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Potential of Electricity Generation from Rice Husk-A Case Study of Rice Mill

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Abstract: Energy crisis is a major problem in Pakistan now a days, in order to overcome this energy crisis an alternate renewable source must be exploited. Biomass has become an alternate source of energy for developing countries, where the economy is dependent on agriculture and forestry. Rice husk (RH) that is being generated in the mill can be utilized efficiently through fluidized bed (FB) technology to meet the energy demand and increase the production capacity of the mill, this will results in cost savings, greenhouse gases reduction and environmentally sustainable supply of electricity. The purpose of this study is to access resource potential of RH generated in the rice mill and to carryout technical and economic evaluation of RH based 1 MW fluidized bed combustion (FBC) power plant. In order to quantify the RH generated in the mill data regarding the potential of RH was collected from mill personnel and from the literature. It is estimated that through the FBC power plant, annual electricity of 5360 MWh can be generated with RH fuel consumption of 6968 tons; cost of generating electricity through FBC is approximately Rs. 4/kWh. Hence it can be concluded that FBC technology is more economically feasible than conventional systems for the power generation.

Keywords: RH, FBC, Energy potential, Electricity Generation

1. INTRODUCTION

In Pakistan the supply of electricity is much less and incapable to meet the demand because of increased dependency on fossil fuels. The best solution to overcome the energy crisis is the utilization of renewable and sustainable energy sources (Amjid *et al.*, 2011). Biomass is one of the most important sources of energy in renewable energy. Biomass has become an alternative source of energy for developing countries, where the economy is dependent on agriculture and forestry. When paddy is processed, RH and rice bran are by-products. RH can be converted into heat and electricity efficiently through available technologies. (Mathur *et a.l*, 2013).

Rice husk/straw is a renewable energy source and is known as carbon dioxide (CO_2) free because the CO_2 produced by combustion and gasification process is absorbed by the grown biomass during photosynthesis, hence net CO_2 emissions become zero (Singh *et al.*, 2011). RH generated in the mill can be efficiently utilized to meet the heat and electricity demand of the mill through various conversion technologies.

FBC is a viable technology as it has advantages of flexibility, higher combustion efficiency and low emissions over other combustion technologies (Obernberger, 1998).During the combustion process, the FB boilers suspend the fuel in the air blowing upwards. FB boilers are categorized according to fluidization velocity into bubbling FB and circulating

FBs. Bubbling FBs have lower fluidization velocity. The circulating FB boiler separates and captures the solids present in the high velocity exhaust gas and returns them to the bed for complete combustion (UNIDO, 2009). The burnt husk contains 91% silica. If burnt husk is heated up to 700°C, amorphous silica is produced which contains pure silicon. This product is required by electronic industry. Burnt husk also contains sodium and potassium silicate which have large demand in adhesive and detergent industries (Mujeebu *et al.*, 2011).

In order to overcome energy crisis and interrupted supply of electricity to the mills the alternative solution is to utilize the RH generated in the mill through FB this will results in costs savings, increased production and sustainable supply of electricity in the mill.

2. BACKGROUND OF AK RICE MILL

A.K Rice Mill, which is located at Bagirji, District Sukkur. The milling processes in this mill combine a number of operations that produces higher quality and higher yields of white rice from paddy or rough rice. Details of the mill were collected from technical personnel of the mill and are presented in (**Table 1**).

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The milling capacity is 96 Tons per day and rice mill works 16 hours a day due to load shedding problem. The RH is a by-product of rice milling and forms 20% by weight of the paddy processed. Daily husk generated is 19.2 Tons, the generated quantity of husk is sold at Rs. 3/kg. RH can be used in economical manner as fuel for heating and power generation, in order to supply process heat and electricity to meet the rice mill's energy needs and sell surplus electricity generated to the national grid. The paddy is transferred from fields to the rice mills where it is placed in open space to reduce its moisture up to desired level then it is processed different stages as presented in **(Fig. 1)**.

Table 1: Details of A.K Rice Mill

Item	Details
Capacity (Tons/hr)	6
Rice as output (Tons/hr)	4.2
Operating time (hr/day)	16
Paddy Milling (Tons/Day)	96
Residue to Paddy Ratio	1:5
Potential of Husk(Tons/hr)	1.2
Potential of Husk(Tons/Day)	19.2
Electricity Load (KW)	400
Selling price of Husk (Rs. /Kg)	3
Moisture of Paddy after drying (%)	14
Milling duration (Hours/year)	5360

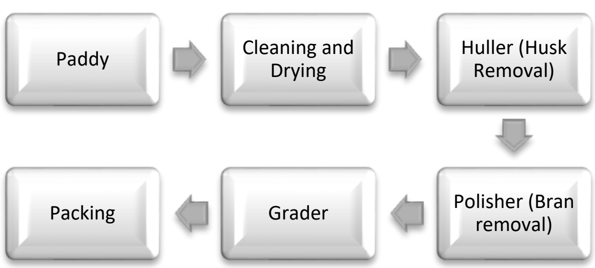

Fig.1: Flow Chart of Rice Milling Process

3. METHODOLOGY

The research is aimed to evaluate the potential of RH biomass as a viable source of energy in terms of its potential quantity, technical and economic analysis of RH based power plant.

3.1 Resource Potential of RH

RH has some specific characteristics which has made it easy to be used as an energy source. RH availability can be calculated by the relation given in equation 1 (Anka *et al.*, 2015).

$$Hprod = PRprod \times HPR \times H\,Avlt \quad \textbf{(1)}$$

Where, *Hprod* = RH production (tons/hr), *PRprod* = Paddy rice processed (tons/hr)
HPR= Husk to Paddy Ratio (0.2), *H Avlt*= Husk availability (100%)

According to mill owners 8 to 9 kg of husk is generated from 1 mound of paddy, so husk paddy ratio is taken as 0.2. The rice mill does not utilize husk, therefore husk availability factor is taken as 100%.

3.2 Technical Evaluation

Energy potential from RH depends upon heating value and characteristics of RH and conversion technology. HHV and elemental composition of RH is presented in **(Table 2)**.

Table 2: Ultimate analysis and HHV of RH (Mohiuddin *et al.,* 2016).

Composition (%)	RH
Carbon	36.74
Hydrogen	5.51
Oxygen	42.55
Nitrogen	0.28
Sulfur	0.55
HHV (MJ/kg)	15

3.2.1 Energy Potential of RH

- Thermal energy from RH based on its HHV is calculated 15 MJ/kg as studied by Mohiuddin *et al.*, 2016. It shows the amount of thermal energy available from RH which can be utilized for drying the paddy and steam for power generation.
- The potential of RH as an energy source is estimated and its equivalence with furnace oil (FO) as a fuel for energy generation is done.
- Potential of electricity from RH can be finding out by considering Steam turbine technology. For a steam turbine power plant consumption of RH is 1.3 kg per kWh electricity as reported by Abedin *et al.*, (2014). By considering this conversion factorannual potential of 4947 MWh electricity can be generated from 6432 tons of husk.

3.2.2 Size of the plant:

The size of the plant for combustion technology can be estimated from equation 2. RH availability as a fuel source and capacity of power plant can be find out by following formulas. (Bergqvist *and* Wårdh, 2007).
Available amount of husk for power production = Amount of processed paddy $\times HPR \times$ Husk availability factor

$$Psize = \frac{Available\ amount\ of\ husk\ for\ power\ generation}{SFC \times Operating\ hours} \textbf{(2)}$$

Where:
HPR = Husk paddy ratio, $Psize$ = Power plant size [kW], SFC = Specific fuel consumption [kg/kWh], Operating hour = given as equivalent number of full load hours. In order to meet the energy demand of the mill, **(Fig.2)** shows the Schematic of proposed RH based FBC power plant which is used for conversion of RH into electricity Pak. by Mohiuddin, *et al.*, (2016).

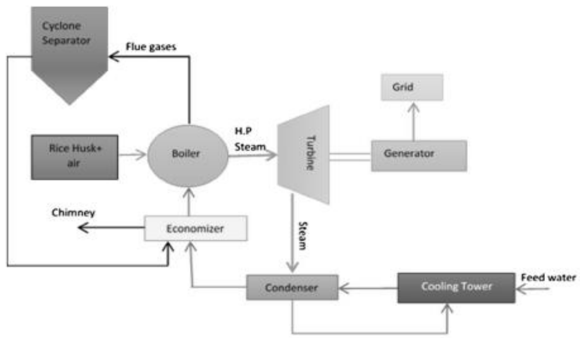

Fig. 2: Proposed RH based FBC power plant

RH is fed into the boiler with a capacity of 15 ton/hr for the purpose of combustion. The combustion efficiency of the boiler is 88%, the high pressurized super-heated steam at the pressure of 42 bars is applied to the turbine which is coupled to a shaft that runs the generator and power is produced. Flue gas first will pass through cyclone separator in which solids are taken away from flue gas then passes through economizer where feed water is heated and finally gas is exhausted into atmosphere. The efficiency of the plant is 29.8%. Main operating parameters of boiler and turbine of the proposed plant are presented in **(Table 3)**.

Table 3: Operating parameters boiler and turbines of the proposed power plant

Parameters	Values
Input pressure	42 Bar
Capacity of boiler	15 t/hr
Combustion efficiency	88%
Steam consumption	13.5 t/hr
Overall efficiency	29.8%
Input Temperature	420°C

3. ANALYSIS

Analysis is carried out by studying different costs involved in FBC technology. e.g. Capital cost, operating and maintenance cost, fuel costs and cost of electricity (COE).

3.3.1 Cost of electricity

The cost of electricity generation has three components, capital and investment cost (C*and*I), operating and maintenance cost (O*and*M) and the fuel cost (F). Cost of electricity generation can be calculated by the equation 3 as reported by Koornneef *et al.,* (2007).

$$COE = \frac{CandI + OandM + F}{annual\ production\ of\ electricity} \quad (3)$$

Where,
COE = Cost of electricity (Rs./kWh), C*and*I = annualised cost of Capital and Investment (Rs), O*and*M= operating *and* maintenance cost per year(Rs),
F= fuel cost per year (Rs),
Σ kWh= annual production the total produced kWh per year

Cost analysis of 1MW FBC technology has been carried out, capital cost, operating and maintenance costs per year are taken from IRENA, 2012 while fuel cost is already known. Different types of costs for FBC technology are presented in **(Table 4)**.

Table 4: Costs analysis of 1MW Circulating FBC technology

Parameter	Unit	Value
Capital Cost	Rs/kW	350175
Operating and maintenance cost	Rs. /year	15757.875
Fuel Cost	Rs./year	20904000

I USD= 105 PKR

4. RESULTS AND DISCUSSIONS

Amount of thermal energy can be produced from annual potential of RH based on its HHV which is $9.64\times 10^7\ MJ$.FO is compared with RH in terms of required quantity and cost for the generation of same amount of thermal energy as presented in **(Table 5)**.

Table 5: Comparison between RH and FO energy equivalent

Potential (tons)	RH	6432
	FO	2265
HHV (MJ/kg)	RH	15
	FO	42.6
Thermal energy potential (MJ)	RH	9.64×10^7
	FO	9.64×10^7
Fuel cost (Rs./Ton)	RH	3000
	FO	47810
Total fuel cost (Million PKR)	RH	19.3
	FO	108

Annual RH potential is 6432 tons which produces 9.64×10^7 MJ and the total cost of fuel is 19.3 million PKR. The amount of FO required to produce 9.64×10^7MJ thermal energy is 2265 tons and total cost of FO is 108 million PKR.

The husk generated in the mill is 6432 tons per year which produce annual potential of electricity 4947.280MWh through combustion technology. Hence by utilizing husk for electricity generation, the production of mill can be enhanced.

Technical and economic comparison of RH based 1MW FBC power plant has been done as presented in **(Table 6)**. The operating time of the plants is considered as 5360 hours per year. As from the literature biomass consumption is 1.3 kg per unit of electricity for combustion technology with 88% combustion efficiency and 29.8% overall efficiency.

Table 6: Technical and economic analysis of FBC

Parameter	Unit	Combustion
Electrical Capacity	kW	1000
Operating time	h/year	5360
Electricity output	kWh/year	5360000
Biomass consumption	Kg/kWh	1.3
Biomass consumption	Tons/year	6968
Efficiency	%	88
Boiler capacity	ton/h	15
Steam consumption	ton/h	13.5
Fuel consumption	ton/hr	3
Overall efficiency	%	29.8
Biomass price	Rs/Ton	3000
Fuel cost	Rs/year	20904000
Capital Cost	Rs/kW	350175
Operating and maintenance cost	Rs. /year	15757.875
Cost of electricity	Rs./kWh	3.96

The capacity of the boiler is 15 tons/hr with fuel consumption of 3 tons/hr. Cost of generating electricity by considering combustion technology is approx. Rs. 4 per unit of electricity which is cheaper than conventional power plants, therefore FBC technology is more economically feasible than conventional power systems.

5. CONCLUSION

On the basis of study carried out, it is concluded that:

- The husk generated in the mill is 6432 tons per year which produce annual potential of electricity 4947. 280MWh through FBC technology.
- Production of the mill can be enhanced by utilizing husk for electricity generation in the mill which results in increased potential of husk for power generation.
- Cost of generating electricity by considering FBC is approx. Rs. 4 per unit of electricity, hence this technology is more economical and feasible for power generation than conventional power systems.

ACKNOWLEDGEMENT

In order to meet the heat and electricity demand of rice mills, RH generated in mills can be efficiently utilized for heat and power generation through FBC technology. Moreover production capacity, resource potential and cost savings for the mill can be enhanced by considering FBC technology.

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