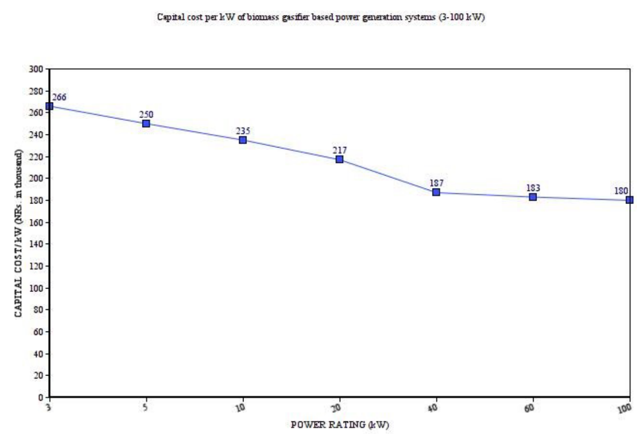

Figure 4: Capital cost per kW of biomass gasifier based power generation systems (3-100 kW)

4.2 Overall Cost Calculation

A biomass gasifier having 5 kW capacity has been taken for the detail financial calculation.

Table 3: Capital Cost of biomass gasifier based power generation systems

Cost summary	In NRs
Estimated Project Cost	1,250,000
Depreciation benefit available	300,000
Net Investment	950,000
Net power generated (units/yr)	31,536

4.3 Operational Parameter

4.3.1 Power Generation

(For whole year figures gasifier availability of 80 % considered)

Table 4: Capital Cost of biomass gasifier based power generation systems

Gross Power Generation/set, kW/hr	5
Captive Power Consumption/set, kW/hr	0.5
Net Power Generation/set, kW/ hr	4.5
Gross Power Generation in a day/set, kW	120
Net Power Generation in a day/set, kW	108
Gross Power Generation in a year/set, KW	35040
Net Power Generation in a year/set, KW	31536

4.4 Operating Cost

Table 5: Biomass Consumption

Specific Biomass Consumption, kg/kWhr	1.2
Gross Power Generation in an year, kW/year	35,040
Annual Biomass Consumption, kgs/year	42,048

4.4.1 Manpower Cost

Table 6: Manpower Cost

Description	Number	Rate/month	Cost
Project Incharge	1	12,000	12,000
Supervisor	1	10,000	10,000
Labour	2	5,000	10,000
Total per month			32,000
Total per year			384,000

4.5 Repair and Maintenance Cost

For the first year repairs and maintenance have been calculated as 6% of the basic gasifier cost and for subsequent year, escalation of 5% is considered.

Table 7: Manpower Cost

Year	Cost: Repair & Maintenance (NRs.)
1	6,000
2	6,300
3	6,615
4	6,946
5	7,293

4.6 Economic Feasibility/Viability

4.6.1 Fund Flow Statement

Table 8: Fund Flow Statement

Description	1st year	2nd year	3rd year
Net Power Generated (kW/yr)	31,536	31,536	31,536
Consumption of Biogas (kg)	42,048	42,048	42,048
Cost of Biomass (Rs/kg)	5	5	5
Total Cost of Biomass (Rs.)	210,240	210,240	210,240
Manpower Cost (Rs.)	384,000	403,200	423,360
Repair and Maint Cost (Rs.)	6,000	6,300	6,615
Total Cost of Gen (Rs./Unit)	600,240	619,740	640,215
Unit Cost of Gen (Rs./Unit)	19.03	19.65	20.3
Engine Maint Cost/Unit	0.5	0.53	0.55
Net Cost/Unit	19.53	20.18	20.85

Table 9: Revenues from the Plant

Assuming sale price of electricity, Rs./unit	25.00
Cost of Electricity from the system, Rs./unit	19.53
Savings per unit,Rs./unit	5.47

Table 10: Benefits through charcoal production

Charcoal generated per unit, kgs/unit	0.06
Charcoal generated per year, kgs/year	2,102
Cost of Charcoal per kg, Rs/kg	40
Total revenues from charcoal, Rs/kg	84,096

Table 11: Results

Total revenues per year when the system is installed	256,488
Recovery of Net investment per year	3.7
Recovery of Net investment without depreciation	4.87

5. Results and Discussion

Figure 2 shows a comparison of the actual values for the cost of biomass gasifiers, C with the values obtained from the following cost function, for the capacity range 3-20 kW.

$$C = 300000\ P^{\ 0.895}$$

Similarly, C with the values obtained from the following cost function, for the capacity range 40-100kW is

$$C = 250000\ P^{\ 0.931}$$

This shows per kW cost of biomass gasifier reduced with its increasing capacity. So the cost function shows that the larger plants are viable than small size plants.

One of the figures of merit most commonly used for comparing different power-generation options is the unit cost of electricity generation (in Rupees per kWh). As explained earlier, the unit cost of electricity is obtained by dividing the net annual cost by the total units of electricity generated by the system in a year. Owing to the economy of scale observed, it is expected that the unit cost would depend upon the size of the biomass-gasifier-based power generation unit, besides its obvious dependence on the costs of biomass feedstock, manual labour, repair and maintenance, and the useful life times of gasifier and DG sets. The choice of discount rates would also affect the unit cost.

6. Conclusion

A simple framework for estimation of unit cost of electricity for biomass-gasifier-based power generation systems has been presented in this paper. The results of typical numerical calculations indicate that medium- and large-capacity systems could be financially attractive for higher values of the capacity utilisation factor. The study on 5 kW plant shows that recovery of total investment with depreciation is about 4 years and without depreciation is about 5 years which is attractive returns on investment.

Biomass-gasifier-based power generation systems can be useful in providing decentralised electricity to remote unelectrified villages. A 20-25 kW system can meet the domestic lighting requirements. Irrigation water pumping is another potential area for effective utilisation of these systems. In addition, these systems can also find application in several other small-scale mechanical and thermal applications. It may, however, be noted that the capital costs of such biomass-gasifier-based systems may be well beyond the purchasing power of individual households in rural areas and community level systems may have to be designed for their effective dissemination in rural areas.

Acknowledgments

The authors would like to thank Prof. Dr. Bhakta Bahadur Ale for being a constant source of encouragement with valuable guidance and prompt suggestions in this research work. The authors would like to express deep sense of thanks to Enserol Biopower Company, Jaypur, India for providing technical assistance, providing raw materials and fabrication of Gasifier.

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