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Studies on Biomass Based Power Generation System Using *Prosopis julifloa* and *Leucaena leucocephala*

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ABSTRACT: *Biomass based power generation having power rating of 10 kW was installed at Department of Unconventional Energy Sources and Ele. Engg. College of Agril. Engineering, Dr. PDKV, Akola. Thermo gram of Leucaena leucocephala (Subabool) and Prosopis juliflora (Vilaytee babool) are found better for getting sufficient amount of tar in case of gasification of this material. The quantum of lighter volatile for Leucaena leucocephala, and Prosopis juliflora ranges from 55 and 52 per cent, respectively. Heavier volatile for Leucaena leucocephala and Prosopis juliflora during gasification range from 15 and 17%, respectively. However, on the basis of TGA analysis biomaterial can be gasified effectively. The concept of energy from biomass through gasification is picking up commercially also and many industries are coming forward to install these system. High bulk density and volatile matter as well as low moisture and ash content in the fuel are advantageous for gasification process. While high moisture content and high ash content lower heating value of fuel and affect gasification process. For efficient gasification of woody biomass for power generation system rated rpm 2800 rpm was found suitable for gasification process. Both the woody biomass gave maximum gas flow rate, gasifier efficiency and power factor at 2800 rpm at full load condition of power generation system.Leucaena leucocephala gave maximum gas flow, maximum efficiency and maximum power factor as 49.80 m^3/h, 71.7, and 0.81, respectively at 2800 rpm, at full load condition. Prosopis juliflora gave maximum gas flow as 51.80 m^3/h, maximum efficiency 73.51 per cent and power factor as 0.83, respectively at 2800 rpm, at full load condition.The system performance was found better for Leucaena leucocephala and Prosopis juliflora at full load (9 kW). Further increase or decreased in std. rpm of 2800 in rpm adversely affected the performance of the system. Economic indicators in terms of net present worth benefit cost ratio and pay back period for 11 kVA power generation system was determined. Operating hour of the system was taken as 12 and 16 hour per day.*

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The system was found economically feasible for 12 and 16 hours of operation considering Government subsidy and without Government subsidy. Net present worth for 12 and 16 hour was Rs 307950.95 and Rs 571696.39, respectively with subsidy. Similarly without Government subsidy net present worth for 12 and 16 hour was Rs 197950.95 and Rs785382.08, respectively. The benefit cost ratio for with subsidy for both operated hour was 1.20 and 1.30, respectively. Similarly without Government subsidy for both operated hour was 1.12 and 1.47, respectively. It is concluded from economic analysis that system is economical feasible for both cases.

Key words: *Producer gas, woody biomass, gasification, pyrolysis, Thermo- gravimetric Analysis, net present worth, payback period, subsidy.*

I. INTRODUCTION

The continuous growth of global energy consumption raises urgent problems related to energy availability, safe operation and its efficiency. The larger part of mineral oil and gas reserves energy supply is located within a small group of countries, forming a vulnerable energy supply. Moreover, this supply is expected to reach its limits. On the other side, the use of fossil fuels causes numerous environmental problems, such as local air pollution and greenhouse gases (GHGs) emission (Carlo et al., 2005).A possible way to deal with these problems is the development of cleaner and renewable energy sources. Modern use of biomass is an interesting option, because biomass is worldwide available, it can be used for power generation and biofuels production, and it may be produced and consumed on a CO_2-neutral basis (Hall et al., 1993; Rogner, 1999; Turkenburg, 2000).

Biomass is used since millennia for meeting myriad human needs including energy. Main sources of biomass energy are trees, crops and animal waste. Until the middle of 19th century, biomass dominated the global energy supply with as seventy percent share (Grubler and Nakicenovic, 1988). Biomass gasification is the process of converting solid into combustible gases; it is a thermo-chemical process in which the fuel gas is formed due to the partial combustion of biomass (Tripathia et al., 1999; Pletka, 2001; Dasappa et al., 2003). This technology was developed around 1920 and played an important role in generating motives power till other fuels made their appearance (Rathore et al., 2007). The use of biomass as an energy source has high economic viability, large potential and various social and environmental benefits.

(Ravindranath, 2004). Inexpensive materials such as forest residue, wood residue, and rice straw are few potential feed stocks for biomass gasification. However, the cellulose, hemicelluloses and lignin composition of these materials may differ significantly (Minowa et al., 1998).

A wood based gasifier engine system was procured and installed at Department of Unconventional Energy Sources and Ele. Engg., College of Agricultural Engineering, Dr. PDKV, Akola. The project was undertaken for testing and evaluate performance of downdraft gasifier for power generation using different woody biomass.

Description of Power Plant

The biomass-based power plant is of 10 kW rated capacity and the system consists of a gasifier, water scrubber filters and gas engine coupled with AC Generator. The details of the system are given in Table 1 and Fig 1.

Table 1. Technical specification of 11 kVA power generation system

Gasifier	
Model	WBG-20 in scrubbed, clean gas mode
Mode	Gas Power Pack Model GAS-11 giving a gross output
Gasifier types	Downdraft
Gas flow	50 NM3/hr
Fuel Storage capacity	150 kg
Fuel type & size	Woody fuel with maximum dimension not exceeding 25 mm
Typical gas composition	CO - 19+3% H2 – 18+ 2% CO2 – 10+3% CH4 – up to 3% N2 – 50%
Engine system	
Description	Twin cylinder , 1500 RPM, 20 HP/12 KW , 2.6 Amp, 12 Volts, Water cooled.
Electric Generator	
Description	Directly coupled to engine, 1500 rpm, 415 V, 3-phase , 15 kVA Alternator.

II. GASIFIER: The gasifier is downdraft type and the ash is removed through ash collection pit. The gasifier outlet is connected with ventury water scrubber. In a ventury negative pressure is created through which producer gas is supplied to burner for starting of gasifier.(ii) **Cooling and cleaning system**: The gas produced from gasifier is passed through a cooling & cleaning system consisting of a ventury, one course filter, and one security filter. The gas coming out from the gasifier is cooled in a ventury scrubber. The cooled gases received after ventury scrubber was further sent through the fine filter. The fine filter is filled with sawdust in which the tar is further removed and the gas is sent to security filter. The security filter is fitted with fabric cloth. The gases are passed through fabric cloth to arrest the remaining dust particles present in the producer gas. The cleaned gases are supplied to SI Engine coupled with AC Generator.

Engine: The producer gas engine coupled with gasifier is spark ignition water cooled engine having 1500 RPM, 20 HP/12 kW, two cylinders. The carburetor has been fitted to regulate mixing of producer gas and air for smooth running of the engine at different load. Gas engine : The gasifier efficiency was calculated by following formula,

$$\text{Gasifier efficiency } (n_g) = \frac{Hg \times Qg}{Hs \times Ms} \times 100$$

Where,

Hg = Heating value of gas, kJ/ m^3

Qg = Volume flow of gas, m^3/s

Hs = Heating value of solid fuel, kJ/ kg
Ms = Gasifier solid fuel consumption, kg/s

AC generator: The AC Generator is of three phase operating at 1500 rated rpm, 415 V, 3 Phase. The rating of AC generator is 15 kVA at 50 Hz. The generator has self-regulated exciter including battery charger DC output at 12 V.

Economic analysis

For the success and commercialization of any technology, it is essential to know whether the technology is economically viable or not. Therefore, an attempt was made to evaluate economics of 11kVA power generation unit working on groundnut shell pellets and mixture of groundnut shell pellets and woody biomass. Economics analysis of the system was carried out by employing economic indicators as,

i) Net present worth
ii) Benefit-Cost ratio
iii) Payback period

The following parameters were considered to carry out economic analysis of gasifier system.

i) The life of biomass gasifier system was considered as 20 years.
ii) Repair and maintenance cost at 20 per cent of initial investment spread over 20 years.
iii) Discount rate for the system was assumed 10 per cent.
iv) The labour cost was taken @ Rs 100/day
v) The cost of groundnut shell pellet and woody biomass (for1:1 proportion) were Rs 2.5/kg and Rs 1.5/kg, respectively. Thus average fuel cost was Rs 2/kg
vi) The annual operating days of the system was 300 days.
vii) System was operated for 12 hour per day as per requirement
viii) Sale price of electricity was Rs 6/ kW-h.

Net present worth (NPW)

The difference between the present value of all returns and the present money required to make an investment is the net present worth or net present principals for the investment. The present value of the future returns was calculated through the use of discounting. Discounting essentially a technique by which future benefits and cost streams can be converted to their present worth (Rathore et al., 2009; Sharma and Panwar, 2009). The mathematical statement for net present worth can be written as:

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

Where

If NPW > 0 Investment is worthwhile
NPW < 0 Investment is not worthwhile
NPW = 0 Neutral case.

Benefit cost ratio

This is the ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. The formal selection criteria for project worth is to accept projects for a benefit cost ratio of one or greater. Mathematical benefit-cost ratio can be expressed as:

$$\textbf{B-C ratio} = \frac{\sum_{t=1}^{N} \frac{R_t}{(1+i)^t}}{\sum_{t=1}^{N} \frac{C_t}{(1+i)^t}}$$

The decision criteria are
If B-C > 1 Investment is worthwhile
B-C < 1 Investment is not worthwhile
B-C = 1 Neutral case.

Payback period

The pay back period is the length of time from the beginning of the project until the net value of the incremental production stream reaches the total amount of the capital investment. It shows the length of time between cumulative net cash outflow recovered in the form of yearly net cash inflow. Mathematically it can be expressed as

$$P = \frac{I}{C}$$

1. Thermo gravimetric analysis

Thermo gravimetric analyzer is used for determination of gasification related properties of biomass such as volatile, fixed carbon and ash content. Thermo gravimetric Analysis or TGA is a type of testing that is performed on samples to determine changes in weight in relation to change in temperature. Such analysis relies on a high degree of precision in three measurements: weight, time and temperature range. TGA is commonly employed in research and testing to determine characteristics of material such as polymers, to determine degradation temperatures, absorbed moisture content of materials, the level of inorganic and organic compounds in material, decomposition points of explosives and solvent residues. The analyzer usually consists of a high-precision balance with a pan (generally platinum) loaded with the sample of *Leucaena leucocephala* (Subabool), *Prosopis julilflora* (Vilayatee babool) weighted 0.25 g, each. The pan is placed in a small electrically heated oven with a thermocouple to accurately measure the temperature. The atmosphere may be purged with an inert gas to prevent oxidation or other undesired reactions. A computer is used to control the instrument. Thermo gravimetric analysis of the biomass samples were carried out at Power and Energy Division, Central Institute of Agricultural Engineering, Bhopal (M.P.).

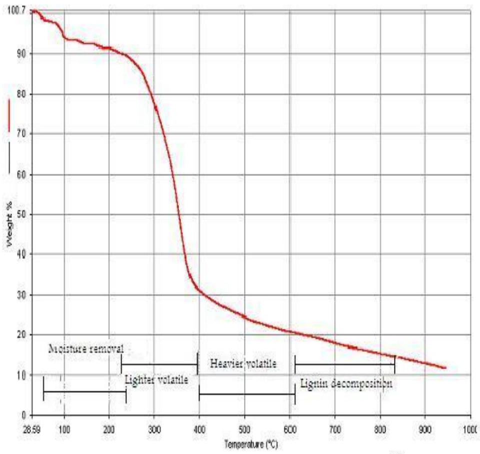

Fig 2. Thermo gram of Subabool at a rate of 10 ^{0}C/min

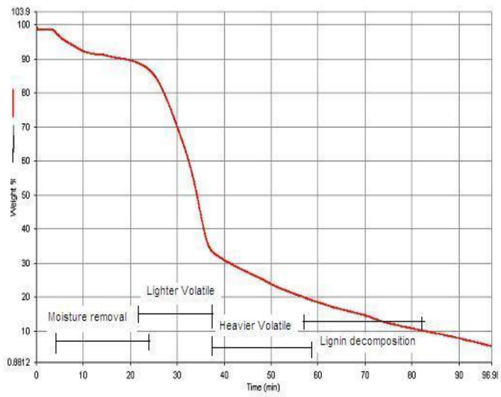

Fig. 5 Loss in weight with respect to time for Prosopis Juliflora at HR 10 ^{0}C/min

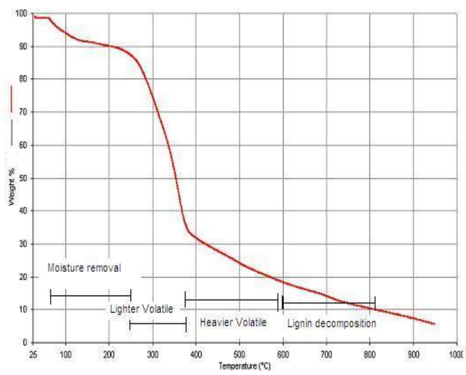

Fig 4.Thermo gram of prosopis Juliflora at a rate of 10 ^{0}C/min

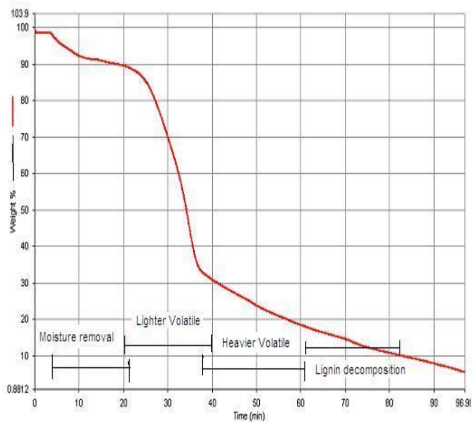

Fig. 3 Loss in weight with respect to time for Subabool at HR 10 ^{0}C/min

III. PERFORMANCE OF 11 KVA BIOMASS BASED POWER GENERATION SYSTEM

Performance of 11 kVA producer gas power generation system was evaluated by using *Leucaena leucocephala (*subabool) and *Prosopis juliflora (Vilaytee babool)* wood.

Effect of scrubber pump speed on performance of the system

Initially the system was operated using *Leucaena leucocephala* as a fuel for power generation through gasification shows effect of speed of scrubber pump on gasification of *Leucaena leucocephala* i.e., on gas flow rate and gasifier efficiency. It is that the gas flow rate increased with increase in speed of scrubber pump at 2800 rpm and gas flow rate was 45.97 m^3/h and at 2900 rpm it went down slightly up to 43.62 m^3/h. It was found that at 2900 rpm gas flow was increased due to increasing water flow. After visual inspection of fine filter, it was observed that more tar and ash accumulated on filter media and thus affected the quality of gas, at 2900 rpm. Due to increase in speed, gas also contained more moisture. When the system was continuously operated at 2900 rpm, fine filter blocked and not worked properly. Gas flow rate was found maximum at 2800 rpm, which comes to (45.97 m^3/h), and minimum at 2700 rpm (41.02 m^3/h). It was observed that gasifier efficiency was found more at scrubber pump speed of 2800 rpm (70.60 per cent) and at 2900 rpm it suddenly went down to 70.33 per cent. However, it was found minimum i.e. 68.53 per cent at 2700 rpm of scrubber pump. The power factor was found maximum at 2800 rpm as 0.66, However, as rpm changed to 2700 it declined to 0.60. It is revealed from that the biomass consumption and specific biomass consumption at 2700, 2800 and 2900 rpm were found to be 13.6, 14.8 and 14.1 kg per hour and 3.02, 3.29 and 3.13 kg/kWh, respectively. It was observed that as the scrubber pump speed increased, the biomass consumption also increased up to 2800 rpm and it decreased at 2900 rpm, correspondingly the specific biomass consumption decreased.

Table 2. Effect of Scrubber pump speed on 11 KVA power generation unit at 4.5 kW load

Scrubber pump (RPM)	**GF**	**SGR**	**GE**	**BC**	**SBC**	**PF_{Th}**	**PF_{act}**
Leucaena leucocephala (Subabool)							
2700	41.02	9.12	68.53	13.6	3.02	0.64	0.60
2800	45.97	10.22	70.6	14.8	3.29	0.69	0.66
2900	43.62	9.69	70.33	14.1	3.13	0.67	0.64
Prosopis juliflora (Vilaytee babool)							
2700	43.3	9.62	70.96	13.2	2.93	0.63	0.60
2800	46.6	10.36	71.40	13.8	3.06	0.70	0.68
2900	42.9	9.53	70.31	12.9	2.87	0.63	0.61

Where,
GF = Gas flow rate, m^3/h
SGR = Specific gas flow rate, m^3/kW-h
GF = Gasifier efficiency, %
BC = Biomass consumption, kg/h
SBC = Specific biomass consumption, kg/kW-h
PF_{Th} = Power factor, theoretical
PF_{act} = Power factor, actual

It is revealed from Table 2 that at maximum scrubber pump rpm of 2800; gasifier efficiency, gas flow rate, observed power factor and theoretical power factor was found maximum. Thus, *Leucaena leucocephala* was observed to be gasified efficiently at 2800 rpm.

The system was further evaluated by using *Prosopis juliflora* as fuel in 11 kVA power generation system. At *2700*, 2800 and 2900 rpm, the gas flow rate and gasifier efficiency were found to be 43.30, 46.6, 42.9 m^3/h and 70.96, 71.40 and 70.31 per cent, respectively It was observed that the gas flow rate and gasifier efficiency were found maximum at rated rpm of 2800. The biomass consumption and specific biomass consumption at 2700, 2800 and 2900 rpm were found to be 13.2, 13.8, 12.9 kg/h and 2.93, 3.06 and 2.87 kg/kWh, respectively. It was observed that biomass consumption and specific biomass consumption increased with the increase in speed. From Table 2 it was observed that gas flow rate, gasifier efficiency, observed and theoretical power factor and actual power factor were maximum at rated rpm of 2800. Thus at scrubber pump rpm of 2800, *Prosopis juliflora* was gasified efficiently.

During the first test run at scrubber pump speed of 2700, 2800 and 2900 rpm, the gas flow rate, gasifier efficiency and power factor was found maximum at 2800 rpm, for *Leucaena leucocephala* and *Prosopis juliflora*. Therefore, in second phase of experiment performance of the system was evaluated by varying load from 0-9 kW rated speed of scrubber pump (2800 rpm).

Effect of load on performance of the system

During the test run *Leucaena leucocephala* and *Prosopis juliflora* were tested at different load varying from 0 to 9.0 kW. All the tests were replicated and average values were taken and summarized in table 3.

When *Leucaena leucocephala* was used for gasification at varying load of 0, 3.0, 4.5, 6.0 and 9.0 kW, the corresponding gas flow rate and gasifier efficiency were found to be 41.1, 43.6, 46.0, 47.9, 49.8 (m^3/h) and 68.53, 70.33, 70.61, 71.54, 71.70 per cent, respectively. It is observed that maximum gas flow rate and efficiency was found at 9.0 kW load. The theoretical and actual power factor was found to be 0.66, 0.69, 0.70, 0.81 and 0.61, 0.66, 0.67. 0.80 at 3, 4.5, 6.0 and 9.0 kW load, respectively. Theoretical and actual power factor were found to be maximum i.e., 0.81 and 0.80, respectively at 9.0 kW load. Thus, at 9.0 kW load maximum power was obtained by using *Leucaena leucocephala* as fuel. Since the system was designed for 10 kW maximum outputs therefore, power factor was improving by increasing in load.

Biomass consumption and specific biomass consumption for *Leucaena leucocephala* operated at 0, 3.0, 4.5, 6.0 9.0 kW load were found to be 13.6, 14.1, 14.8, 15.2, 15.8 kg/h and 0, 4.7, 3.29, 2.53, 1.76 kg/kW-h, respectively. It is observed that with the increase in load biomass consumption also increased correspondingly specific biomass consumption decreased.

The performance of system was evaluated at varying load condition by using *Prosopis juliflora*. The gas flow rate and gasifier efficiency were found to be 42.9, 44.3, 46.6, 48.7, 51.8 m^3/h and 70.32, 70.36, 71.4, 72.01, 73.51 per cent at 0, 3.0 4.5 6.0 and 9.0 kW load, respectively (Table 3). It is revealed that with the increase in load, gas flow rate and gasifier efficiency increased. When the system was operated at full load, it gave maximum efficiency as 73.51 per cent and maximum gas flow rate 51.8 m^3/h. Theoretical and actual power factor of the system were found to be 0.68, 0.7, 0.72, 0.83 and 0.65, 0.69, 0.70, 0.82 at 3.0, 4.5, 6.0 and 9.0 kW load respectively. It is observed that as the load increased theoretical as well as actual power factor improved and it was found maximum as 0.83 and 0.82 at full load, respectively.

Biomass consumption and specific biomass consumption were found to be 12.9, 13.2, 13.8, 14.3, 14.9 kg/h and 0, 4.4, 3.07, 2.38, 1.66 kg/kW-h at 0, 3.0, 4.5, 6.0, and 9.0 kW load, respectively. It is observed from Table 4, that biomass consumption increased with increase in load. However, specific biomass consumption decreased with increase in load. Biomass consumption was found maximum as 14.9 kg/h at 9.0 kW load. It is concluded from the Table 4 that when *Leucaena leucocephala* was used as a fuel in the system at 9.0 kW load and scrubber pump operated at 2800 rpm, performance of the system was improved in terms of gas flow rate, gasifier efficiency and power factor.

Performance of the system using *Prosopis juliflora* was found maximum at 9 kW load and Scrubber pump was operated at 2800 rpm. Power factor of the system for both the fuel was improved at the electrical output of 9 kW. Thus, *Leucaena leucocephala* and *Prosopis juliflora* gasified well and gave better performance scrubber pump, speed of 2800 rpm.

Table 4. Effect of Load on 11 KVA power generation Unit

Fuel	Load (kW)	BC	SBC	GF	SGR	Temp. of Water		Temp of Exhaust	Ash obtain (kg)	GE	PF act	PF th
						T_i	T_f	T_e				
LL	0.0	13.6	--	41.1	--	33.7	42.2	130.6	0.95	68.53	--	--
	3.0	14.1	4.7	43.6	14.5	33.4	42.3	145.4	0.99	70.33	0.61	0.66
	4.5	14.8	3.29	46.0	10.2	33.2	43.4	178.3	1.04	70.61	0.66	0.69
	6.0	15.2	2.53	47.9	07.9	34.3	44.9	198.6	1.06	71.54	0.67	0.70
	9.0	15.8	1.76	49.8	05.5	34.8	46.9	218.4	0.95	71.70	0.80	0.81
PJ	0.0	12.9	--	42.9	--	34.4	40.6	138.2	0.77	70.32	--	--
	3.0	13.2	4.4	44.3	14.8	35.3	41.8	167.4	0.79	70.36	0.65	0.68
	4.5	13.8	3.07	46.6	10.4	36.2	43.7	223.6	0.83	71.40	0.69	0.70
	6.0	14.3	2.38	48.7	08.1	35.1	45.3	232.7	0.86	72.01	0.70	0.72
	9.0	14.9	1.66	51.8	05.8	35.6	47.3	248.9	0.82	73.51	0.82	0.83

Where,

LL= *Leucaena Leucocephala,* P = *Prosopis juliflora*, BC= Biomass consumption
SB = Specific biomass consumption, GF= Gas flow rate, SGR= Specific Gas flow rate
T_i= Initial Temp. of water, T_f = Final Temp of water (After gas cleaning)
T_e= Temp of Exhaust at silencer, GE= Gasifier efficiency, PF= Power factor

Pressure drop variation in the system for *Leucaena leucocephala* and *Prosopis juliflora* fuels : During the test run pressure drop variation in the system was found negligible. The pressure in the fabric and fine filter was not changed during the test run. When *Leucaena leucocephala* was used as a fuel in gasifier pressure drop across gasifier increased from 35.4 to 41.6 mm of water column. Nozzle pressure increased from 16.2 to 18.3 mm of water column**.** Pressure drop in fine filter increased from 10.1 to 11.2 mm of water column. And pressure drop across safety filter increased from 3.6 to 4.3 mm of water column.Similarly, Pressure drop for *Prosopis juliflora* across gasifier was increased from 36.2 to 40.8 mm of water column. Pressure drop across nozzle also increased from 13.6 to 19.1 mm of water column**.** Similarly, pressure drop across fine filter was found increased from 10.1 to 11.8 mm of water column. And across safety filter pressure drop was increased from 3.7 to 4.2 mm of water column.

Effect of load on frequency with respect to time

When the system was operated by using *Leucaena leucocephala* as a feed material and operated for 1, 2, 3, 4 and 5 h, frequency were found to be 51.2, 50.8, 50.5, 50.3, and 50.1 Hz. for the load 0, 3.0, 4.5, 6.0 and 9.0 kW, respectively. It is revealed that as the load increased, frequency of the system decreased. The standard frequency of 50 $\pm$ 1.5 Hz is required for operating the electrical appliances. At varying load condition, the system performed well and gave frequency within acceptable limit.

Similarly, for *Prosopis juliflora,* system was operated for 1, 2, 3, 4 and 5 h and frequency were found to be 50.9, 50.7, 50.4, 50.2, and 50.0 for the load 0, 3.0, 4.5, 6.0 and 9.0 kW, respectively. Similar trend of frequency was observed in Fig. 5.19 when system was operated on *Prosopis juliflora.*

Table 5. Performance of the 11 kVA power generation system

S. N.	Particular	Parameter (Value)
1	Max. power generated	10 kW
2	Biomass consumption	12.9 - 15.8 kg/h
3	Specific biomass consumption	1.64 kg/kW-h
4	Tar content at outlet	198 mg/Nm^3
5	Tar content after cleaning	12 mg/Nm^3
6	Exhaust gas temperature	130.6 - 248.9 ^{0}C
7	Overall efficiency of the system	16.04 %

Overall performance of the system is depicted in Table 5. It is revealed that at varying load condition, biomass consumption was found in the range of 12.9 - 15.8 kg/h, where as specific biomass consumption was found to be 1.64 kg/kWh. Tar content in producer gas before filtering was found to be 198 mg/Nm^3. After cleaning, tar content was found 12 mg/Nm^3 acceptable limit for electricity generation using 100 per cent producer gas based engine, the acceptable limit of tar content is less than 50 mg/ Nm^3. Thus it is found that the gas cleaning unit operated efficiently. The overall system efficiency of generating the electricity from biomass was 16.04 per cent at maximum load of 9.0 kW.

Economics of gasifier system

Economics of 11 kVA power generation system was examined by computing net present value, benefit cost ratio and pay back period. Capital statement of 11 kVA power generation unit is given in Table 6.

Table 6. Capital Statement for 11 kVA downdraft gasifier

Sr. No.	Particular	Parameter
1	Power (kW)	10
2	Installation cost (Rs)	6,50,000
3	Subsidy (Rs)	1,10,000
4	Net Installation cost (Rs)	5,50,000
5	Project lifetime (years)	20
6	Sale price of electricity (Rs/kW-h)	6
7	Annual interest rate (%)	10

The economics of the system was evaluated for 12h and 16h of operation. The economic analysis was carried out for considering subsidy and without subsidy on initial investment. To bring the past and future cost to present, discounted cash flow was determined with a 10 per cent discount rate.

Net present worth

Net present worth for 11 kVA power generation system is presented in Table 5.7. When the system was operated for 12 and 16 hours per day, net present worth calculated by considering subsidy on initial investment was found to be Rs 307950.95 and Rs 571696.39. When the system was operated for 12 and 16 hours per day, net present worth determined by without subsidy was found to be Rs 197950.95 and Rs 785382.08, respectively. Thus, the project was feasible for operating on 12 and 16 hours operations with the Government subsidy. Also, it found feasible without the Government subsidy for both 12 and 16 hours of operation per day.

Table 7. Economic indicators for 11 kVA producer gas based power generation system

Particular	12 h		16 h	
	With subsidy	Without subsidy	With subsidy	Without subsidy
NPW(Rs)	307950.95	197950.95	571696.39	785382.08
B-C ratio	1.20	1.12	1.30	1.47
Payback period	1101 days	1466 days	787 days	1293 days
cost of operation (Rs/h)	32.33	40.97	36.12	36.35
Cost of electricity Gen. (Rs/kW)	3.38	4.27	3.72	3.77

IV. BENEFIT-COST RATIO

The B-C ratio of the system was found out by taking ratio of present worth of benefit and present worth of cost. Table 5.7 revealed benefit cost ratio of the system operated for 12 and 16 hour per day. It was found that benefit cost ratio for the system operated for 12 and 16 hour per day operation with considering the subsidy and without subsidy were 1.20, 1.30 and 1.12, 1.47, respectively. Thus, it is concluded from Table 5.7 that the investment is justified and the project is economically feasible (viable) considering Government subsidy and without Government subsidy.

Payback period

Payback period discriminates whether the project is feasible or not for the threshold lifetime. The net cash flow was calculated by deducting yearly operating costs from the gross annual income of the gasifier system. The cumulative net cash flow was then calculated for different years. For the system operating 12 hour per day and 16 hour per day with government subsidy, the payback period was worked out to be 1101 days for 12 hour per day and 787 days for it 16 hour per day, operation. Similarly for the system operated 12 hour per day and 16 hour per day without Government subsidy, the payback period was worked out to be 1466 days for 12 hour per day and 1293 days for 16 hour per day, operation.

V. COST OF OPERATION

Cost of operation of system was calculated by using eq^n no. (4.12). Table 5.7 revealed cost of operation of system operated for 12 and 16 hours per day, considering with Government subsidy and without Government subsidy. It was found that cost of operation with Government subsidy and without Government subsidy were Rs 32.33, 36.12 and 40.97, 36.35, respectively.

VI. COST OF ELECTRICITY GENERATION

Cost of electricity generation of system was calculated by using eq^n no. (4.13). Table 5.7 revealed cost of electricity generation of system operated for 12 and 16 hours per day, considering with government subsidy and without government subsidy. It was found that cost of electricity generation with government subsidy and without government subsidy were Rs 3.38, 3.72 and 4.27, 3.77, respectively.

VII. CONCLUSIONS

Biomass based power generation having power rating of 10 kW was installed at Department of Unconventional Energy Sources and Ele. Engg. College of Agril. Engineering, Dr. PDKV, Akola. Thermogram of *Leucaena* *leucocephala* (Subabool) and *Prosopis juliflora* (Vilaytee babool) are found better for getting sufficient amount of tar in case of gasification of this material. The quantum of lighter volatile for *Leucaena leucocephala*, and *Prosopis juliflora* ranges from 55 and 52 per cent, respectively. Heavier volatile for *Leucaena leucocephala* and *Prosopis juliflora* during gasification range from 15 and 17%, respectively. However, on the basis of TGA analysis biomaterial can be gasified effectively. The concept of energy from biomass through gasification is picking up commercially also and many industries are coming forward to install these system. High bulk density and volatile matter as well as low moisture and ash content in the fuel are advantageous for gasification process. While high moisture content and high ash content lower heating value of fuel and affect gasification process. For efficient gasification of woody biomass for power generation system rated rpm 2800 rpm was found suitable for gasification process. Both the woody biomass gave maximum gas flow rate, gasifier efficiency and power factor at 2800 rpm at full load condition of power generation system.*Leucaena leucocephala* gave maximum gas flow, maximum efficiency and maximum power factor as 49.80 m^3/h, 71.7, and 0.81, respectively at 2800 rpm, at full load condition. *Prosopis juliflora* gave maximum gas flow as 51.80 m^3/h, maximum efficiency 73.51 per cent and power factor as 0.83, respectively at 2800 rpm, at full load condition.The system performance was found better for *Leucaena leucocephala* and *Prosopis juliflora* at full load (9 kW). Further increase or decreased in std. rpm of 2800 in rpm adversely affected the performance of the system.

Economic indicators in terms of net present worth benefit cost ratio and pay back period for 11 kVA power generation system was determined. Operating hour of the system was taken as 12 and 16 hour per day. The system was found economically feasible for 12 and 16 hours of operation considering Government subsidy and without Government subsidy. Net present worth for 12 and 16 hour was Rs 307950.95 and Rs 571696.39, respectively with subsidy. Similarly without Government subsidy net present worth for 12 and 16 hour was Rs 197950.95 and Rs785382.08, respectively. The benefit cost ratio for with subsidy for both operated hour was 1.20 and 1.30, respectively. Similarly without Government subsidy for both operated hour was 1.12 and 1.47, respectively. It is concluded from economic analysis that system is economical feasible for both cases.

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