Analyzing Performance for Generating Power with Renewable Energy Source using Rice Husk as an Alternate Fuel

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Abstract
Energy demand is increasing continuously due to sharp growth in population and industrial development. The development and installation of energy sources are not keeping pace with spiraling demand of energy. Although energy production has increased manifold but still there is big gap between production and demand. The major energy demand is met by conventional energy sources like coal, petroleum, diesel, and natural gas etc. This causes depletion of fossil fuel reserve and environmental pollution.
The use of fossil fuel not only causes environmental impact but also energy security problem. Energy from biomass is renewable energy, being looked at as an alternative of fossil fuel. One of the biomass energy sources is rice husk, which is a very promising renewable energy source as it is indigenous and has environmental benefits. However, the environmental and financial profiles of the electricity generation from biomass must be assessed to ensure reduction in greenhouse gas emission and positive cash flow. Environmental impact potential from rice husk is generally lesser than fossil fuel plants. A dual fuel diesel engine-generation of 800 kW, using rice husk gasifier, is considered for the analysis purpose.
Keywords: Renewable energy, Rice husk, Gasification, Dual fuel generation, Energy model, GHG (Green House Gas) emission.

Introduction

Biomass is one the most important energy sources amongst renewable energies. It is third among the primary energy sources after coal and oil [1]. In India, rice is a major cereal which is nearly 40 percent of total food grain cultivated, and cropped in over 30 percent of its area. India's share in world rice production is nearly 21 percent. Rice hull/husk and rice bran are by-products when its edible form of paddy is processed. Rice bran is used for oil extraction and in feed formulations, whereas husk is generally used as fuel to generate heat for parboiling of paddy and in other applications. The use of husk in industries involves difficult handling and bulky transportation because of its low density of 112-44 Kg/m^3 [2]. Onsite use of rice husk in industries may be achieved to avoid transportation and carriage as average husk production from rice mills is 187 kg/ton [3]. Techniques of conversion of husk into electricity and heat energy at relatively higher efficiencies are available.
The potential of biomass is well known to meet the global energy demand. Foreign exchange on import of fossil fuel and conservation of limited supply of fossil fuel widely depend upon utilization of all other indigenous fuel energy sources. Therefore, biomass has become an alternate energy source for developing countries like India, where economy is based on agriculture and forestry. Biochemical and thermo-chemical processes are used to extract energy from the biomass. Biochemical process is used for bio-methanization of biomass whereas thermo-chemical process involves combustion, pyrolysis and gasification. Researchers and entrepreneurs are taking keen interest in generation of energy by biomass [4]. In USA, according to Department of Electricity, electricity generation from biomass accounts for the largest source of nonhydroelectric renewable generation. It is expected that by the year 2025, biomass will continue its dominant role of electricity generation and electric capacity addition among renewable energy sources [5]. Indian Railways has already started using biomass in the form of biodiesel in its engines and is aiming to replace up to 10 percent of its diesel with biodiesel [6]. In northern China, a 'four in one' model of biogas is successfully developed in households. It typically includes: a greenhouse in the courtyard; a piggery and a toilet beside the greenhouse; and a biogas digester below the piggery and toilet. Then the four components – greenhouse, piggery, toilet and biogas digester – constitute a 'Four in one' model [7].
The output of gasifier is a combustible gas, which may be burnt in a burner for the purpose of saving fossil fuels like fuel oil, light diesel oil, high speed diesel etc. In this study an attempt is made to evaluate the viability of saving fossil fuel, economical production of energy using rice husk biomass in dual fuel diesel engine-generator for onsite energy requirement, to reduce green house gas (GHG) emission, and to judge financial feasibility. For this purpose Ret Screen software is used to make energy model of the project.

Biomass Gasification

Biomass gasification is basically conversion of solid fuels - like wood, wood-waste, agricultural waste, rice husk, and rice straw etc. - into a combustible gas mixture called producer gas. The process, called pyrolysis, involves partial combustion of biomass materials when there is short supply of oxygen than what it is sufficient for complete combustion.

A chemical reactor is used as gasifier in which various complex physical and chemical reactions are carried out. Biomass materials are allowed to pass through different processes, in the order, namely drying of the biomass, pyrolysis, combustion, and reduction. There is significant overlap between any two consecutive processes, though each section/zone is designed for a particular process where chemical and thermal reactions take place. The biomass, to be converted into producer gas, must pass through all the zones.

Gasification or pyrolysis is highly efficient process – the efficiency ranging from 70 percent to 85 percent. The process can be applied to over a range of 5 kWe to 850 kWe, which may be used for generating power and thermal applications in oven, furnace, kiln, hot air generator, dryer, boiler etc.

Depending upon degree of cleanliness, a gasifier can work in three modes namely hot gas mode, scrubbed mode, and ultra clean mode. In hot gas mode, the gas is neither cooled nor cleaned before burning, whereas in case of scrubbed mode gas is made to clean and cool. In case of ultra clean mode, the gas is further cleaned to a very high degree in a series of filters after coming from scrubber. In any one of the modes of application, one liter of oil can be saved through the use of either 5.5 kg of rice husk approximately or 3.5 to 4 kg of wood [8].

Availability of Rice Husk

In India, paddy is cultivated in all the states, particularly Andhra Pradesh, West Bengal, Uttar Pradesh, Punjab, and Bihar are leading states. Form these states, total production of paddy is nearly 50 percent of entire India. Approximately 92-94 percent of gross cropped area is used to crop 86-90 percent of gross production of paddy during July-October (Kharif season). Average productivity of paddy in November-April (Rabi season) is 1.5 times that of Kharif. The availability of rice husk depends upon the production of paddy, production process and husk-to-paddy ratio (HPR) which ranges from 0.14 to 0.27. The total energy potential depends on calorific value and the quantity available. Paddy is processed into rice for consumption with nearly 10 percent paddy is retained for seed and other use [2].

Power Generation Using Rice Husk

A biomass gasifier based power generation system mainly consists of biomass gasifier, a cooling and cleaning unit, and a dual fuel engine-generator set as shown in fig. 1. Different biomass material needs different gasification technology and equipment. Generally a fixed bed gasifier is suitable for gasifying high apparent density biomass materials, e.g., wood and cornstalk etc. The gasification of loose materials such as rice straw, wheat straw, rice husk, sawdust, and combustible municipal waste is carried out in a cone shape fluidized bed gasifier of mild steel structure with a combustion chamber of conical shape at the bottom end [9]. Rice husk is fed from the hopper at the top of the structure. The gasification takes places under controlled conditions in which basic thermo-chemical process takes place to convert the biomass into a more valuable producer gas. To achieve this, rice husk is heated either in absence of oxygen or by partial combustion in restricted air or oxygen. The products of pyrolysis are usually a mixture of gaseous fuel (H_2, CO, CO_2, CH_2, and N_2), oil like liquid called pyrolytic liquid (water soluble phase including acetic acid, acetone, methanol, non-aqueous substances, oil and tar) and nearly pure carbon char (solid). The energy value of producer gas is about 5 MJ/m^3 [10-12].

The cooling and cleaning unit consists of a scrubber and a separate box with cloth filter. The scrubber is used to cool the producer gas and to remove coarse particulates. Fine dust particles are removed through a separate filter. The clean and cool gas is mixed with air, before it enters the cylinder of engine coupled with a generator set, to supplement/replace the liquid diesel fuel. Engine which uses conventional diesel and gaseous fuel is referred as dual fuel engine. A pilot quantity of liquid fuel is injected towards the end of the compression stroke to start combustion. About 65 to 100 percent of diesel oil may be replaced by the producer gas in a diesel engine. This paper suggests use of 98 percent producer gas to supplement 2 percent pilot quantity diesel oil for a dual fuel engine. Similarly 100 percent producer gas may also be suggested to replace entire diesel oil. A number of important factors like type of gaseous fuel, performance and design, parameters are to be considered for proper selection of the engine [13].

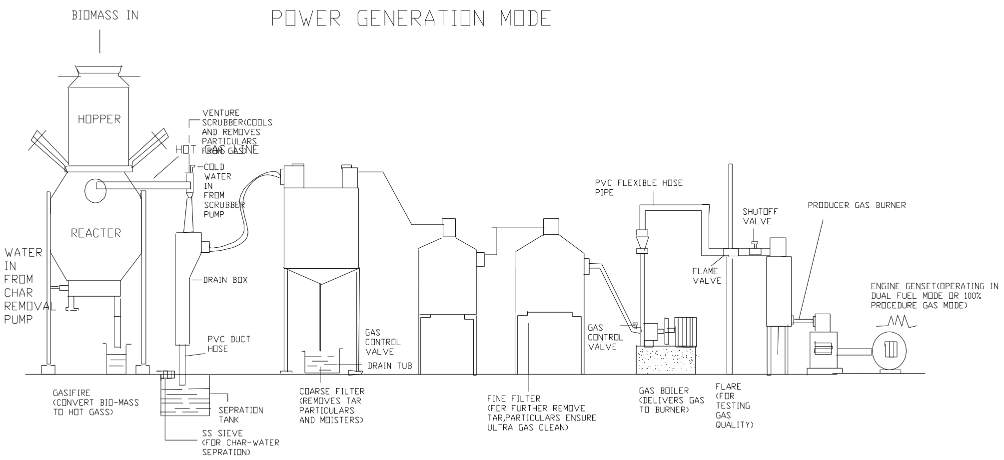

Fig. 1: Rice Husk Based Power Generation
(Source: Ankur Scientific Energy Technologies Pvt. Ltd., India)

Proposed Biomass Project Model

A biomass project is suggested for a slaughter house-cum-food packaging factory Hind Agro Industries Limited which is located in Cherat village, in the District of Aligarh, State of Uttar Pradesh in Northern India. The district is surrounded by agricultural land where paddy is cultivated which makes husk availability very easy. The village is not connected to the utility grid. An uninterrupted electric supply, for 24 hours in a day, is required for the production as well as for its coldrooms and cold storages. For this purpose, there are four 1000 kVA/800 kW (one standby) and four 500 kVA/400 kW (two standbys) diesel generators for their Refrigeration Load of 2000 ton, Effluent Treatment Plant of 250 kW, Rendering Plant of 1000 kW, and lighting and other loads. The consumption of diesel oil is 140 liters/hour for 1000 kVA and 80 liters/hour for 500-kVA engine. Therefore consumption of diesel is 580 liters/hour, i.e. 13920 liters/day. The biomass power project Ret Screen model proposes a dual fuel engine-generating set using rice husk for gasifier and diesel as pilot fuel. The generator is coupled with a dual fuel diesel engine. Method 1 is used for the analysis when less detailed information is required whereas Method 2 is for detailed analysis. Typically, Method 1 is used first to determine if a Method 2 analysis is warranted. Availability of proposed case power system may be selected either in hours or in percent of hours per year. Availability of new power system is generally in the range from 8000 to 8400 hours or from 91.3 to 95.9 percent. A practical mean value of 92 percent is considered. Older plants have less availability due more maintenance and shut down. In fuel selection, either single or multiple fuels in monthly/percentage mode may be opted. Rice husk/hull as first fuel (98 percent) and diesel as second fuel (2 percent) are considered. If a 100 percent producer gas is required to run an engine, single fuel mode is chosen. Market rates of both fuels are entered as shown in Table 1. The market price of rice husk varies significantly from place to place, i.e., Rs. 1.50 to Rs. 3 depending mainly upon transportation cost; whereas diesel price is nearly same throughout India. A suitable dual fuel engine of Energy Conversion make, model CAT 399 is chosen for power capacity requirement of 800 kW as per site condition. Manufacturer and model number of the engine are selected as per product database. Incremental initial cost, i.e., total market cost of dual fuel engine and gasifier
along with other accessories, is estimated as Rs. 11,000,000. Heat rate is the amount of energy input from the fuel to produce 1 kWh of electricity. It may be taken as 9600 kJ/kWh. This value may be judged from the typical heat rate curve for reciprocating engine between Power Capacity in kW and Heat Rate for Low Heating Value for 800 kW. The model calculates the fuel required per hour based on the power capacity and heat rate, which is 7.7 GJ/h. The electricity generated by the proposed system is utilized as per site requirement. The rate to be paid for the usage of per kWh of energy to the utility grid in the absence of proposed system would have been according to the set tariff. The present electricity rate of utility grid of Rs. 3 per kWh is considered to compare the economical aspect of the proposed system with the utility grid.

Table 1: Energy model of biomass proposed system

Proposed case power system								
Show alternative units								
Technology Availability	%	Reciprocating engine	92.0%	8,059 h				
Fuel selection method	Multiple fuel - percentage							
		Fuel type	Fuel mix	Fuel consumption unit	Fuel consumption	Fuel rate - unit	Fuel rate	Fuel cost
	Fuel type #1	Rice - hull	98%	t	5,701	Rs/t	3000.00	Rs 17,103,579
	Fuel type #2	Diesel (#2 oil) - L	2%	L	34,114	Rs/L	36.00	Rs 1,228,114
	Fuel type #3							
			100%			Rs/MWh	1,066.233	Rs 18,331.694
Reciprocating engine								
Power capacity	kW	800				Rs 11,000,000	See product database	
Electricity exported to grid	MWh	6,447						
Manufacturer	Energy conversions							
Model	CAT 399			1 unit (s)				
Heat rate	kJ/kWh	9,600						
Fuel required	GJ/h	7.7						
Electricity export rate	Rs/MWh	3,000.00						

Emission Analysis						
Base case electricity system (Baseline)		GHG emission factor (exct. T & D)	T & D losses	GHG emission factor		
Country - region	Fuel type	tCO2/MWh	%	tCO2/MWh		
India	Coal	1,207	25.0%	1,609		
Electricity exported to grid	MWh	6,447	T & D	0.0%		
GHG emission						
Base case	tCO2	10,376				
Proposal case	tCO2	208				
Gross annual GHG emission reduction	tCO2	10,168				
GHG credits transaction fee	%	0.0%				
Net annual GHG emission reduction	tCO2	10,168	Is equivalent to	10,168	tCO2	
GHG reduction income						
GHG reduction credit rate	Rs/tCO2	1000.00				

GHG reduction credit duration	Yr	20	
GHG reduction credit escalation rate	%	9.0%	

Financial Analysis

Financial parameters			
Inflation rate	%	9.0%	
Project life	Yr	20	
Debt rate	%	70%	
Debt interest rate	%	9.98%	
Debt term	Yr	15	
Initial costs			
Power system	Rs	11,000.000	91.7%
Other	Rs	1,000.000	8.3%
Total initial costs	Rs	12,000,000	100%
Incentives and grants	Rs	0	
Annual costs and debt payments			
O & M (savings) costs	Rs	0	
Fuel cost – proposed case	Rs	18,331,694	
Debt payments – 15 yrs	Rs	1,040,865	
	Rs		
Total annual costs	Rs	19,372,558	
Annual saving and income			
Fuel cost – base case	Rs	0	
Electrical export income	Rs	19,342,080	
GHG reduction income – 20 yrs	Rs	10,168,369	
	Rs		
Total annual saving and income	Rs	29,510,449	
Financial viability			
Pre-tax IRR – equity	%	319.3%	
Pre-tax IRR – assets	%	102.6%	
Simple payback	Yr	1.1	
Equity payback	Yr	0.3	

Emission Analysis

Emission analysis of dual fuel diesel set using rice husk is performed on the basis of type of fuel used in based case power system, which is coal here. Transmission and distribution (T&D) losses of base case are taken as 25 percent. The T&D losses of proposed case power system is for the electricity 'exported' from dual fuel generator set to the air conditioning and other plants, assumed as zero percent, as these installations are very closely located to the generating unit.

Gases like water vapour, carbon dioxide, methane (CH_4), ozone (O_3) and nitrous oxide (N_2O) in the earth's atmosphere permit the passage of incoming solar radiation but prevent outgoing radiation from earth to space.

This effect is similar to a greenhouse of glass, so the phenomenon is called greenhouse gas effect and gases responsible for this is known as greenhouse gases. Increased burning of fossil fuel for energy needs, increases concentration of greenhouse gases. This causes trapping of infrared radiation from sun which results in warming of earth surface, i.e. about 0.2 to 0.3 degrees Celsius over last 40 years [14].

Reduction in net annual GHG emission is evaluated equal to10168 tonnes of CO_2 (tCO_2). Annual GHG reduction income can be found out by properly selecting the value of GHG reduction credit rate as Rs. 1000 per tCO_2 [15]; as of Sep. 2008. The rate varies between US $1 and US $ 35 per tCO_2, widely depending upon how the credit is generated and how it is to be delivered. As for example, prices for credits generated from Clean Development Mechanism (CDM) project may be different from those generated from other type of projects, outlined by Kyoto Protocol (KP) 2003 which was first diplomatic document to combat climate change [14]. CDM also depends upon other factors like voluntary and mandatory emission; private and public purchase of credits; credits from within like the European Union GHG Emission Trading Scheme (EU-ETS), other national, transnational, or regional schemes, type of technology used to generate emission reductions etc. In the context of climate change, it is worth mentioning that KP emphasized developed and East European countries to reduce their GHG emission by an average of 5.2 percent from their 1990 levels during the period of 2008 – 2012. GHG reduction credit duration typically represents the number of years for which the project receives GHG reduction credits. It is used to calculate the GHG reduction income over the project life of 20 years. If a crediting period of 10 years is opted, once the project has been validated and registered, the project may be issued a certificate from Certified Emission Reductions (CERs) to go for another 10 years.

The GHG reduction credit escalation rate, in percentage, is the project annual average rate of increase in the GHG reduction credit rate over the project life. This permits the user to apply rates of inflation to the value GHG reduction credit rates. This value is taken as equal to rate of general inflation of 8.98 percent (as on 14 Nov. 2008).

Financial Analysis and Cash Flow

This analysis is done on the basis of financial parameters like inflation rate, project life, debt ratio, debt interest rate, and debt term. Inflation rate of 8.98 percent is used for financial analysis which fluctuates according to market prices of general commodities and is evaluated every week. The project life, as mentioned, is taken as 20 years which is the duration over which the financial viability of the project is evaluated. Depending upon the circumstances, it can correspond to the life expectancy of the energy-related equipment, debt term or the duration of power purchase agreement. This analysis may be used for project life up to 50 years, if required. The debt ratio is ratio of debt over the sum of the debt and the equity (value of the shares issued by a company) of the project. The debt ratio indicates the financial leverage (capability) created for the project. The higher the debt ratio, the larger the financial leverage will be. The value of debt ratio is required to calculate the equity investment that finances the project. This value should be in the range of 0 to 90 percent with 50 to 90 percent most commonly used value. Here a mean value of debt ratio of 70 percent is chosen. The debt interest rate is the annual rate of interest paid to debt holder at the end of each year the term of debt. This is required to calculate the debt payments. Its value may also be taken as 8.98 percent, same as inflation rate. The debt term is considered for 15 years, which is 5 years less than the expected life of the proposed system. Incentives and grants are financial contributions that are paid for the initial cost (excluding credits) of the project. In the model, the incentive deemed not to be refundable and is treated as income during the development/construction year, i.e. the start year is supposed as zero year.

Initial cost of proposed system, complete with the cost of dual fuel generator, gasifier, separation tank, filters, blower, valves, foundation platform, piping work, wiring etc is taken as Rs. 11,000,000 and a lum-sum amount of nearly 8.3 percent is considered for installation and other charges. Therefore, total initial cost may be taken as Rs. 12,000,000. ‘Incentive and grants’ and ‘annual costs and debt payments’ are assumed as zero. As shown the total annual costs comes out to be Rs.19,37,558. Total annual savings and income, and financial viability are evaluated. The total annual savings and income are Rs. 29,510,449. Cumulative cash flow may be visualized by cash flow graph as sown in fig. 2. The cash flow is positive as equity starts payback just after 0.3 years, i.e. less than 4 months.

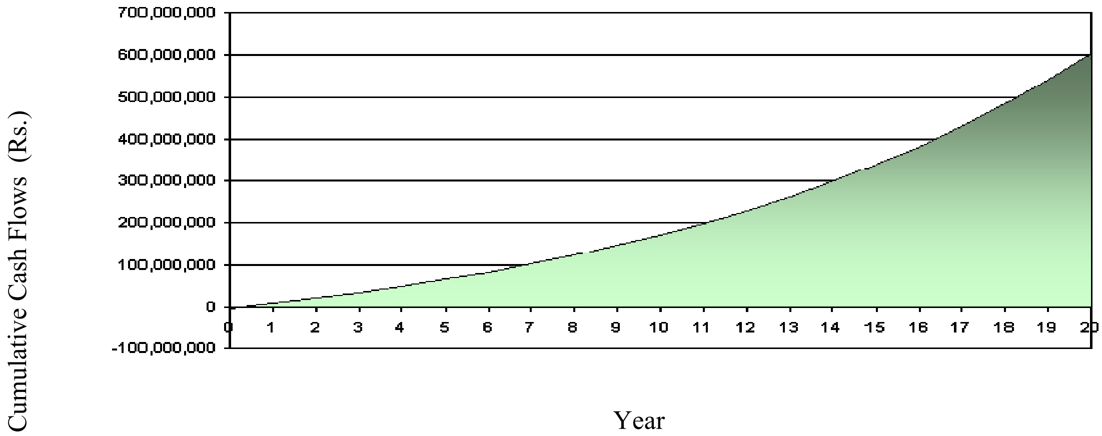

Fig. 2 Cumulative cash flows graph

Result and discussion

Installation of dual fuel generation not only provides energy at lower cost but at the same time reduces GHG emission. An energy model of 100 percent producer gas based generation is also considered to compare with the dual fuel generation, as shown in Appendix-I. The following predictions may be made to analyze the feasibility of the proposed system.

- In the proposed system, diesel oil is used as a pilot fuel. It is only 2 percent of the total quantity of the fuel used. The main fuel, rice husk is available in plenty in the fertile land in the surrounding of the area where the proposed system is suggested to be installed. Therefore, the precious fossil fuel is saved for the purpose where there is no utility grid connection.
- In both dual fuel and 100 percent producer gas based generation of electricity, gasifiers and other accessories are required besides generating set. Even then it is advisable to prefer these two proposed systems over diesel-engine generator set due to net heavy reduction in annual GHG emission.
- In case of dual fuel generation 800 kW, net annual GHG emission reduction is 10,168 tCO_2. Therefore, during entire life of 20 years, the proposed system will be able to save GHG emission 203,360 tCO_2. This is equivalent to 2,067 cars and light trucks not used or 4,134,309 liters of gasoline or 21,113 barrels of crude oil not consumed in one year.
- In case of 100 percent producer gas generation of electricity, net annual GHG emission is 10,258 tCO_2. Obviously it is slightly more than 98 percent producer gas generation of electricity. In its entire life, the proposed system will save 205160 tCO_2.
- Income from GHG reduction in a year is estimated as Rs. 10,168,369, which may rise further as GHG reduction credit rate is bound to enhance in near future.
- It is to be noted that biomass release carbon dioxide when it is used for gasification but because biomass absorbs carbon dioxide as it grows. The entire process of growing, using, and re-growing biomass results in very low to zero carbon dioxide emissions [15].
- The total annual savings and income from the proposed case is Rs. 29,510,449. Simple pay back time is 1.1 years and equity payback is 0.3 year.
- Cumulative cash flow is positive throughout from zero to 20 years, which indicates that the proposed system is financially very much feasible.

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