Electrical Power Generation Potential of Paddy Waste

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Abstract— **India is one of the developing countries whose economy is largely based on agriculture. It has still many remote villages without electricity supply. This paper reports the experimental results of proximate analysis and calorific values of different components of paddy waste. Based on the results, its potential towards electricity generation and corresponding land requirement for energy plantation has been calculated. The results show that approximately 1481 hectares of land are required to generate 20 MWh/day of electricity. The results are also compared with that of coal samples of six different local mines being used in thermal power plants. This comparison reveals that paddy waste can be used to generate considerable amount of power output with negligible emission of suspended particulate matters. Its ash fusion temperatures are also experimentally found out and it is observed that it can be used safely up to a temperature of 900^{0}C without any clinker formation in the boiler.**

I. INTRODUCTION

INDIA is a developing country and agriculture has always been the mainstay of its economy accounting for 17.8 per cent of its gross domestic product during 2007-08 [1]. It constitutes the backbone of rural India whose inhabitants are more than 70% of total population. As a result, lot of agricultural wastes are generated and remain unutilized. Paddy is undoubtedly the major crop of India and it is the second largest producer of this crop in the world. The production of rice in India has been estimated at 99.37 million tonnes during 2008-09 [1].

Even today there are many remote villages in India without any electricity supply. The remoteness and thin population make the grid supply of electricity highly uneconomical. Moreover, there is always a growing concern due to fast depletion of fossil fuel resources for power generation and corresponding pollution of the environment. Therefore, biomass is being considered as one of the alternative sources of electricity generation.

Biomass resources are potentially the world's largest and most sustainable energy source for power generation in the 21st century. The total potential of non-fodder crop residue available for energy production in India was estimated to be 4715 PJ in 1996-97, and the proposed value for the year 2010 is 6565 PJ [2]. As shown in Fig. 1, the estimated global electricity generation capacity of biomass is about 11,000TWh which is greater than that of all other renewable energy sources [3]. It clearly indicates that the current biomass use is much below the available potential. The estimated power generation potentials of various renewable energy sources in India have been outlined in Table I [4]. It is fairly clear from Fig.1 and Table I that the power generation potential of biomass is considerably high in the world including India.

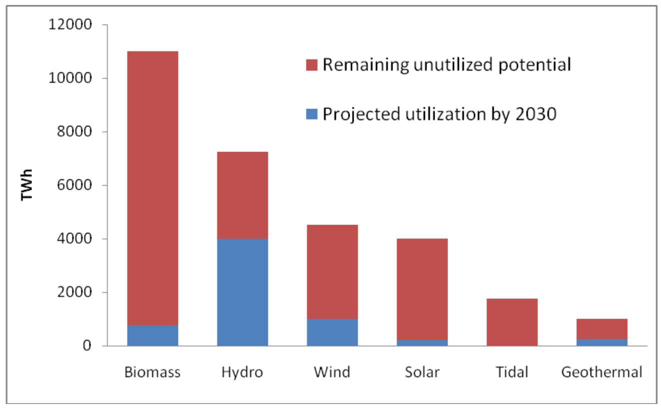

Fig. 1. World long term renewable energy potential for electricity generation.

TABLE I
ELECTRICITY GENERATION POTENTIALS OF RENEWABLE ENERGY SOURCES IN INDIA [4]

Source	Estimated potential (MW)	Cumulative installed capacity (MW)
Wind energy	45,000	4,434.00
Bio-energy	19,500	867.00
Small hydro (up to 25MW)	15,000	1,748.00
Waste-to-energy	2,700	45.76
Solar photovoltaic	20 MW/km^2	2.80

Sustainable production and utilization of biomass in electrical power generation can also solve the problems of rural unemployment, utilization of wasteland, and transmission losses in grid network. Accordingly, the system of biomass-based power generation is being given priority in most of the developing nations including India. Unlike other renewable substances biomass materials, pre-dried up to about 15% moisture content, can be stored for a considerably long period of time without any difficulty. Besides electricity supply to the national grids, biomass offers tremendous opportunities for decentralized power generation in rural areas at or near the points of use and thus can make villagers/

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small industries self-dependent in respect of their power requirements.

To exploit biomass species in electricity generation, it is necessary to find out their various properties like calorific value, chemical composition, reactivity towards oxygen, bulk density, etc. This paper deals with the experimental work on proximate analysis and calorific values of different components of paddy, and their impact on electricity generation. It also experimentally finds out the ash fusion temperatures to confirm its safe operation in the boiler.

II. EXPERIMENTAL

A. Material Collection

In this work, the waste residues of paddy were collected from the coastal area of Orissa state of India. Its botanical specie name is O*ryza Satival* and family name is G*ramineal*. Its components like stump and leaf were removed separately and air dried in a cross ventilated room for about a month till their moisture contents were reduced to be in equilibrium with that of the atmosphere. The air-dried biomass were crushed into powders and then processed for their proximate analysis and calorific value determination.

B. Proximate Analysis and Calorific Value

Analyses for moisture, volatile matter, ash and fixed carbon contents were carried out on samples ground to –72 mesh size by standard method [5]. Moisture content in each sample was determined by heating it at 105 ± 5^{0}C for 1 h in an air oven, while the determination of volatile matter content involved heating the sample (contained in silica VM crucible) at 925^{0}C for 7 min. For the estimation of ash, 1 g of sample was burnt in a muffle furnace at 700^{0}C. The calorific values of the above ground samples were measured by Bomb Calorimeter [6].

III. RESULTS AND DISCUSSION

A. Proximate Analysis and Calorific Value

The study of proximate analysis of fuels is important because it gives an approximate idea about the energy values and the extent of pollutant emissions during combustion. The biomass waste contains a large amount of free moisture, which must be removed to decrease the transportation cost and increase the calorific value. The proximate analyses of different components of paddy are presented in Table II. Compared to leaf, stump contains more moisture but less volatile matter and ash content. The stump has higher fixed carbon content than the leaf.

The calorific value of a fuel is an important criterion in judging its quality for electricity generation since it gives an idea about the energy value of the fuel. As shown in Table II, the calorific value of stump and leaf are nearly the same. The major chemical constituents affecting the calorific values of carbonaceous materials are carbon and hydrogen. The above variation in calorific values of plant components is obviously related to the combined effects of their carbon and hydrogen contents.

TABLE II
PROXIMATE ANALYSIS AND CALORIFIC VALUES OF DIFFERENT COMPONENTS OF PADDY

Component	Proximate analysis wt %, air dried basis				Calorific value (kcal/kg, dry basis)
	Moisture	Volatile matter	Ash	Fixed carbon	
Stump	8.0	60.5	17.5	14.0	3614
Leaf	7.5	61.0	21.0	10.5	3609

B. Ash Fusion Temperatures

Ash fusion temperature of solid fuel is an important parameter affecting the operating temperature of boilers. Clinker formation in the boiler usually occurs due to low ash fusion temperature and this hampers the operation of the boiler. Hence the study of the ash fusion temperature of solid fuel is essential before its utilization in the boiler. The four characteristic ash fusion temperatures were identified as : (i) initial deformation temperature (IDT) – first sign of change in shape; (ii) softening temperature (ST) – rounding of the corners of the cube and shrinkage; (iii) hemispherical temperature (HT) – deformation of cube to a hemispherical shape; and (iv) fluid temperature (FT) – flow of the fused mass in a nearly flat layer. These four temperatures are listed in Table III from which it may be concluded that the boiler operation with paddy residues can be carried out safely (without clinker formation) up to the temperature of 900^{0}C. Compared to coal, it has lower ash fusion temperature which may be due to the lower contents of Al_2O_3 and SiO_2. Due to higher combustion reactivity of biomass compared to coal, the compete combustion of biomass often takes place at comparatively low temperature.

TABLE III
ASH FUSION TEMPERATURES OF PADDY WASTE

Ash fusion temperature, ^{0}C			
IDT	ST	HT	FT
930	1095	1165	1180

C. Estimation of Decentralized Power Generation Unit

For the estimation of power generation to meet the electricity requirements of villages, a group of 10-15 villages consisting of 3000 families may be considered, for which one power station could be planned. The electricity requirement for lighting and domestic work in these villages may be 6 MWh/day. An additional 14 MWh/day (approx.) may be required for agriculture (irrigation) and small scale industries situated in a group of villages. Thus, a power plant should be capable of generating 20 MWh/day (i.e., 0.73 MWh/year) for a group of 10-15 villages.

The design of energy plantation of paddy for power plant of 20 MWh/day capacity has been presented in Table IV and Appendix. The results indicate that in order to meet the yearly power requirement of the order of 7.3 MWh for a group of 10-15 villages, approximately 1481 hectare of land should always be ready for harvesting, in order to have perpetual generation of power.

TABLE IV
TOTAL ENERGY CONTENTS FROM FULLY GROWN UP PADDY PLANTS

Component	Calorific value (kcal /t, dry basis)	Biomass production (t/ha, dry basis)	Energy value (kcal/ha)
Stump	3614×10^3	3.50	12649×10^3
Leaf	3609×10^3	1.10	3970×10^3

D. *Comparison with Coals*

The results of proximate analysis and calorific values of six different types of locally available non-coking coals being used for electricity generation in Orissa (India) were reported by Kumar and Patel [7] and shown in Table V. This table also shows that the calorific values of paddy components are superior than that of coals of Hingola mine. The ash contents in all these coals are much higher (range : 39-60%) and they are expected to pollute the environment heavily with SPM (suspended particulate matter). This is a big problem and the solution is not easy. On the other hand, all components of paddy waste have ash content much less than all the available coals listed in Table V.

TABLE V
PROXIMATE ANALYSIS AND CALORIFIC VALUES OF NON-COKING COALS OBTAINED FROM DIFFERENT MINES OF ORISSA (INDIA) [7]

Coal mine	Proximate analysis (wt.%, dry basis)			Calorific value (kcal/kg) dry basis
	Volatile matter	Ash	Fixed carbon	
Lakhanpur	21.21	52.24	26.55	3938
Siding	30.62	44.30	25.08	4952
Hingola	21.90	59.83	18.27	3355
Yeurve	35.66	38.90	25.44	4682
Kalinga	24.77	50.77	24.46	4237
Jagannath	31.10	52.68	16.22	4660

IV. CONCLUSIONS

The main conclusions made out of the present work are outlined below.

1. The stump and leaf of paddy have nearly the same calorific value.
2. The waste of paddy crop can be safely used in the boiler up to a temperature of 900^0C without any risk of clinker formation.
3. Nearly 1481 hectares of land would be required for continuous generation of 20 MWh electricity per day from paddy waste.
4. Paddy waste has been found to have more calorific value than the coals of some local mines being used for power generation. Besides. all components of paddy waste have much lower ash content than the coals of all the six local mines considered for study.
5. The present work could be useful in the exploration of paddy waste for power generation in small decentralised power plant suitable in rural areas.

APPENDIX

Calculation of Land Requirement for Energy Plantations:

Referring data from Table IV, on oven dried basis the total energy from one hectare of land = $(12649 + 3970) \times 10^3 = 16619 \times 10^3$ kcal.

It is assumed that conversion efficiency of wood fuelled thermal generators = 30 % and mechanical efficiency of the power plant = 85 %.

Energy value of the total utilizable biomass obtained from one hectare of land at 30% conversion efficiency = $16619 \times 10^3 \times 0.30 = 4985.7 \times 10^3$ kcal = $4985.7 \times 10^3 \times 4.1868/ 3600 =$ 5798.4 kWh.

Power generation at 85 % mechanical efficiency = $5798.4 \times 0.85 = 4928.6$ kWh /ha.

Land required to supply electricity for the whole year = $73 \times 10^5 / 4928.6 = 1481$ ha.

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