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Performance of Biomass Power Generation System

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The present research work has been carried out on biomass based 10 kW capacity gasifier power generation system installed at College of Agricultural Engineering and Technology, Dr. Panjabrao Deshmukh Agricultural University (Dr. PDKV), Akola Maharashtra, India. The main objectives were to evaluate various costs and benefits involved in the power generation system. The costs of energy per unit were calculated for the first year of operation. The economics of gasifier based power generation system and thereby the feasibility of the system was examined by estimating per unit cost, Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR) and payback period. The discount cash flow method was used to find out the IRR. In the present analysis, three costs viz. installed capital cost, operation and maintenance cost, and levelised replacement cost were examined for the evaluation of the power generation per unit. Discount rate on investment in case of subsidy (Case I) and in case without subsidy (Case II) for installation cost of system was considered as 12.75 %. The BCR comes in Case I for operating duration of 22 h, 20 h, and 16 h are 1.24, 1.18, and 1.13 respectively. Similarly for Case II BCR comes 1.44, 1.38, and 2.39. The IRR comes in Case I for operating duration of 22 h, 20 h, and 16 h are 26 %, 22 %, and 19 % respectively. Similarly for Case II IRR comes 52%, 44 %, and 39 % for operating duration of 22 h, 20 h, and 16 h respectively. The payback period in the present analysis was worked out. The payback period for biomass based gasifier power generation system were observed to be for Case I from 3 to 4 years and for Case II it was 1 to 2 years.

Keywords: cost of energy, discounted cash flow, benefit cost ratio, net present value, payback period

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1. Introduction

India is a rural based country and nearly about 65 per cent populace is living in villages. Farming is the basic source for earning which requires energy as an intensive measure for production. The country itself faces acute shortages of electricity, which affect the irrigation facility in the villages across the country. The low level of increasing power plants, improper prediction of energy requirement and depletion of fossils fuel has restricted to supply of adequate power to farming. To avoid the circumstances of the power, another way is use of the renewable energy sources. The villages in the country are naturally endowed with variety of natural energy sources, by which means it is possible to develop self energy generating villages to satisfy the energy demand. The villages in the country have strong and abundant natural energy sources. The biomass in villages is available in variety of forms. The crop residue and livestock waste and the forest excess wood are main available sources of biomass in the villages. India is emerging as one of the fastest growing countries in the world with a GDP growth consistently exceeding 8% for the past couple of years and this trend is expected to continue. Energy being the driver of this growth, its availability is of the utmost importance to sustain this level of growth. The official projections show that the energy demand is expected to be more than three to four times the current level in another 25 years [1]. Though 74 % of Indian villages were electrified as of March 2005 [2] only 54.9 % of households had access to electricity [3] [4]. About 42% of people had access to clean LPG for cooking as of January 2005. With respect to the rural–urban divide, in 2005, 9% of rural households had access to LPG whereas about 57% of urban households had access [4] [5]. Biomass of agro residue, cattle waste has acquired considerable importance as biofuels at domestic cooking, industrial application and some of extent power generation for satisfying the energy demands of the end users [6]. Biomass energy sources may be able to offer socio-economical and technical benefits compared to other renewable energy sources. The exact predication of the socio-economic benefit has not yet been completed in the India and could help to guide level of additional subsidies that may be appropriate for bioenergy compared to the other renewable energy sources [7].

Biomass source is the emerging energy among renewable energy sources having potential to fulfill the energy demand of the rural areas to enhance the rural economy in developing countries.

The present research work was mainly intended towards the assessment cost of energy generation and the feasibility for the power generation through biomass based gasifier power generation system. This information will help in deciding in retrofitting such system in rural area of the country to fulfill the energy demand. The gasifier based power generation system installed at Dr. PDKV, Akola was studied as a case for the research project work which considering the various aspects of energy generation with the various cost measures.

2. Materials and Methods

The present study was carried out at biomass power generation system of 10 kW installed capacity at the College of Agricultural Engineering and Technology, Dr. Panjabrao Deshmukh Agricultural University (Dr. PDKV), Akola Maharashtra, India. The system has been installed during March 2009. The installation and the maintenance cost of the system for turnkey operation was gathered and determined. In the present study, cost of energy generation has been evaluated. The cost of energy generation was evaluated by considering the optimum performance of the gasifier system[8];[9];[10]. The life cycle cost of energy generation was determined by considering the present economic appraisal. The feasibility of the power generation of gasifier system was evaluated by discounted cash flow technique (DCF) [8];[9];[10]. The parameters like net present value, benefit-cost ratio, internal rate of return and payback period of the system was evaluated by considering the current nature of discount rate.

2.1 Theory of Economic Analysis

The economics of gasifier based power generation system was calculated by evaluating various costs measured and by using the discounted cash flow techniques for system economic feasibility. The data regarding installation cost, cost of fuel and cost of labour for the case determined by operations considered.

The present analysis has been carried out for power generation of 22 h, 20 h, 16 h with the scenario of without subsidy (Case I) and subsidy of 50 percent (Case II) on total installation cost of gasifier based power generation system.

2.1.1 Cost of Energy Generation

The cost of energy generation from biomass based gasifier system has decreased significantly over the past decades. Three methods are customarily used to measure the costs and economic performance of power generation system. This begins with the installed capital cost (ICC), specific capital cost and cost of energy[8];[9];[10].

2.1.2 Installed Capital Cost

This measure of cost includes all planning, equipment purchase, construction and installation costs for a turnkey of biomass based gasifier power generation system, ready to operate. As such, this cost includes installation at the site together with all maintenance and other supporting infrastructure [10] [11].

2.1.3 System Specific Capital Cost

This measure of the cost combines installed cost and the power generation per year. The capital cost is the installed cost to obtain energy generation per year.

$$C = \frac{\text{Installed capital cost (INR)}}{\text{Total energy generation (kWh) per year}} \quad \text{INR/kWhyear}^{-1} \tag{1}$$

Installed capital cost (INR)

This capital cost does not include the cost of operation and maintenance over the lifetime of the system.

2.1.4 Cost of Energy Generation

This cost is most comprehensive measure of power generation system, which is the cost of energy (CoE). This measure incorporates all elements of cost, i.e. ICC, cost of capital, cost of operation and maintenance, cost of major overhauls and subsystem replacement.

$$CoE = \frac{ICC + FCR + O\&M + LRC}{\text{Total energy generation (kWh) per year}} \tag{2}$$

where, ICC, installed capital cost; FCR, annual fixed charge rate; O&M, operation and maintenance cost; LRC, levelised replacement cost (considered 25% over O&M).

2.2 Economic Feasibility of Biomass Power System

The project evaluation technique (discounted cash flow) was used to measure the economic feasibility of power generation system. This technique measures the productivity of the capital invested and for which the flow of costs and returns over life period. These costs can be brought to refer to the particular point of time i. e., present period by discounting them [11];[12];[13].

Comparative picture of different measures of capital productivity used in economic evaluation of investment in biomass energy systems used are: net present value, benefit cost ratio, internal rate of return and payback period.

2.2.1 Net Present Value

In this method, generally the discounted rate/ compound rate, which reflects the price of the investment funds, is used to arrive at costs and returns to a common point of time. These costs are subtracted from the return to get the net present values of the systems. The positive net present values indicate that the investment is worthwhile and the size of the net present value (NPV) indicates how worthwhile the project is in utilizing the resources to maximize income. Following expression is used to work out the net present value;

$$NPV = \sum_{t=1}^{N} \frac{R_t - C_t}{(1+i)^t} \tag{3}$$

where, R is the returns in the year t, C is the costs in year t, N is the project life, *i* is the discount rate in per cent.

The decision criteria are:

If NPV > 0 Investment is worthwhile

NPV < 0 Investment is not worthwhile

NPV = 0 Neutral case

2.2.2 Benefit Cost Ratio

The benefit cost ratio measures the returns or benefit per unit of cost of investment.

$$BCR = \frac{\sum_{t=1}^{N} \frac{R_t}{(1+i)^t}}{\sum_{t=1}^{N} \frac{C_t}{(1+i)^t}} \tag{4}$$

The decision criteria are:

If BCR > 1 Investment is worthwhile

BCR < 1 Investment is not worthwhile

BCR = 1 Neutral case.

2.2.3 Internal Rate of Return

The internal rate of return means the discounted/ compound rate at which the present value of returns equals that of costs. Accordingly the derived discounted rate (IRR) is compared with the price of the investment funds to know the worthiness of the project.

$$\mathrm{IRR} = \sum_{t=1}^{N} \frac{R_t - C_t}{(1+i)^t} \quad (5)$$

The decision profitability criteria are:

If IRR > 1 Investment is worthwhile

IRR < 1 Investment is not worthwhile

IRR = 1 Neutral case.

2.2.4 Payback Period

This is the simplest of the techniques for evaluating an investment proposal. It is defined as the time period within which the initial investment of the project is recovered in the form of benefits. In other words, this is the length of time between the starting time of the project and the time when the initial investment is recoupled in the form of yearly benefits. Expressing it in notation:

$$\mathrm{P} = \frac{I}{\mathrm{C}} \quad (6)$$

where, P is the payback period, I is the initial investment, and C is the yearly net cash flow.

3. Results and Discussion

3.1 Economic Analysis of Power Generation System

The economics of biomass based power generation system and feasibility by estimating per unit cost in initial year and by estimation of NPV, BCR, IRR and payback period. The information gathered regarding capital cost and energy generation for the one year are indicated in Table 1. The present analysis has been carried out for power generation of 22 h, 20 h, 16 h with the scenario of without subsidy (Case I) and subsidy of 50 per cent (Case II) on total installation cost of gasifier based power generation system. The maintenance cost was considered for both scenarios of one per cent to the installed cost. Similarly, levelised replacement cost was considered 25 per cent of maintenance cost. The gasifier based power generation system is operated to 22 h, 20 h, and 16 h having biomass fuel feeding of 15 kg/h. The cost of purchased biomass fuel was 1.5 INR/kg. The gasifier system has been considered for 300 days in operation in one year. For the condition of 22 h, 20 h, and 16 h, three labours were required to operate the power generation system. The cost per man laborers per day was INR 80. While considering the above stated fact the operational requirement of fuel and labour with maintenance cost, the capital statement and energy production scenario is depicted in Table 1.

The total installation cost for a 10 kW capacity gasifier based power generation system comes to INR 650000 in case I and INR 325000 in case II. The annual energy generation is 66000 kWh for 22 h, 60000 kWh for 20 h and 48000 kWh for 16 h in case I and case II. The cost of electricity for calculating the grass annual income from the power generation system were considered as 6 INR/kWh as per present tariff of Maharashtra Electricity Regulation Board for biomass energy generation system. The annual fixed charge rate of power generation system was INR 12.75 % for both cases. The interest rate for biomass based power generation system is reported to be 13 % [14]. The project life time of gasifier based power generation system was considered for 20 year. The gross annual income was obtained INR 396000 for 22 h, INR 360000 for 20 h and INR 288000 for 16 h in both cases. The annual operation and maintenance cost in both cases was INR 228625 for 22 h, INR 215125 for 20 h and INR 164125 for 16 h. The return per unit of energy generation was obtained in case I of 1.261 INR/kWh for 22 h, 1.01 INR/kWh for 20 h and 0.831 INR/kWh for 16 h. In case II, return per unit of energy generation was obtained 1.887 INR/kWh for 22 h, 1.698 INR/kWh for 20 h and 1.685 for 16 h. The economic return of 0.3 millions USD/year is reported [14]. The reported electricity revenue of biomass based project is about 10.34 €/GJ [16] Levelised replacement cost was considered to be 25 % on maintenance cost.

Table 1: Capital statement and energy production of gasifier system

SN	Particular	Case I	Case II
1	Gasifier power generation capacity (kW)	10	10
2	Total installation cost (INR)	6500000	325000
3	Annual energy generation (kWh)		
	for 22 hour	66000	66000
	for 20 hour	60000	60000
	for 16 hour	48000	48000
4	Annual operation and maintenance cost (including labour & fuel cost in INR)		
	for 22 hour	228625	228625
	for 20 hour	215125	215125
	for 16 hour	164125	164125
5	Cost of electricity (INR/kWh)	6	6
6	Discount rate/annual fixed charge rate (%)	12.75	12.75
7	Project life time (year)	20	20
8	Gross annual income (INR)		
	for 22 hour	396000	396000
	for 20 hour	360000	360000
	for 16 hour	288000	288000
9	Returns (INR/kWh)		
	for 22 hour	1.261	1.887
	for 20 hour	1.01	1.698
	for 16 hour	0.831	1.685
10	LRC (25% on operation & maintenance cost) INR	1625	1625

3.1.1 Cost of Energy Generation (Case I)

The annual energy generation for operating of 22 h, 20 h, and 16 h was 66000 kWh, 60000 kWh and 48000 kWh respectively. The ICC (all equipment) at value of in case I of INR 650000 for 10 kW power generation installed capacity. The specific capital cost of biomass power generation system was calculated for Case I of 22 h, 20 h and 16 h comes to be 9.84, 10.83 and 13.54 INR/kWhyr-1 respectively. Capital cost component was calculated using these specific capital cost and annual fixed charge rate of 12.75 per cent which comes to be 1.25, 1.38 and 1.72 INR/kWh for 22 h, 20 h and 16 h respectively. The interest rate for 50 kWe biomass project is reported as 13 % and 10 % for the useful life of 20 years [14];[17]. Annual operation and maintenance was INR 228625, INR 215125 and INR 164125 for biomass based power generation system and these were 3. 46, 3.59 and 3.42 INR/kWh for 22 h, 20 h and 16 h respectively. The operating cost was reported for biomass project of 4 % to the total installation cost [16]. The cost of levelised replacement were examined by considering 25 per cent of operation and maintenance cost of biomass based gasifier power system, which comes to be 0.0246, 0.0270 and 0.0338 INR/kWh. The potential and cost of energy of biomass have reported by Downing & Robin 1996 [18]. The case study of biomass based power generation is reported by Ravindranath, 2004 [19].

The cost of energy for the biomass based gasifier power generation system is the equal to sum of three component mentioned above, i.e., capital cost component (1.25, 1.38, 1.72 INR/kWh), operation and maintenance cost (3.46, 3.59, 3.42 INR/kWh) and cost of replacement (0.0246, 0.0270, 0.0338 INR/kWh) giving a total of 4.74, 4.10 and 5.10 INR/kWh for 22 h, 20 h and 16 h operation of power generation system respectively. The costs of electricity generation from biomass based project are reported as 0.0 USD/kWh [15], for rice hull as fuel 0.27 Yuan RMB/kWh [20]. The relative effect of these estimated cost values (Table 2; Table 3; Table 4) gives insight into where the overall economics of the system may be impacted. From Table 2; 3 and 4, it is seen that the leading component of cost of bioenergy are of operation and maintenance cost followed by the cost of capital. The operation and maintenance cost in Case I represent 73 %, 72 % and 62 % for 22 h, 20 h and 16 h operation of power generation system respectively. The operation and maintenance cost for 10 % wood co-firing biomass project is reported to be 0.04 p/kWh at which fuel cost is found about 0.16 p/kWh [22]. The replacement cost of the system is in the range of not more than 0.65 % for 22 h, 20 h and 16 h operation of power generation system respectively.

Table 2: Comparison of calculated cost of energy component (22 hours; Case I)

Cost of gasifier energy component	Value (INR/kWh)	Basic of estimate	Percent of total CoE
Capital cost	1.25562	Used FCR=12.75% per year	26.49
Operation & maintenance cost	3.46	Actual incurred	73.01
Levelised Replacement cost	0.0246	25% on the O&M cost	0.51
Total CoE	4.739	Total of all cost	100

Table 3: Comparison of calculated cost of energy component (20 hours; Case I)

Cost of gasifier component	Value (INR/kWh)	Basic of estimate	Percent of total CoE
Capital cost	1.3808	Used FCR=12.75% per year	27.66
Operation & maintenance cost	3.585	Actual incurred	71.81
Levelised replacement cost	0.0270	25% on the O&M cost	0.54
Total CoE	4.992	Total of all cost	100

Table 4: Comparison of calculated cost of energy component (16 hours; Case I)

Cost of gasifier component	Value (INR/kWh)	Basic of estimate	Percent of total CoE
Capital cost	1.726	Used FCR=12.75% per year	33.33
Operation & maintenance cost	3.419	Actual incurred	66.02
Levelised replacement cost	0.0338	25% on the O&M cost	0.65
Total CoE	5.178	Total of all cost	100

3.1.2 Profit Statement of Biomass Power System (Case I)

The system benefit for the overall project has been determined over a year for operation of 22 h, 20 h, and 16 h. The information presented Table 5 shows the profit statement for 10 kW gasifier based power generation system for one year. The profit per unit was worked out to be 1.268 INR/kWh for 22 h, 1.008 INR/kWh for 20 h and 0.822 INR/kWh for 16 h. The gross annual income has been calculated by considering annual energy production and the return on per unit of energy generation. The gross annual income comes to INR 396000, INR 360000 and INR 280000 and the production cost of energy comes to be (INR 4.74 x 66000) INR 312842, (INR 4.99 x 60000) INR 294400 and (INR 5.178 x 48000) INR 248544 giving a profit for the first year of operation (22 h, 20 h and 16 h operating duration per day) as INR 83688, INR 60480, INR 39455. The reported income from selling of electricity from biomass project is 1.66 baht/year [23].

Table 5: Profit per kWh of biomass power generation system for case I

SN	Particular	INR/kWh		
Operation condition		22 h	20 h	16 h
1	a) Capital cost component	1.255	1.3808	1.726
	b) Annual operation and maintenance cost	3.46	3.586	3.419
	c) Levelised replacement cost	0.0246	0.0270	0.0338
	Total cost of energy (a+b+c)	4.732	4.992	5.178
2	Return/unit	6	6	6
3	Net profit	1.268	1.008	0.822

3.1.3 Cost of Energy Generation (Case II)

The annual energy generation for operating of 22 h, 20 h, and 16 h was 66000 kWh, 60000 kWh and 48000 kWh respectively. The ICC (all equipment) at value of INR 325000 for 10 kW power generation installed capacity (case II). The similar case was considered at 40 % subsidy of total cost of project [24]. The specific capital cost of biomass power generation system was calculated for case II of 22 h, 20 h and 16 h which comes to be 4.92, 5.41 and 6.77 INR/kWhyr-1 respectively. Capital cost component were calculated using these specific capital cost and annual fixed charge rate of 12.75 per cent which comes to be 0.63, 0.69 and o.86 INR/kWh for 22 h, 20 h and 16 h respectively. The capital cost for the biomass system has been reported as 1588, 1696, 1371, 1108 and 1350 $/kW [25]. The installed capital cost for wood fired system is reported as $1765/kWe[26]. Besterbroer *et al.,* have reported capital cost of biomass project in range of $5835-$8335 per kWe[27]. Annual operation and maintenance was INR 228625, INR 215125 and INR 164125 for biomass based power generation system and these were 3. 46, 3.59 and 3.42 INR/kWh for 22 h, 20 h and 16 h respectively. The cost of levelised replacement were examined by considering 25 per cent of operation and maintenance cost of biomass based gasifier power system, which comes to be 0.0246, 0.0270 and 0.0338 INR/kWh.

The cost of energy for the biomass based gasifier power generation system is the equal to sum of three component mentioned above, i.e., capital cost component (0.63, 0.69 and 0.86 INR/kWh), operation and maintenance cost (3.46, 3.59, 3.42 INR/kWh) and cost of replacement (0.0246, 0.0270, 0.0338 INR/kWh) giving a total of 4.11, 4.30 and 4.31 INR/kWh for 22 h, 20 h and 16 h operation of power generation system respectively.

The reported cost of electricity generation from biomass for pyrolysis and combustion are 9.40 c/kWh and 10.79 c/kWh respectively [17] and 3.50 $c/kWh for biomass project [21]. The cost of biomass energy for the scenario considered was reported to be Rs. 68, Rs. 51 and Rs. 47 per GJ [28]. The specific capital cost was assessed to be £ 1035/kWe [29]. The relative effect of these estimated cost values (Table 6; Table 7; Table 8) gives insight into where the overall economics of the system may be impacted. From Table 6; 7 and 8, it is seen that the leading component of cost of bioenergy are of operation and maintenance cost followed by the cost of capital. The reported capital per kWh of electricity generation from biomass is 0.28 p/kWh [22]. The operation and maintenance cost in case II represent 84 %, 83 % and 79 % for 22 h, 20 h and 16 h operation of power generation system respectively. The estimated maintenance cost per annum was 1.2 % of the total investment of 0.60$c/kWh [21]. The replacement cost of the system is in the range not more than 0.77 % for 22 h, 20 h and 16 h operation of power generation system respectively.

Table 6: Comparison of calculated cost of energy component (22 hours Case II)

Cost of gasifier component	Value (INR/kWh)	Basic of estimate	Percent of total CoE
Capital cost	0.6278	Used FCR=12.75% per year	15.26
Operation & Maintenance cost	3.46	Actual incurred	84.13
Levelised Replacement cost	0.0246	25% on the O&M cost	0.59
Total CoE	4.1124	Total of all cost	100

Table 7: Comparison of calculated cost of energy component (20 hours Case II)

Cost of gasifier component	Value (INR/kWh)	Basic of estimate	Percent of total CoE
Capital cost	0.690	Used FCR=12.75% per year	16.03
Operation & Maintenance cost	3.585	Actual incurred	83.33
Levelised Replacement cost	0.0270	25% on the O&M cost	0.62
Total CoE	4.302	Total of all cost	100

Table 8: Comparison of calculated cost of energy component (16 hours Case II)

Cost of gasifier component	Value (INR/kWh)	Basic of estimate	Percent of total CoE
Capital cost	0.863	Used FCR=12.75% per year	20
Operation & Maintenance cost	3.419	Actual incurred	79.23
Levelised Replacement cost	0.0338	25% on the O&M cost	0.77
Total CoE	4.315	Total of all cost	100

3.1.4 Profit Statement of Biomass Power System (Case II)

The system benefit for the overall project has been determined over a year for operation of 22 h, 20 h, and 16 h. The information presented Table 9 shows the profit statement for 10 kW gasifier based power generation system for one year having considering 50 per cent financial assistance (subsidy). The profit per unit was worked out to be 1.881 INR/kWh for 22 h, 1.698 INR/kWh for 20 h and 1.685 INR/kWh for 16 h. The gross annual income has been calculated by considering annual energy production and the return on per unit of energy generation. The gross annual income comes to INR 396000, INR 360000 and INR 280000 and the production cost of energy comes to be (INR 4.11 x 66000) INR 271260, (INR 4.30 x 60000) INR 258000 and (INR 4.31 x 48000) INR 206880 giving a profit for the first year of operation (22 h, 20 h and 16 h operating duration per day) as INR 124146, INR 101880, INR 80880. The electricity revenue per kWh is reported as 0.037 € [16].

Table 9: Profit per kWh of biomass power generation system for case II

S.N.	Particular	INR/kWh		
Operation condition		22 h	20 h	16 h
1	a)Capital cost component	0.6278	0.690	0.863
	b) Annual operation and maintenance cost	3.46	3.858	3.419
	c) Levelised replacement cost	0.0123	0.0135	0.0169
	Total cost of energy (a+b+c)	4.1124	4.302	4.315
2	Return/unit	6	6	6
3	Net profit	1.881	1.698	1.685

3.2 Economic Feasibility of Biomass Power Generation System

For initial project appraisal, some form of DCF is normally required.

In economic terms, the discount rate is an indication of the opportunity cost of capital to owner. This cost is the return on the next base investment and if the rate is below it, then it is not worthwhile to invest in the system. In India, at present discount rate of gasifier based power generation system in industrial sector was 12.75 % which would for commercial power generation system reflect the value placed on capital and the perceived level of risks[9];[10]; [14];[22];[24];.

For the cost and the return from biomass power generation system in the above analysis for first year of installation, the time factor was considered. To bring the past and future costs to present, worth corresponding and discounting technique was used with a 12.75 % discount rate. The economic feasibility of gasifier based power generation system was examined by working out the NPV, BCR, IRR, payback period, using operation and maintenance cost for both the cases with gross annual income from the system in one year. For the income calculations, the return per unit was calculated which has been taken as income generation of the system in the project life time (20 years).

The cost of replacement was considered as 25 % on the total maintenance cost of the system. The present worth of benefits used at 12.75 % discount rate for case I give INR 2824138, INR 2567398, and INR 2053919 and for case II give INR 2824138, INR 2567398 and INR 2131132. The present worth of cost used at 12.75 % discount rate for case I give INR 2280476, INR 2184199, and INR 1820484 and for case II give INR 1955476, INR 1859199 and INR 889486.

Table 10: Financial Outlet for Power Generation System

	Economic indicator	Operating condition					
		Case I			Case II		
		22 h	20 h	16 h	22 h	20 h	16 h
1	Present worth of benefit (INR)	2824138	2567398	2053919	2824138	2567398	2131132
2	Present worth of cost (INR)	2280476	2184199	1820484	1955476	1859199	889486
3	Net present value (INR)	587741	412353	266058	912741	746353	559700
4	IRR (%)	26	22	19	52	44	39
5	B/C ratio	1.24	1.18	1.13	1.44	1.38	2.39
6	Payback period (Y,M,D)	3,2,10	3,8,10	4,3,24	1,7,7	1,10,8	2,1,26

3.2.1 Net Present Value(NPV)

The Net present value was found to be positive in both cases. Hence it seems the project is feasible and can be considered for the next parameters determination. The Net present value was found to be INR 266058 for 16 h, INR 412353 for 20 h and INR 587741 for 22 h in case I. The NPV for case II was INR 559700 for 16 h, INR 746353 for 20 h and INR 912741for 22 h. The reported NPV 196960274 Dra at 40 % subsidy [24].

3.2.2 Internal Rate of Return (IRR)

The IRR was found to be positive in both cases. The IRR was found to be 19 % for 16 h, 22 % for 20 h and 26 % for 22 h in case I. For with subsidy (case II) IRR was 39 % for 16 h, 44 % for 20 h and 52 % for 22 h. The reported IRR for biomass project are 44.644 to 44.525 % respectively [24], 30 % [23], 19 % [30] and 51 % [31].

3.2.3 Benefit Cost Ratio(BCR)

The information presented in Table 10 reveals that the benefit cost ratio was positive. The benefit cost ratio was found to be 1.13 for 16 h, 1.18 for 20 h and 1.24 for 22 h for without subsidy case. For with subsidy case benefit cost ratio was observed to be 2.39 for 16 h, 1.38 for 20 h and 1.44 for 22 h. The reported benefit cost ratio for biomass based electricity generation projects are 2.270 to 2.763[24], 1.68 [30].

3.2.4 Pay Back Period

The information presented in Table 10 reveals that the payback period was found to be in the range of 4 years to 1 year for case I and 2 years to 1 year for case II. The discounted payback period reported including subsidy (40 %) is 2.905-2.914 years. The assessed payback period is reported 7 years [30] and 2.28 years [31].

4. Conclusion

Biomass power generation cost was determined in term of INR/kWh. A simple technique was used in finding the cost of energy generation from biomass. The costs of biomass energy include the three costs namely installation cost, specific capital cost and the cost of energy generation. In cost of energy generation from the biomass sources, operation and maintenance cost is the leading cost component that the installation cost.

For both the cases operation and maintenance cost was observed in the range of 66 -73 % (Case I) and 79-84 % (case II) in energy generation. The costs of energy generation have varied with the burden of capital taking in to consideration for analysis. The cost of energy generation was observed to be less in case II as compared to case I which similarly affected on the profit of the system.

The economic feasibility of the biomass power generation system was determined over the life of the system. The results obtained from this method indicate that the implementation of the system is feasible for both the cases with an acceptable NPV. The IRR in the both cases was more than the discount rate considered for the system. The payback period of the power generation system for case I was in the range of first 1-4 years of operation and for case II was in the range of 1-2 years of operation. The benefit cost ratio was found out by considering present worth of cost and present worth of benefit which is more in case II for operating condition of 16 hours of 2.39.

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